Multiliteracies for academic purposes: A metafunctional exploration of intersemiosis and multimodality in university textbook and computer-based learning resources in science

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AUTHOR'S DECLARATION

This is to certify that:

I. this thesis comprises only my original work towards the Degree of Doctor of Education.
II. due acknowledgement has been made in the text to all other material used
III. the thesis is less than 50,000 words in length, exclusive of tables, maps, bibliographies, appendices and footnotes.
IV. no part of this work has been used for the award of another degree.
V. this thesis meets the *University of Sydney's Human Research Ethics Committee (HREC) requirements for the conduct of research.*

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ABSTRACT

This thesis is situated in the research field of systemic functional linguistics (SFL) in education and within a professional context of multiliteracies for academic purposes. The overall aim of the research is to provide a metafunctional account of multimodal and multisemiotic meaning-making in print and electronic learning materials in first year science at university. The educational motivation for the study is to provide insights for teachers and educational designers to assist them in the development of students' multiliteracies, particularly in the context of online learning environments.

The corpus comprises online and CD-ROM learning resources in biology, physics and chemistry and textbooks in physics and biology, which are typical of those used in undergraduate science courses in Australia. Two underlying themes of the research are to compare the different affordances of textbook and screen formats and the disciplinary variation found in these formats.

The two stage research design consisted of a multimodal content analysis, followed by a SF-based multimodal discourse analysis of a selection of the texts. In the page and screen formats of these pedagogical texts, the analyses show that through the mechanisms of intersemiosis, ideationally, language and image are reconstrued as disciplinary knowledge. This knowledge is characterised by a high level of technicality in image and verbiage, by taxonomic relations across semiotic resources and by interdependence among elements in the image, caption, label and main text. Interpersonally, pedagogical roles of reader/learner/viewer/ and writer/teacher/designer are enacted differently to some extent across formats through the different types of activities on the page and screen but the source of authority and truth remains with the teacher/designer, regardless of format. Roles

are thus minimally negotiable, despite the claims of interactivity in the screen texts. Textually, the organisation of meaning across text and image in both formats is reflected in the layout, which is determined by the underlying design grid and in the use of graphic design resources of colour, font, salience and juxtaposition. Finally, through the resources of grammatical metaphor and the reconstrual of images as abstract, both forms of semiosis work together to shift meanings from congruence to abstraction, into the specialised realm of science.

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CHAPTER 1

Introduction and background

In today's universities, traditional technologies in teaching and learning are increasingly being supplemented or replaced with newer information and communication technologies (ICTs). In response to a complex array of economic, social and political factors, universities have been involved in major efforts to harness the power of new learning technologies. At the same time, governments in the US, Australia and the UK and elsewhere have embraced the concept of technology-led teaching and learning in higher education as a platform for educational and economic reform, with claims that it can be used to address the changing demands in the sector: 'for more flexible learning; for extension of university services to national and international markets; and for more cost-effective delivery of higher education in an increasingly competitive environment' (McCann, Christmass, Nicholson, & Stuparich, 1998); (see also (Dearing, 1997; Nelson, 2002a, 2002b; West, 1998). Aligned with government policy, major higher education funding bodies in these countries have supported technology-driven innovation in teaching and learning in the tertiary sector with a massive injection of funds, resulting both in substantial ICT development across a wide range of discipline areas and in institutional policies supporting and guiding the innovation.

While the economic rationalist rhetoric of government and institutional directives towards the technologisation of higher education are important to acknowledge, the implications of the new learning technologies for redefining literacy and pedagogical practices have not yet been fully explored. The growing body of research on students learning with ICTs has yielded different perspectives on its benefits for learning. Research has tended to focus on the nature of the innovation or on measuring student 'learning gains', rather than on what kinds of literacies students need in the new learning environments (Alexander, 1999; Dugan, 1999; Emerson & Mosteller, 1998; Kearney & Treagust, 2001). The assumptions underlying much of the research are that students already have the broader set of literacies they need in order to benefit from technology-enhanced learning environments.

In the disciplines, the supplementation and enhancement of traditional technologies by newer learning technologies poses challenges for literacy practices, while the blend of old and new teaching and learning approaches has shifted boundaries which were previously clearly delineated. Learning science at university today is a very different experience from ten or fifteen years ago. In addition to face to face activities such as attending lectures, tutorials and laboratory sessions, students spend a large proportion of their course time in an on-line learning environment. Here they may receive all their course information, communicate via chat rooms with their lecturers and other students, search on the Internet for relevant information for their assignments, compose and submit these online and complete interactive computer modules and quizzes on their course content. Even their textbooks may be digitised or the print versions supplemented with interactive media. The complexity of practices in which students are now engaged necessitates broadening the 'singular' concept of literacy to a pluralised set of literacies, encompassing visual, verbal and other literacies. Such a concept has been termed 'multiliteracies' (Cope & Kalantzis, 2000; New London Group, 1996; Unsworth, 2001), with the more narrowly termed 'electronic literacies' (Snyder, 1997; Warschauer, 1999), 'digital' literacies, 'cyberliteracies', 'new' literacies and ‘multimedia’ or ‘hypermedia’ literacies also used.

1.0 Professional context and motivation for the research

The motivation for the research undertaken for this thesis derives from my professional context as a lecturer in the Learning Centre (LC) at the University of Sydney. The role of the Learning Centre is to provide academic literacy support for all students regardless of language background, discipline or year of study. The Learning Centre services a very large and diverse community at the University of Sydney, with over 40,000 students and 17 Faculties. The Centre lies outside the faculty structure and is located within a central administrative portfolio as a unit of Student Services. Since its inception in 1991, the Learning Centre has offered a program of support for students in three modes encompassing a complex mix of teaching practice:

- *a Central Program* of academic skills workshops, offered outside the students’ degree courses,
- *a Faculty Program* of discipline-specific face-to-face and online learning resources to support the development of students’ academic literacies within their degree courses,
- *an Independent Learning Program* of learning resources designed for individual students and offered in consultation with a LC lecturer or as computer-based resources for independent study.

Increasingly, and in collaboration with staff in academic departments across the University, the Centre has become engaged in curriculum design of online learning resources to support the development of students’ multiliteracies. Many of these projects have involved collaboration with departments in science and engineering. These include the online report writing projects for undergraduate students in biology, biochemistry and chemical engineering (e.g. Drury et al., 2003). It is this work which is the primary motivation for my research, since it requires a deeper understanding not only of the multiliteracies undergraduate students need but also of how different disciplines construe meanings in the new learning environments.

The other motivating factor for the research from a professional perspective is to understand how Systemic Functional Linguistic (SFL) theory (Halliday, 1985, 1994; Martin, 1992), which is the theoretical foundation for much of the teaching and research of the Learning Centre, can be extended to support the teaching of multiliteracies. At the core of such an approach would be the development of a metalanguage for students and teachers to understand how meaning is construed in print and screen environments.

1.1 Framing the concept of multiliteracies

The concept of multiliteracies marks an important shift away from a language-based view of literacy towards one which involves an understanding of systems of meaning other than language and of the complex interrelationships among all systems. This broader conceptualisation of literacy is increasingly being framed within the research field of 'multimodality'. In discussing the impact of the Web and computer-based multimedia on print literacy, Warschauer (1999, p. 8) points to the transformation of reading and writing processes into 'multimedia interpretation and authoring' and concludes that students need to understand 'how communication varies across media and how different grammars (text and visual) combine to express meaning' (Warschauer, 1999, p. 162). As Cope and Kalantzis (2000, p. 5) argue, in the new media environments, 'meaning is made in ways that are increasingly multimodal'. Moreover, the presence of hypertext and hypermedia in screen environments further complicates the nature of literacy and meaning-making in that students now engage with 'texts' which are multilayered, multimedia-based, non-sequential and which can be adapted to their needs.

As will be shown in Chapters 2 and 3, the current literature relating to multimedia learning covers a wide area, with perspectives from diverse fields of enquiry such as cognitive science, social semiotics, critical theory and computer-science. Despite the fact that there is a growing body of literature on the need to redefine the concept of literacy for multimodal and hypermedia learning environments, research on the meaning-making resources in these environments is still relatively new.

1.2 Key terms: multimodality, multisemiosis and hypertext

Before introducing the research context and the broad theoretical framework, the terms multimodality, multisemiosis and hypertext as they are used in this thesis deserve some brief explanation. As will be reviewed in Chapter 2, although the term 'multimodality' has been used in cognitive theoretical frameworks, within social semiotics the term refers to the relatively recent research field which explores the interaction of different systems of meaning, including language. However, as this thesis will demonstrate, the theory to describe multimodality is still evolving and confusion exists over the use of terms such as 'mode', 'modality' and 'semiotic'. O'Halloran (2005, p. 20) distinguishes between 'multisemiotic', which is used for texts constructed from more than one semiotic resource such as language, visual display and mathematical symbolism, and 'multimodal', which is used for discourses which involve more than one 'mode' or channel, such as the visual and auditory mode. Thus a website may be at the same time *multimodal* if it contains both the visual mode (e.g. written text or images) and the auditory mode (e.g. music), and *multisemiotic* as it contains language, visual images and music. For the sake of consistency, the terms multimodal and multisemiotic used in this thesis will be based on O'Halloran (2005).

Thibault (2000, p. 312) characterises multimodality as the diverse ways in which a number of distinct semiotic resources (linguistic, visual images, sound, movement) 'are both co-deployed and co-contextualised in the making of a text-specific meaning'. It has also been described as a multiplicative rather than additive concept (e.g. Lemke, 1998b; Thibault, 2000), in which the combination of semiotic resources produces new patterns of relations which are not the same as the sum of each resource. This broad conceptualisation of multimodality will be explored through the analysis in later chapters. Thus the term multimodality will be used in one sense to refer to the research field and in another, to the theoretical concept which forms the basis of this thesis.

The basic concept of hypertext is that information is organised as a network, the 'nodes' of which are chunks of information related by different types of links. Although the terms hypertext and hypermedia are frequently used interchangeably by some authors (e.g. Landow, 1997; Snyder, 1997), in other cases there have been serious attempts to sort out what has been described as a 'definitional quandary' (Dugan, 1999). For the purposes of this thesis, however, I will make no distinction between the terms hypertext and hypermedia, since hypertextually-organised content can consist of multimodal and multisemiotic resources.

1.3 Introducing the research context

As mentioned above, the theory and research which underpin this thesis derive from Systemic Functional Linguistics, the social semiotic theory of language which has inspired much of the recent research in the field of multimodality. The key principles of the theory will be outlined in Chapter 3, where the role of the theory in the research design will be discussed, together with a review of research on multimodality. At this point, however, in order to contextualise the research aims, a brief overview of key research on multimodality will be provided.

Over the past decade, social semiotic accounts of multimodality and multisemiosis in a range of contexts, largely based on SFL (Halliday, 1985, 1994; Martin, 1992), have emerged. These have been enriched by accounts of the grammar of images (Kress & van Leeuwen, 1996; O'Toole, 1994), sound, (van Leeuwen, 1999) and action (Martinec, 1998, 2000a). The unifying theoretical principle underlying much of this research is Halliday's metafunctions. This principle posits three metafunctions which simultaneously construe meaning - the *ideational* (representation and ordering of experience - oriented towards the field of discourse), the *interpersonal* (enacting social relationships - oriented towards the tenor of discourse) and the *textual* (organising text - oriented towards the mode of discourse) (Halliday, 1985).

Some researchers within this field have argued that all texts are multimodal (e.g. Baldry, 2000b; Kress, 2000; Kress & van Leeuwen, 2001; Lemke, 1998b), and that there is a need for re-theorisation of 'text' to include multimodal meaning, particularly in computer-based environments (Unsworth, 2001), since the notion of text has for too long focussed on a linguistically motivated account of meaning. In discussing visual and verbal modes of communication in computer environments, Kress (1997, p. 72) notes that the predominance of writing is being challenged by the ‘screen - the new space of representation’. He argues that current theories of language are inadequate to explain the interrelationships between the different modes and advocates a theory which permits ‘an integrated description of multimodal texts and their production’ (Kress, 1997, p. 75). Thus the common sense view of meaning, which holds language as central, is no longer tenable in a multimodal theory of communication (Kress & van Leeuwen, 2001).

More significantly for this thesis, recent investigation of multimodal communication and representation on the page and screen has been carried out in educational contexts in science (Baldry, 2000a; Guo, 2006; Lemke, 1998b, 2000a, 2002a; O'Halloran, 1999b, 2003, 2005). However, apart from Baldry and Guo, whose interest is in English for Academic Purposes/English for Specific Purposes (EAP/ESP), much of this research has been confined to school-based contexts. In university settings, with the exception of Guo (2006), multimodal research has tended to focus on the ‘expert’ genres of the conference presentation (e.g. Rowley-Jolivet, 2002) or the journal article (e.g. Lemke, 1998b; Miller, 1998). Adopting the SF theoretical principle of the metafunctional organisation of meaning, the research proposed in this thesis will build on research in the field by examining a relatively under-researched corpus of multimodal texts in university undergraduate science.

1.4 Research aims

The overall aim of this research is to provide an account of multimodal and multisemiotic meaning in textbook and computer-based teaching and learning resources in first year science at university and to consider the implications of this account for students' multiliteracies for academic purposes.

The materials to be investigated will be computer-based (CD-ROMs and online) and print-based (textbooks) resources, which are both typical of those used in undergraduate science courses and relevant to my professional context.

1.4.1 Specific objectives:

- to classify teaching and learning resources in undergraduate science in Australian universities according to their distinctive textual features and context of use
- to describe how multisemiotic and multimodal systems combine and interact to construe meaning in disciplines in science on the page and the screen.

1.4.2 Research questions

The research aim is formulated as a series of research questions, which are framed according to Halliday's metafunctional principle. These questions concern the ideational, interpersonal and textual metafunctional analyses of multimodality of the thesis corpus. Specifically, the research aim translates into the following sub-questions:

Ideational:

1. How is content knowledge represented in conventional page format and on the computer screen through different modes and forms of semiosis?
2. How do images and language work together to construct technicality?

Interpersonal:

3. How are pedagogical roles such as reader/viewer/learner and

writer/teacher/designer/knower constructed in the multimodal learning environment of the page and screen?

4. How does the notion of interactivity compare in page and screen formats?
5. How is the notion of scientific realism constructed across text and image?

Textual

6. How do layout and organisational structure contribute to meaning on the page and screen?
7. How do images and language work together to construe abstraction on the page and screen?

1.4.3 Scope of the research

There are still significant theoretical and methodological challenges posed by multimodal analysis - managing the quantity of data, transcribing and presenting the analyses, selecting an appropriate unit for analysis and mapping intersemiotic meaning relations are but a few! The potential to generate an overwhelmingly large quantity of data necessarily limits the scope of the analysis. As a result, the primary focus of the metafunctionally-based analysis of intersemiosis in this thesis will be on the ideational metafunction and the secondary focus will be on the interpersonal and textual metafunctions.

1.4.4 Significance of the research

It is hoped that the research will lead to useful outcomes, which are both relevant to my professional context and to the wider university community. These may include:

- a typology of computer-based and print-based learning resources in science at university level
- a framework for the analysis of multimodality and intersemiosis, which could inform the teaching of multiliteracies.
- an understanding of what kinds of transformations in literacy practices and in conceptions of literacy are taking place for students learning science in technology-enhanced environments at university.
- a set of principles which can be used to inform the educational design of teaching and learning resources for university students.

1.5 Thesis outline

To contextualise the research, Chapter 2 reviews the literature from cognitive and social theoretical perspectives. Although far-reaching in its coverage, this context will span two broadly intersecting areas of research. The first is current and traditional technologies in teaching and learning science at university and the underlying theories of learning and knowledge construction. The second is the social construction of scientific knowledge and its relevance for understanding multimodal representation in scientific discourse.

Chapter 3 will provide a rationale for the theoretical framework underpinning the thesis. Key tenets in SFL theory, which are of relevance in the reasoning about multimodality in this thesis, will be reviewed. The chapter concludes by discussing recent research on multimodality.

The first part of Chapter 4 outlines the research design for the whole study and the second part provides a description of the context of the corpus. The third part presents the methodology for Stage 1, the multimodal content analysis, in which further details of the corpus, the approach to analysis and a description of the categorisation of the content are provided. The chapter concludes by pointing to some of the methodological issues which arose during Stage 1.

Chapter 5 presents the results of Stage 1 and discusses their significance, concluding with the principles for the selection of the Stage 2 corpus.

Chapter 6 describes the analyses undertaken for Stage 2, the multimodal discourse analysis and Chapter 7 discusses the results for this stage.

Finally, Chapter 8 discusses the general significance of the research and its limitations, concluding with implications for the teaching of multiliteracies at university.

CHAPTER 2

LITERATURE REVIEW PART 1

2.0 Introduction

Chapter 1 laid the foundations for the research by referring to the changing context in teaching and learning science at universities today and the increasing role of ICTs in that process. It also pointed to the need to broaden the concept of literacy in this context to multiliteracies and to the need for research into how language works together with other systems of meaning-making in the new learning environments of the page and screen. The review in this chapter will extend this discussion by situating the study within its broader context in order to provide a basis for a review of social semiotic theory and research into multimodality and intersemiosis in Chapter 3. As pointed out at the end of Chapter 1, the literature related to this study has points of contact with a wide range of fields of enquiry, many of which are informed by sociocultural theories of learning and of knowledge construction. These include the sociology of scientific knowledge and social constructivist and cognitive approaches to learning with ICTs.

The purpose of this review is to discuss the relevance of two broadly intersecting fields of enquiry to the concepts of multimodality within social semiotics. The first relates to current and traditional technologies in teaching and learning science at university and their underlying theories of learning and knowledge construction. Of interest will be how multimodality and learning with multimedia have been researched within social and cognitive theoretical frameworks. The second field of enquiry is the social construction of science and its relevance for understanding visual and verbal representation in science.

2.1 Technologies in teaching and learning science at university

In the introduction in Chapter 1, I discussed the broad role of information and communication technologies in universities today in reshaping teaching and learning and in driving research. I also alluded to such research as tending to focus on the technological innovation or on measuring student ‘learning gains’ rather than on the meanings afforded by different technologies and on the development of students’ multiliteracies. The review will now take up this issue by first examining how print and electronic educational media are being used in university curricula, particularly in science and then by reviewing the research and underlying theories of learning and knowledge which inform this use.

2.1.1 Which technologies?

In a report which evaluated the future uses of digital technologies in higher education at Queensland University of Technology (Rossiter, 1997, p. 84), four main electronic technology clusters relevant to university curricula were identified. These have now become commonplace:

- the Internet and the World Wide Web, including the use of web-based courseware such as WebCT (http://www.webct.com/) and TopClass (http://www.wbtsystems.com/)
- Continuous media over networked environments, including interactive multimedia and hypermedia, real time streaming of audio and video
- Metadata and advanced indexing systems and digital libraries
- Computer-mediated Communication (CMC) or collaborative and conferencing technologies.

Since this report, newer technologies have emerged which are beginning to have an impact on teaching and learning in schools and universities. These include:

- mobile technology and wireless networks
- interface technologies such as:
    - advanced visualisation technologies which allow simulation and virtual reality in virtual environments (VEs) or in 3D learning environments (3DLEs) like virtual laboratories
    - electronic books
- interoperability and learning/institutional management systems
    - learning objects accessible via the Web and linked to meta-databases which can be configured by teachers (Reimann & Goodyear, 2004, pp. 7-8).

In such a rapidly changing environment, it raises the question of where to place 'traditional' technologies such as textbooks and lectures, which are still integral components of most on-campus courses in science. It should also be acknowledged that traditional technologies and their applications have evolved along with electronic media in the delivery of course content.

More learner-centred attempts to classify the main types of technologies have been proposed using broad-based terms such as 'educational media' and 'multimedia' (Laurillard, 2002; Mayer, 2001). Mayer's use of the term 'multimedia' covers many scenarios in which verbal and visual material can be presented in print or on screen and via the auditory or visual channels. Using more specific criteria, Laurillard's (2002) division of educational media is not only according to their logistical properties, such as whether they require prior design and development and how labour intensive the delivery is, but also, more importantly, according to the teaching and learning processes and the learning experiences they support. For Laurillard, the media of text, talk, visuals or interaction can be delivered in a variety of ways, such as meetings, print, cassette, disc or network. As learning technologies have advanced a more complex array of approaches has emerged.

2.1.2 Which approaches?

Much of the teaching and learning of science in on-campus courses today involves a 'hybrid' or 'mixed delivery' approach to the use of educational media, where part of the course is delivered face-to-face and part online. Such an approach combines traditional and computer-based pedagogies, where textbooks supported by multimedia, online course modules, discussion boards and online course management systems make up the complex array of media which are integrated into the course. The biology, chemistry and physics texts of the thesis corpus are situated in a course context which involves a 'hybrid' approach to the delivery of course content. This context will be described in detail in Chapter 4, but here I will make some general observations about hybrid approaches.

Among the justifications for a hybrid approach are that it is a more cost effective, flexible and learner-centred way of delivering a course, particularly to introductory high enrolment classes such as biology (Franklin & Peat, 2001; Riffell & Sibley, 2005) and the physical sciences (Beichner et al., 1999; Saul, Deardorff, Abbott, Allain, & Beichner, 2000; Seymour, 2001). Although textbooks and their supporting multimedia are considered integral to most mixed-mode delivery courses, they tend not to be included in the evaluation and research related to such courses. Paper-based resources, including textbooks or digitally available readings from textbooks, may feature as part of a 'virtual learning environment' (VLE) or as part of a unit of study managed by courseware such as

WebCT. In these environments and in their own time, students can work online on computer-based learning modules such as quizzes and content activities, and can access print-based resources such as lecture notes, course handouts, and digitally-reproduced pages from a printed textbook. The 'virtual spatiality' typical of VLEs is said to provide an environment which is 'easy to navigate and use' (Peat, 2000, p. 2). The claim is that such environments offer students an alternative 'space' for learning through an online domain that allows 'synchronous, collaborative interaction among teachers and students, while also providing asynchronous learning resources for individual use by students at any time' (Peat, 2000). Their flexibility is part of their appeal, but, as these authors point out in a later article, their 'value-addedness' is not necessarily guaranteed (Peat, Franklin, Lewis, & Sims, 2002).

Considerable investment has been made not only in the development of online learning environments and in the design of resources, but also in research into their effectiveness. Section 2.2 will explore research into the effects of ICTs on student learning in science and the theories of learning which inform this research. Although the focus is on research into ICTs, textbook research will be discussed where relevant. At issue will be alternative epistemologies in teaching and learning science which are manifest in cognitively and socially-oriented notions of meaning and representation and in differing views of knowledge and knowledge construction.

2.2 Research on applications of ICTs in science: underlying theories of learning and knowledge construction

An increasing number of journals are devoted to the educational applications of digital technologies in science. Many studies in these journals are concerned to establish the benefits of learning with ICTs by comparing print and electronic learning resources or comparing face to face and electronic modes of delivery (e.g. Dillon & Gabbard, 1998; Eveland & Dunwoody, 2002; Kozma & Russell, 1997; Rodrigues et al., 1999; Samson et al., 1999; Senese, Bender, & Kile, 2000). Other studies are more focussed on the technological capabilities of the media (Alexander, 1999; Alexander & Hedberg, 1994; Baker & Dwyer, 2005; Emerson & Mosteller, 1998; Rossiter, 1997). The theories of learning which frame this research are predominantly social constructivist or cognitive in orientation. For a variety of reasons, not least of which is to justify the cost of ICT-based development, both cognitively and socially framed research have attempted to understand how students learn with ICTs, but, as will be demonstrated in sections 2.1.1 and 2.1.2, the focus has not generally been on how students' literacies are being challenged in fundamentally new ways.

2.2.1 Social constructivist theory

Social constructivist learning theory is not a single unified theory (Hyslop-Margison, 2004) and many have attributed its origins to Vygotsky's sociocultural theory of learning (Duffy & Cunningham, 1996; Laurillard, 2002; Taylor & Willison, 2002). ICT-based research within a social constructivist theoretical framework has been motivated by a need to examine the way in which the use of technology has necessitated change in teaching and learning practices. This change has been described broadly as a shift from a teacher-centred model of teaching to a student-centred one or from an instructivist approach - located within behaviourist theories of learning- to a social constructivist approach - located within socio-cognitivist theories (e.g. Challis, Holt, & Rice, 2005; Harper & Hedberg, 1997; Hedberg & Harper, 2002; Jonassen, 1994; Jonassen, Peck, &

Wilson, 1999; Laurillard, 2002; McLoughlin & Taji, 2005; McRobbie & Tobin, 1997; Neo & Neo, 2001; Tam, 2000; Tse-Kian, 2003).

In a clear analysis of the role of constructivism in instructional design and technology, Tam (2000) argues that social constructivism cannot solve all instructional problems but does present a useful alternative view to the behaviourist objectivist conception of learning, where knowledge exists outside the individual, unrelated to its social construction and is transmitted to the learner as a set of discrete skills and facts. A constructivist model of instructional design enables a learning environment to be created in which 'learners are engaged in negotiating meaning and in socially constructing reality' (Tam, 2000, p. 6). For a number of decades social constructivist views have been particularly prevalent in science education at the school level in Australia (Taylor & Willison, 2002, p. 472).

One study which exemplifies a social constructivist approach in university science teaching is that of Kearney & Treagust (2001). The researchers used software containing interactive digital video clips to present real world demonstrations to physics students 'to elicit their pre-instructional conceptions of Force and Motion and encourage discussion about these views'. Students were given 16 tasks involving the 'predict-observe-explain' (POE) strategy advocated by White & Gunstone (1992), while interacting with the video material. This strategy was identified as being useful for eliciting and encouraging discussions of students' science conceptions, where students predict the outcome of a demonstration, decide on a reason for their prediction, observe the demonstration and then explain any differences between their prediction and observation (Kearney & Treagust, 2001, p. 65). When applied to an interactive multimedia program, the POE strategy used in this study, which was built on constructivist principles, provided an opportunity for research into student learning during their interaction with the program. Findings from this study suggest that students were engaged in more meaningful ‘science talk’ while using the program.

However, exactly what is meant by ‘meaning’ and how this relates to a social context are factors not made explicit within social constructivist frameworks. Nor is there any explicit acknowledgement of how meaning is made across modalities and the implications of this for literacy practices. Interestingly, however, some of the research on learning across modalities has been done within cognitive theoretical frameworks, as the next section will demonstrate.

2.2.2 Multimodal research within cognitive frameworks

Within cognitive frameworks, the concept of different modalities (e.g. visual, verbal, tactile and animation) in screen and print media and their effect on student learning in science is not new and is the subject of ongoing research (e.g. Iding, 2000; Kalyuga, 2000; Mayer & Anderson, 1992; Milheim, 1993; Moreno & Mayer, 2000; Reimann, 2003; Rieber, 1996; Shu-Ling, 1998). The theoretical framework for much of this research has been provided by cognitive load theory (Sweller, 1999) and dual coding theory (Paivio, 1986). Some of the research is subject specific (e.g. university students’ difficulties with visuospatial cognition in chemistry (Wu & Shah, 2004); the effect of multimedia-based instruction on high school students’ understanding of macroscopic, symbolic and molecular representations of chemical phenomena (Ardac & Akaygun, 2004); and the impact of integrating a tactile model into an existing computer visualisation of thermal equilibrium on students’ conceptions within thermodynamics in physics (Clark & Jorde, 2004). In engineering, Kalyuga (2000) found that combining audio explanations with the same visually presented text when explaining a diagram for students had a negative effect on their learning (as measured by multiple choice tests), because of working memory overload. The conclusion was that textual explanations should be presented in auditory rather than written form and that the same text should not be presented concurrently in both written and auditory form (ibid, p. 171).

Within this field, one of the most influential theoretical frameworks informing research and instructional design is Mayer's theory of multimedia learning (Mayer, 2001; Moreno & Mayer, 2000). With its origins in textbook design, Mayer and his fellow researchers are concerned with the problem of cognitive load and how learners construct knowledge from words and pictures in screen and paper-based presentations (Mayer & Anderson, 1992; Mayer, Bove, Bryman, Mars, & Tapangco, 1996; Mayer, Steinhoff, Bower, & Mars, 1995). The multimedia theory of learning is based on three well-established assumptions in cognitive science: a) the dual-channel assumption (that we possess separate information processing channels for auditory and visual material); b) the limited-capacity assumption (that we are limited in the amount of information we can process in each channel at once); and c) the active processing assumption (that we actively select, organise and process information to construct meaning) (Mayer, 2001, pp. 42-50). An example of this research is Moreno and Mayer's (2000) study comparing the problem-solving transfer performance of US college students viewing alternative presentation formats of a multimedia explanation of lightning. Six principles of instructional design were derived and tested. These included the 'modality principle' which states that students learn better when verbal information is presented auditorily rather than visually on screen text for both concurrent and sequential presentations; and ‘the redundancy principle’, which states that students learn better from animation and narration than from animation, narration and text, if the visual information is presented simultaneously to the verbal (Moreno & Mayer, 2000). The findings supported all six principles and concluded that multimedia presentations should minimise working memory load and not contain extraneous modalities. Mayer has since built on this research and developed a cognitive theory of multimedia learning, which is based on three assumptions as summarised in Table 2.1.

Table 2.1

Three Assumptions of a Cognitive Theory of Multimedia Learning Adapted from (Mayer, 2001, p. 44)

Assumption	Description
Dual channels	Humans have separate channels for processing visual and auditory information
Limited capacity	Humans are limited in how much information they can process in each channel at one time
Active processing	Humans engage in active learning by attending to relevant incoming information, organising selected information into coherent mental representations and integrating these with other knowledge.

According to Mayer’s theory, visual and auditory information passes from the sensory memory (via the dual visual and auditory channels) into the working memory, where the visual and verbal representations become constructed into knowledge, through cognitive processes of selection and organisation. Finally, the knowledge passes into the long-term memory where it becomes integrated with prior knowledge and stored for later use. Some of the typical ways knowledge can be structured are: *process* (e.g. cause and effect chains), *comparison*, *generalisation* (e.g. main idea with supporting details), *enumeration* and *classification* (Mayer, 2001, pp. 51-52). Again, although these categories refer to the ways knowledge is structured, there is no explicit reference to language and its relationship to thought or how these categories relate to either visual or verbal representations.

Mayer's theory has been very influential in driving research into student learning as well as providing a theoretical rationale for instructional design (e.g. the online tutorial system, MasteringPhysics™, www.masteringphysics.com). This is perhaps not surprising since the appeal lies in its simplicity – the view of learning and cognition which is said to be effective for instructional design can be reduced to 'five principles' or 'three assumptions' (see also (Iding, 2000). Over the last fifteen years Mayer and his colleagues have conducted an impressive body of research to support and refine the theory (e.g. Mayer, 2001, 2003; Mayer & Anderson, 1991, 1992; Mayer et al., 1996; Mayer et al., 1995; Moreno & Mayer, 2000). The overriding claim, called 'the multimedia effect' is that students learn 'more deeply from well-designed multimedia messages' (Mayer, 2003, p. 125). This is based on the premise that 'the intelligent design of multimedia instructional messages depends on an understanding of how the human mind works' and is driven by the goal of increasing 'the power of human cognition' (Mayer, 2003, p. 137).

Several relevant issues for this thesis emerge from this body of research:

- The view of knowledge construction does not take into account the social context.
- Knowledge and meaning are theorised from an 'information processing' point of view and not explicitly related to language.

- Cognition is not explicitly linked to visual or verbal literacies since the view of ‘thinking’ and ‘knowing’ are internal, personal and not socially constructed.
- Learner characteristics and learning styles do not tend to be related to a social context.
- Although verbal and visual and verbal representations are at the core of this theory and research, they are not theorised from the point of view of meaning or how they co-construct meaning.

More recent research, however, still within cognitive frameworks, has begun to address some of these issues. In a special volume devoted to current issues in research into multimedia learning Reimann's (2003) summary of the papers in this volume raises some valid issues, not least of which are the points of contact between ‘mentalistic’ or cognitive views of learning with different modalities and more socially oriented views. His paper, entitled ‘Multimedia learning: beyond modality’, argues that one of the main limitations of dual coding theory is the one-dimensional view of multimedia, which addresses only the ‘modality’ i.e. either the audio or the visual. He defines modality as ‘the forms of expressions that are used for displaying information’ (Reimann, 2003, p. 250). Other limitations of dual coding theory relate to what he describes as ‘representational issues’, such as decisions about what to represent and in how much detail and about how best to represent phenomena graphically for problem-solving tasks (Reimann, 2003, p. 250).

Reimann acknowledges the importance of extending cognitively-based theory and research of multimedia learning to include an understanding of how external representations are transformed into internal ones, in other words, how best to design multimodal learning resources containing animations, graphs and other visuals to foster learning. He goes further to endorse the sociology of scientific knowledge research (Lynch, 1990; McGinn & Roth, 1999) on the ‘material features of external representations and their cognitive and social affordances’, conceding that ‘the material aspects of representations may be more important for (scientific) practice than psychologists admit’ (Reimann, 2003, p. 250).

Others working within socially-oriented theories, such as Laurillard (2002), have raised the point that students need representational skills or explicit practice in the representation of knowledge of their subject, in language, symbols, graphs, diagrams, and in the manipulation and interpretation of those representations’ (Laurillard, 2002, p. 40). While not directly acknowledging social semiotic theory, she argues that a key aspect of learning subject specific knowledge is understanding its relational nature and that ‘the sign-signified relation, which concerns the interpretation of symbol systems, whether linguistic, symbolic or pictorial’, is one of the most important activities in this process (Laurillard, 2002, p. 48). She does not expand further on how these symbol systems might work together but points to the lack of research at university level into how students learn the subject-specific forms of representation, i.e. multimodal literacies.

The above section has discussed some of the limitations of the research into multimedia and multimodality within cognitive frameworks. What also emerges consistently is a lack of focus on the meanings learners have to negotiate in print and screen environments and on the literacies they need. Much of the research does not take into account the social contexts of these meanings and does not attempt to define a metalanguage which could be used to describe these socially constructed meanings. To explore ‘meaning-oriented’ perspectives of multimedia and multimodality in science therefore, we need to move beyond cognitive theories and descriptions to more interpretive and socially constructed theories for which meaning and context become a prime concern.

2.3 The social construction of science and multimodality

Since the 1970’s the notion of science as a progressively accumulated body of objective knowledge has been challenged by sociologists interested in the social construction of scientific knowledge (Lynch, 1990). In most of this work however, the application of sociological reasoning about scientific knowledge to science education and to the development of scientific literacies was not a priority. Apart from studies by Myers (1992) on biology textbooks, the objective of much of this work was to understand the practices and social contexts of expert scientists rather than those of students learning science. The literature on the sociology of scientific knowledge (SSK) covers a wide range of themes, too broad to be dealt with in this review. However, as I will demonstrate in the next section, many sociological interpretations of representational practices in science have points of contact with SFL-based description of multimodality.

In their introduction to a seminal volume of papers on representation in science, Lynch & Woolgar (1990a, p. 2) point to the ‘heterogeneity of representational order’. This goes beyond diversity in types of visual, verbal and actional representational devices such as graphs, diagrams, equations, written reports and laboratory conversations, since it includes ‘the theoretical principles and functions of representation' - i.e. resemblance, symbolic reference, similitude, abstraction, exemplification and expression. Despite this assertion about theory and description, the papers are not based on a single analytic perspective such as semiotics, ethnomethodology, speech-act theory or constructivism. The reader is left to decide whether this lack of a single coherent method is a strength. In my view the strength lies in the rich discourse on the ‘situated’ processes of knowledge construction in science – the ‘case studies’ - rather than on the methods of analysis.

The origins of much of the discussion on representational practices in this volume can be found in postmodernist critiques of traditional views of science (Derrida, 1970; Foucault, 1970) and in later work by Knorr-Cetina (1981) and Latour & Woolgar (1986). According to Latour and Woolgar (1986) representations other than written text are seen as ‘inscriptions’, such as readings and recordings from screen-based devices, tables, graphs and micrographs. They are more than simply representations of ‘natural objects’ but are rich ‘repositories’ of social and cultural processes (Lynch & Woolgar, 1990a, p. 5), socially constructed as scientific products to be shared among different communities. They are intricately bound to their contexts of production and use and should not be seen as independent of the social institutions and practices which created them.

Before reviewing the more recent work in SSK and its application to science education, I will discuss three interrelated themes on visualisation of scientific objects in the visual displays of scientific documents, which occur in the earlier work in SSK. The first is the theme of selection, i.e. how scientists employ certain methods of visualisation to select objects of study and then simplify and schematise them. The second is the process of mathematisation - how mathematical order is assigned to these to these objects (Lynch, 1990, p. 153). The third theme, not just confined to SSK, is the conceptualisation of abstraction in visuals and its relation to the notion of scientific reality. The themes are of relevance to this thesis in helping to inform the description of technicality and abstraction in images and will be picked up again in Chapters 3, 6 and 7.

2.3.1 The selection and mathematisation of visuals

Lynch, 1990 (p. 154) was among those who sought to detach the idea of visual representation from its 'individualistic cognitive foundation' to focus on externalised and socially constructed visual displays. His work and that of others in the same volume (e.g. Bastide, 1990; Myers, 1990) is mainly concerned with print-based visuals in scientific papers and signalled a significant move away from analysis preoccupied with verbal content in science, or at best, analysis which regarded visuals as secondary to verbal content. Visuals thus began to be acknowledged as pivotal to the construction of scientific texts. The different types of visuals in these texts have undergone procedures of selection and mathematisation, transformed into visual displays which are used as evidence to support arguments (Lynch, 1990).

Selection of visual displays for scientific texts involves 'the coordinated practices' of those involved in research who 'transform invisible or unanalysed specimens into visually examined, coded, measured, graphically analysed, and publically (sic) presented data' (Lynch, 1990, p. 156). In other words, selection is a social process as much as one which relates to mental or perceptual activity. The selection of data for presentation may also involve processes of transformation, say in the case of laboratory specimens which are photographed and then 'rendered' into diagrams for visual displays. The juxtaposition of the photograph (on the top) and the diagram (on the bottom) in Lynch's examples also plays a role in the interpretation of the images. This is described as a 'directional' relationship, or one of interdependence but not equivalence (Lynch, 1990, p. 160).

Mathematisation of visual displays, such as that found in tables and graphs, involves the integration of ‘the substantive, mathematical, and literary resources’ of scientific practices (Lynch, 1990, p. 169). Lynch argues that the graph is not inherently mathematical but involves the transformation of selected ‘natural’ specimens ‘into analysable points and lines within Cartesian coordinates’ (p. 170), resulting in a hybrid (and socially constructed) object. There is no ‘cognitive universality’ inherent in these visual displays but each is a carefully manipulated artefact for a very specific social purpose. Underlying this argument therefore, is the belief that the practices which lead to the production and display of visuals should be made explicit and not be taken for granted or hidden from analysis. Before drawing together the points on these two themes, I will examine the third theme of abstraction, thereby broadening the discussion beyond SSK.

2.4 Studies of visual abstraction

The concept of abstraction in visuals has long interested researchers from diverse fields of enquiry. Studies range from those focussed on the psychological and cognitive aspects of visual abstraction to those more concerned with sociological aspects. The seminal work by scholars such as Gombrich (1960) and Arnheim (1969) in the 1960’s on the psychology of perception in art each in its own way challenged many established ideas on visual representation, on the portrayal of reality and on perception and its relationship to cognition. Each scholar also developed the notion of a ‘language of art’, recognising the value of systematic inquiry to explain how artistic conventions (or symbol systems) are related to their context.

2.4.1 Arnheim and abstraction

Arnheim's publications of *Towards a Psychology of Art* in 1967 and his *Visual Thinking* in 1969 were significant in their assertion that thinking is not limited to manipulation of words and numbers but includes visual perception. Visual perception (or thinking) takes time and is learned, laying the groundwork for concept formation (Arnheim, 1969, p. 294). He claimed that education has downplayed the importance of the visual for learning. He broadened the boundaries of discussion of the visual from the arts to science, claiming that the criteria of exactness in art are quite different from those in science.

Arnheim was also concerned to promote a functional perspective on images rather than a decontextualised classification of types of images. Indeed, Kress & van Leeuwen (1996, viii) would like 'to claim him as a great social semiotician', although he was working from the perspective of Gestalt psychology. He recognised three functions of images – as pictures, symbols or signs. 'The image itself does not tell which function is intended. A triangle may be a sign of danger or a picture of a mountain or a symbol of hierarchy' (Arnheim, 1969, p. 136).

Arnheim's insights into visual abstraction are significant. He posited two scales of abstraction, one scale for images and the other for experience, in order to reason about the relationship between the image and the experiential world as depicted in pictures and symbols. 'Pictures and symbols depict experience by means of images in two complementary ways. In a picture, the abstraction level is higher than the experience it represents; in a symbol the opposite is the case' (p. 150). He argued that the relationship between concrete and abstract entities was a continuum and that it was not useful to see them as dichotomous. Nor was concrete simply related to 'that which is physical and abstract to that which is mental' (p. 155).

2.4.2 SSK and abstraction

Abstraction in visuals and its role in the scientific construction of evidence has been a particular focus of study by some within the SSK literature (e.g. Bastide, 1990; Lynch & Woolgar, 1990b; Myers, 1990). Lynch and Myers were particularly interested in analysing varying levels of abstraction in the photographs, drawings, tables, diagrams and graphs of different genres in the field of biology such as textbooks, popular science articles and research papers. Lynch's (1990) discussion of abstraction relates to the processes of selection, transformation and mathematisation reviewed in 2.3.1. To further his argument, he analyses two juxtaposed photograph-diagram pairs from different fields in which the diagram is a 'rendering' or transformation of the same phenomenon in the photograph or, more precisely, the micrograph. The key points of interest for me in this discussion relate to what happens in the shift from the micrograph to the diagram. Lynch claims that this shift involves more than reduction or simplification of features of the micrograph and more than a synthesis of form: 'Most importantly, it [the transformational process] strives to identify in the particular specimen under study 'universal' properties which 'solidify' the object in reference to the current state of the discipline' (Lynch, 1990, p. 157). Thus transformation processes serve to shift the focus from the specific, concrete 'reality' of the micrograph to a more generalised and abstract version in the diagram.

Different levels of abstraction in images have also concerned Myers (1990), although he analyses a different genre from Lynch – that of E. O. Wilson's scholarly 'textbook' *Sociobiology: The New Synthesis*. Like Lynch, he argues that in the shift from the ‘apparently realistic’ photograph to the ‘highly abstract’ diagram or graph there is a move ‘from the particularity of one observation to the generality of a scientific claim’ (Myers, 1990, p. 235). His examples of photographs are full of ‘gratuitous detail’ which gradually gets eroded in the drawings, maps and graphs. Within a certain category he also identifies a cline of abstraction. For example, a drawing may be closer to the conventions of a photograph or closer to those of a diagram in its depiction of the object and its setting. In a diagrammatic drawing many details as well as the setting may be completely removed.

In her analysis of scientific images, Bastide (1990) recognised the importance of understanding different ‘dimensions’ (or ‘semi-symbolic’ systems) such as quantity, space, time, position and colour. Bastide discusses these in her analysis of various photographs, particularly micrographs, tables, graphs and diagrams. While not specifically focussing on abstraction she does examine the different representational processes involved in the transition from a scientific photograph to a table and to a graph. Using the example of the water-circulation mechanism through countercurrent in a hamster kidney, Bastide compares how the same data is represented in a table, a graph and a series of photographs, pointing out their advantages from the point of view of readability. What she also appears to be acknowledging are the typological and topological dimensions of different types of images in scientific publications. This is an important aspect of the work of social semioticians like Lemke (1998b, 2002a) and will be taken up in Chapter 3.

2.4.3 Rhetorical studies and abstraction

Other studies on abstraction in visuals in science have been carried out within the field of rhetoric (Beck & Osman-Jouchoux, 1992; Rodman, 1985) with application to the teaching of technical writing and visual literacy. The studies draw on ideas of visual syntax (form) and visual semantics (content) from the visual literacy movement of the 70s and 80s (Kovalik & Lambdin, 1996). Form or visual syntax relates to the orderly arrangement of components of the visual such as dots, lines, shapes, tone, colour and size. Rodman (1985), for example, classified images according to their form and their content. For her, content includes semantic notions of 'area' for maps and aerial photographs, 'quantity' for tables, bar graphs and line graphs' and 'process' for flow charts. She claimed that in the shift towards abstraction visuals may show:

- movement from the depiction of the particular to the depiction of the generic
- movement from focus on surface characteristics to a focus on structure or organisation
- movement from mimetic to symbolic means of representation

According to Rodman, these characteristics of visuals constitute differing levels of abstraction and visuals can be ranged along a continuum of abstraction.

Rodman's work was extended by Osman-Jouchoux (1991) and then by Beck & Osman-Jouchoux (1992), who took the theory of tagmemics developed by the linguist Kenneth Pike (1982) and applied it to the analysis of visuals. For Pike, each structural unit or tagmeme is at the same time a particle (an individual unit in context), a wave (a dynamic factor) and a field (a system). 'Each of these functional perspectives can be examined from differing points of view: their **contrast** - what makes them unique; their **variation** - how they differ from other things of the same kind; and their **distribution** - how they fit into a larger system, network or environment’ (Beck & Osman-Jouchoux, 1992, p. 706). Based on this framework, Beck and Osman-Jouchoux proposed a grid of nine aspects which ‘help to analyse the definition, form, function, and context of an entity’ (Beck & Osman-Jouchoux, 1992, p. 706).

Another key aspect of Beck and Osman-Jouchoux’s work is recognition of the importance for graphic design, of the integration of text and visuals as rhetorical elements. Although no details are given as to how this might translate into teaching resources, his three step process of rhetorical analysis consisting of: a) describing the rhetorical context; b) describing the rhetorical structure of graphics in terms of their relative abstraction; and c) correlating graphics with the text, could have important implications not only for graphic design but for teaching multiliteracies.

The themes of selection, mathematisation and abstraction discussed above provide some valuable insights into variation in visual displays and their social construction. What is generally lacking however, despite very detailed discussion of visual representation in scientific genres, is first, a consistent set of analytical tools to describe how the linguistic and visual meanings of these texts are co-constructed and second, a descriptive theory of language and visual representation to explain how the texts vary according to their social context. Since the application of this work to science education and to the development of multiliteracies in science was not generally a concern of those reviewed in 2.3 and 2.4, the focus of this review will now shift to discuss researchers who have extended the SSK work to teaching and learning.

2.5 Educational applications of SSK work on visual and verbal representations in science

The educational implications of the SSK work on representation practices for school and university science and for instructional design were of major interest to researchers such as Myers (1992); Han & Roth (2006); McGinn & Roth (1999); Roth, Bowen, & McGinn (1999); Roth & McGinn (1998); Kozma (2003); Kozma & Russell (1997) and Mishra (1999). The research used different methods of analysis to compare expert and novice understandings of multiple representations in science and also foregrounded social rather than cognitive orientations to learning. No longer were students' difficulties in developing scientific understandings attributed to their cognitive deficits or their lack of knowledge. Pointing out the limitations of research from cognitive perspectives on students' use of graphs, Roth & McGinn (1998, p. 37) stress the importance for classroom practice of understanding social accounts of representation practices, advocating a shift from 'individual minds to social arenas', while Kozma (2003, p. 206) advocates a 'situative approach' to learning about multiple representations, which emphasises the social practices which construct them. Integrating perspectives from the psychology of perception and SSK, Mishra (1999) discusses the role of abstraction in scientific images and its pedagogical implications. He identifies three 'danger areas' for students in their reading of scientific illustrations. These can be overcome, he argues, by learning the 'artistic conventions' of illustration; by understanding the hidden assumptions of science and finally by understanding the evolution of illustrations from their original representation to their representation in textbooks. However, despite the promise at the beginning of the article, he does not make clear how his analysis of abstraction could transfer to pedagogy.

More significant contributions to pedagogy were made by Han & Roth (2006); Roth et al. (1999); Roth & McGinn (1998) and Kozma (2003); Kozma & Russell (1997). Using tasks based on multimedia presentations, Kozma (2003) and Kozma & Russell (1997) compared the representational skills of expert chemists with those of chemistry students. Whereas experts could move across multiple representations of the same phenomena and conceptualise their similarity, students were not easily able to do this, often attending to ‘surface features’ such as colour, motion and labels. When students worked collaboratively using a multimedia software package of multiple, linked representations of chemical concepts, their understanding of these concepts improved and they ‘replicated the discourse practices of scientists’ (Kozma, 2003, p. 224). Although this is not stated explicitly, Kozma appears to be arguing for the teaching of multiliteracies and for a metalanguage to help students move easily across multiple representations.

The educational work of Roth and his colleagues derives from their research into inscriptions, which are defined as representations which exist in material form, i.e. on paper or on computer screens. They include graphs, tables, photographs, diagrams, and equations (Roth & McGinn, 1998, p. 37). Roth & McGinn (1998, p. 46) claim that the large gap which exists between representation practices in high schools and those in scientific communities is cause for concern in science education and that focussing on the social orientation of inscription practices will help to bridge the gap. They examined the differences in graph-related practices between high school biology textbooks and expert ecology journals to gain a better understanding of how to teach graphing. They found that in some cases, the graphs in textbooks had little pedagogical value because students were not provided with sufficient support in the textbook to read the graph. The empirical bases of the data were not made clear in the main text and the caption did not help students to interpret the graphs. This work was also important as, unlike much of the earlier work in SSK, the researchers analysed the role of main text and captions in the reading of a graph.

2.6 Concluding comments

The first part of this chapter set out to situate the thesis within its broad research context to establish points of contact between the many fields of enquiry which are of relevance to this study. I began in 2.1 by outlining the context of the new learning technologies in universities and approaches to their use. In 2.2 some of the research on applications of ICTs in science and the socially and cognitively based theories of learning underlying the research were evaluated. It was found that in science education, motivations for this research derived from different and often conflicting perspectives on learning and on the construction of knowledge. Much of the research set out to establish the superiority of screen-based learning environments over print-based or other traditional learning environments, and appeared to be motivated more by a concern to justify the costly investment in the technology than by literacy related concerns. In 2.2.2 the concept of multimodality within cognitively-based research into multimedia learning was discussed. Several issues in this research were identified, which generally related to a lack of acknowledgement both of the social construction of visual and verbal representations of meaning and of the concept of socially situated learning. The discussion in 2.3 moved to the social construction of science and multimodality. Within SSK, work on visual and verbal representations in science was reviewed, with particular reference to the themes of selection, mathematisation and abstraction of visual representations. The concept of visual abstraction in science was explored further in 2.4, drawing on diverse studies from the psychology of perception, SSK and rhetoric. Section 2.5 briefly discussed the educational implications of more recent SSK work on visual and verbal representations in science.

Despite points of contact between some of the research in this chapter and social semiotic descriptions of multimodality, there was a consistent lack of a theory of meaning and tools of analysis to explain how visual and verbal representations co-construct meaning. The very rich discussions of visual representations by various researchers reviewed (Han & Roth, 2006; Roth et al., 1999; Roth & McGinn, 1998) and Reimann (2003) refer to concepts such as multimodality and multiplication of meaning but these are not theorised or drawn on systematically for analysis. Finally, although there were some interesting insights into the educational applications of some of the work reviewed, literacy in science was not a central concern and the need for a concept of multiliteracies was not explicitly articulated.

CHAPTER 3

THEORY AND LITERATURE REVIEW PART 2

MULTIMODALITY AND INTERSEMIOSIS

3.0 Introduction

Chapter 1 introduced the theoretical framework for this study and the role of SFL as the theoretical foundation for the emerging research field of MDA. To provide the rationale for the research aims, some of the major research in MDA was highlighted, particularly that which related to science education and multiliteracies. In addition, to frame the research questions, the metafunctional principle driving much of the existing research into multimodality was explained. The literature review in Chapter 2 situated the thesis in its broad research and pedagogical context through a discussion of the concept of multimodality from cognitively and socially based disciplinary perspectives. This chapter will extend the bases established in Chapter 1 by reviewing:

1) key tenets in SFL theory, which are of general relevance in the reasoning about multimodality and intersemiosis in this thesis (3.1)
2) SFL work on the discourse of science with particular focus on technicality and grammatical metaphor (3.2)
3) educational research on multimodality and multiliteracies (3.3)
4) general research on multimodality and intersemiosis (3.4)
5) theoretical issues emerging from multimodal research which impinge on this thesis (3.5).

The purpose of this discussion is to situate this study in its research and theoretical context and provide a rationale for the methodological framework.

3.1 Key tenets of SFL theory: hierarchies and complementarities

Martin's (2006) conceptualisation of the 'theoretical universe' of SFL as a series of hierarchies and complementarities, summarised in Table 3.1, provides a useful overview which can be used firstly to select key tenets of the theory relevant for this study and secondly, to reflect how these tenets have been taken up by multimodal research.

Table 3.1

Overview of SFL Parameters (adapted from Martin, 2006)

SFL complementarities		**SFL hierarchies**	
metafunction	ideational/interpersonal/ textual	**rank**	composition *whole to part*
axis	system/structure	**delicacy**	classification *general to specific*
agnation	typology/topology	**realisation**	stratification *abstract to concrete*
perspective	synoptic/dynamic	**instantiation**	metastability *system to instance*
modality	verbiage/image etc...	**individuation**	coding orientation *reservoir to repertoire*
...		**genesis**	logogenesis/ontogenesis/ phylogenesis
		...	

Accordingly, aspects of each complementarity and aspects of the hierarchies of rank, realisation and instantiation will be addressed in 3.1.1 and 3.1.2, as a prelude to the discussion in 3.5 on how these aspects have been addressed in multimodal research.

3.1.1 SFL hierarchies: stratification, realisation and rank scale

One of the key principles of SFL theory is that of stratification, deriving from Hjelmslev's (1961) connotative semiotics and Saussure's (1959/66) concept of semiosis, which distinguish between the strata of content (Saussure: signified) and expression (Saussure: signifier). The relationship between content and expression is one of realisation – the content is realised by the expression stratum. Martin (1992) views language as a tri-stratal system, with two levels of content, discourse semantics and lexicogrammar, 'above' the level of expression, phonology/graphology. The lexicogrammar thus is realised through the 'lower-order' stratum of phonology (sounds) or graphology (letters) and realises the 'higher-order' stratum of discourse semantics. Martin (1992, p. 495) extends the notion of the stratified model of language to the interpretation of context, whereby genre (context of culture) and register (context of situation) are seen as two distinct 'communication planes' or strata 'above' language. Language then becomes the expression form of register and register becomes the expression form of genre. Departing from Halliday (1978), Martin (1992, p. 502) regards register as a connotative semiotic system in its own right. Register is organised metafunctionally in relation to the situational variables of field, tenor and mode. As shown in Figure 3.1, Martin represents this stratified model of social context as a series of co-tangential circles, the smaller ones being recontextualised by the larger ones. He also includes Lemke's (1984) notion of metaredundancy, in which 'more abstract levels are interpreted as patterns of less abstract ones' (Martin, 2002b, p. 57). According to Lemke (1984, 1993), metaredundancy relations tend to co-occur in certain contexts, but 'hierarchically' so that there is interdependence in meaning relations across levels.

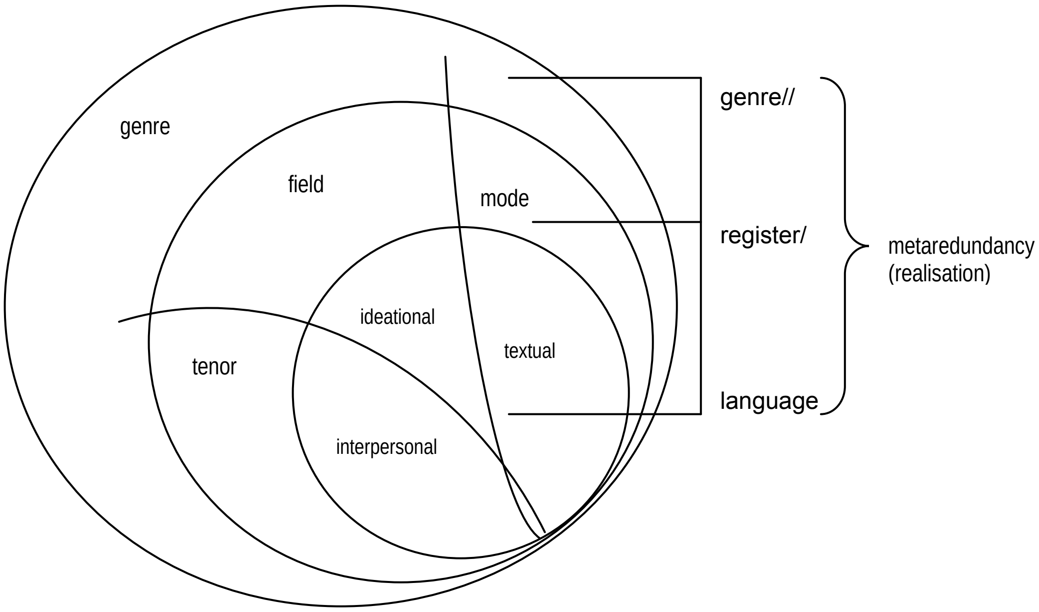


Figure 3.1. Metafunctions in relation to register and genre (Martin, 2002b, p. 57).

The model thus moves through increasing orders of abstraction of meaning. The units of meaning also increase in size, which brings in the notion of the rank scale, where the units at each rank are made up one or more units of the rank below, the relationship here being one of constituency rather than realisation. The units of any rank (including clause) can form serial rather than constituency relationships with other units of the same rank by means of logical relations. These 'complexes' can be linked in a paratactic or hypotactic relation.

When other semiotic systems are combined with text however, the notions of rank, taxis and serial or constituency relationships pose a challenge for analysis and description. At this stage, of interest is the principle of increasing orders of abstraction through a stratified model of context, which are useful for this thesis in building the descriptive power of a theory of multimodality. When other semiotic modalities in addition to language are brought into the model, it could be argued that stratifying the content plane allows meanings to be semioticised and analysed inter-stratally.

3.1.2 SFL complementarities: types of structure and modes of meaning

Drawing on earlier work by Halliday on types of structure for analysing clause grammar and their relationship with metafunctional meaning (Halliday, 1979, 1985), Martin characterises these structuring principles as 'fractal' patterns of organisation across strata (Martin, 1995) and as 'de-privileging' constituency, in his views on discourse and text structure (Martin, 1996). The representation of the types of structure and modes of meaning as particulate (ideational meaning), prosodic (interpersonal meaning) and periodic (textual meaning) opens up more dynamic perspectives on text structure and the unfolding of text (logogenesis). Understanding the rhythmic flow of discourse involves analysis of the mechanisms of hierarchical and serial expansion i.e. the systems of Theme and Information and logico-semantic relations - the interplay of textual and logical metafunctional meanings (Martin, 1996). Martin (1993, 1996) and Martin & Rose (2003) refer to the information flow across a text as the 'hierarchy of periodicity'. Layers of Theme at clause level, paragraph level (hyperThemes) and text level (macroThemes) work together to predict phases of text, creating a hierarchy of smaller units within larger ones. Complementing this text creation strategy, the 'point' of the text is accumulated at clause level (New), paragraph level (hyperNew) and text level (macroNew).

Another aspect of text structure is the orbital/serial interpretation of ideational meaning as a complementary perspective to constituency (part/whole) and dependency (part/part) representation (Martin, 1996). The basis for understanding orbital structure of higher level units is Halliday's (1985) alternative interpretation of Process/Participant relations as ergative patterns

(Process/Medium), where the Process/Medium complex of the clause forms the nucleus, and the Agent and Circumstances the satellites. The notion of serial expansion as a ‘chaining strategy’ (Martin & Rose, 2003, p. 186) extends Halliday’s (1985) representation of logical meaning as a dependency structure, with a head modified by dependent elements. Halliday refers to this as a univariate structure ‘which is generated by the recurrence of the same function’, unlike the multivariate structure of other types of meaning, which is a ‘constellation of elements …with a distinct function’ (Halliday, 1985, p. 172). Serial expansion of text for Martin is characterised by ‘open-endedness’ and serial progression, with each satellite itself becoming a nucleus (Martin, 1996, p. 48). Martin’s account of particulate structure based on the notion of nuclearity ‘opposes mono-nuclear text structures (orbital) to multi-nuclear ones (serial)’ (Martin, 1996, p. 51). Deconstructing the notion of constituency into two complementary perspectives, part/whole and nucleus/satellite and combining these perspectives with serial expansion and the hierarchy of periodicity, opens up the possibility of more dynamic representations of discourse and text structure. As will be shown in later chapters, such perspectives will be useful in reasoning about structures and ideational meaning in multimodal discourse.

3.2 The language of science: grammatical metaphor and technicality

Of central importance for this thesis is an understanding of how meaning is construed in the discourse of science. Within SFL, major contributions have been made to this understanding by Halliday, Martin and others in *Writing Science* (1993) and in *Reading Science* (1998). Particularly significant are the interrelated notions of grammatical metaphor and technicality. Since two of the research questions are concerned with how visual and verbal meaning co-construe technical and abstract meaning in the corpus, a brief explanation of grammatical metaphor and technicality in language will be given here. This explanation serves to underpin the analysis and discussion of visual and verbal technicality and abstraction in Chapters 6 and 7.

The notion of grammatical metaphor was introduced by Halliday (1985) and developed further in relation to science in subsequent writings (e.g. Halliday, 1998; Halliday & Martin, 1993). More recent developments on grammatical metaphor can be found in Simon-Vandenbergen & Taverniers (2003). According to Halliday (1985, p. 321), 'metaphorical modes of expression are characteristic of all adult discourse' and different registers show 'a great deal of variation in the degree and kind of metaphor that is encountered'. In the clause in its ideational function, the grammar typically realises the meaning of the Process as a verb or verbal group, the Participants (people, places, things) as nouns or a nominal group, Qualities as adjectives, logical connections as conjunctions and Circumstances as adverbs or prepositional phrases (Martin, 1986, p. 26). These are the 'congruent' realisations of meaning. But in the expert genres of science, these choices may be realised differently, as metaphoric variants, so that actions and qualities are realised as Things, logical connections as Processes and so on. The effect of this process is 'to distance the text from the social reality to which it refers and its mode becomes more abstract' (Martin, 1986, p. 26).

Technicality in science is characterised as involving a shift from the commonsense world of the everyday to the uncommonsense world of science, a shift into 'an elaborated language of systematic, theory-modulated knowledge' (Halliday, 1998, p. 195). This process is enabled by the potential of language, as a stratified semiotic, for referring to objects in the experiential world, in order 'to create *technical taxonomies'* (ibid, p. 195). The concept of technicality arose from earlier research into how different school subjects such as history, geography and later, science, create their field-specific meanings (Eggins, Wignell, & Martin, 1993; Martin, 1993; Wignell, Martin, & Eggins, 1993). Field-specific technical meanings become distilled through the use of grammatical resources to name, define, elaborate and explain technical phenomena. In the language of science there is a complex interrelationship between the resource of grammatical metaphor and the lexicogrammatical resources for elaboration and distillation, superordination and composition used to set up technicality. Technical terminology is identified, defined, ordered and explained so that generalisations can be made about classes of participants. Grammatical metaphor plays a vital role in this technicalising process, mediating between the grammar and semantics, helping to 'distil' technical terms (Martin, 1993, p. 267).

3.3 Educational research on multimodality: multiliteracies and multimedia learning environments

The motivation for much of the multimodal research in educational settings is to rethink the terrain of literacy to include the concept of multiliteracies, particularly in multimedia learning environments, for example, teaching multiliteracies in science classrooms at secondary school (Kress, 2003; Kress, Jewitt, Ogborn, & Charalampos, 2001); developing a framework for a pedagogy of multiliteracies across the curriculum in primary school in Australia (Unsworth, 2001); developing an understanding of 'multimedia' or computer-based literacies (Bolter, 1998; Lemke, 1998a, 2000b). Bolter (1998) argued that if the computer is 'complicating the nature of text', thereby challenging the notion of literacy, this has reopened the problem of the relation of the text to the visual.

In discussing whether there are two literacies - verbal and visual - he concludes that literacy in electronic environments may have more to do with the visual than the verbal and that graphic rhetoric is so compelling that we need to redefine what text is to include graphics. To extend his argument, he discusses two possibilities for visual media. Firstly, the digital image can be ‘hypertextualised’, and functions as a hypertextual reference to further information, thereby ‘cooperating’ with the verbal text. The second possibility is that graphics will displace hypertext and linear writing (Bolter, 1998, pp. 8-9). However, it is more likely that these two possibilities will coexist and the choice will depend on the context and purpose.

Others argued that while literacy has rarely meant verbal literacy alone, our teaching of literacy has been logocentric or derived from written language (Kress, 1997; Lemke, 1998a). This is despite the fact that young children integrate verbal, the visual, the audio and the gestural modes of meaning from an early age. In Kress and van Leeuwen’s (1996) seminal work on the grammar of visual design, many of the examples chosen for analysis are from science textbooks and include diagrams, photographs, drawings and graphs. The authors compare visual meaning in a high school textbook from the 1930’s with a more recent one and conclude that there has been a shift from the verbal to the visual, in which the visual has assumed greater prominence. They suggest that science itself is being transformed as a result of this shift and that it will be necessary to rethink how to teach the ‘new literacy’ required for producing and reading images (Kress & van Leeuwen, 1996, pp. 31-33). In a similar analysis of images and text in science textbook pages from the 30’s and from more recent times, Kress (1997) also concludes that the nature and function of the visual has changed. In the earlier textbook, the written text carried the essential information while the image illustrated the text, without providing anything new. In the later textbook, the visual assumes a more dominant role, both proportionally and in carrying the information (Kress, 1997, pp. 62-65). The result is ‘an instance of a new code of writing *and* image, in which information is carried differently by the two modes’ (Kress, 1997, p. 65). It will be interesting to ascertain in this thesis corpus if these claims hold true for university level textbooks.

Similarly, in the context of new technologies in education, Lemke (1998a) argues that teachers need an understanding of multimedia semiotics, in order to teach students critical interpretative skills and authoring skills in multimedia environments. Teaching for ‘multimedia literacies’ involves an understanding of how ‘options for meanings in each medium cross multiply in combinatorial explosion’ (Lemke, 1998a, p. 288) so that whole is more than a sum of the parts. ‘Text and picture together are not two ways of saying the same thing; the text means more when juxtaposed with the picture, and so does the picture when set beside the text’ (ibid, p. 288).

From the discussion so far it is clear that the reconceptualisation of literacy has driven research into multimodal texts in educational settings. More recent research on inter-image relations in children’s picture books is being extended to focus on image/text relations in children’s narrative and information texts in print and electronic media in order to develop a framework for a pedagogy of multiliteracies (Hull & Nelson, 2005; Unsworth, in press-a, in press-b). The majority of this work however, has been focussed on primary or secondary school contexts. There appears to be relatively little research into multimodality in the pedagogical genres of mainstream university science education and into the concept of multiliteracies at this level. This is despite the fact that for over a decade, researchers in SF theory have acknowledged the semiotic hybridity of science. In an exploration of visual and verbal meaning in scientific text, Lemke (1998b, p. 87) for example, argues that the concepts of science are 'simultaneously and essentially verbal, mathematical, visual-graphical, and actional-operational'. Scientists communicate by combining and integrating all these systems and hence visual-graphical elements, such as graphs, equations, diagrams, tables and drawings, play a central role in written science genres such as articles and textbooks.

3.3.1 Multimodality and ESP

Some of the educational contributions on multimodality in science at post secondary level have been within the field of ESP (English for Specific Purposes) and EAP (English for Academic Purposes), rather than in mainstream undergraduate science education. ESP and EAP courses are for non-English Speaking background (NESB) students preparing for tertiary study. According to Miller (1998), many teachers of ESP are not aware of the importance of visuals in contributing to the argument in scientific research articles. Using Halliday's metafunctional framework, Miller discusses how visuals are used in two different science genres - the academic research article and the popular press article. In the scientific research article, not only were the visuals found to be larger in size but they were more integrated into the text and more condensed than in the popular press articles. In the latter, visuals were also used more to attract attention and explain content to the reader rather than to be integral to the argument. Miller's research presents a strong case for a more critical reading by ESP teachers of the role of the visual in science articles.

Like Miller, Baldry's (2000a) interest was in designing an EAP/ESP syllabus which builds students' awareness of multimodality in scientific texts. However, Baldry and others working in EAP/ESP courses in universities in Italy (e.g. Taylor Torsello, 2000) went further in the direction of syllabus design than Miller and developed computer-assisted SFL-based text analysis tools for students. Their argument is that the computer environment allows for a 'dynamic' formulation of scientific texts in that more semiotic resources, such as movement and sound, are brought into play and different readings are enabled through the activation of hyperlinks. Importantly, Baldry (2000a) claims that the current generation of students in universities, despite growing up in a visual world, have no metalanguage to talk about meanings in other modalities, particularly the visual. Within his EAP/ESP syllabus, students are given tasks based on a metafunctional analysis of text and image relations in different scientific texts and genres. In addition to a metafunctional analysis, students build their awareness of intertextuality or how texts are interdependent in a given speech community and how they draw on prior texts to create new meanings. Applying the EAP/ESP syllabus in a computer environment with its capabilities of hypertext links brings new possibilities for students to analyse the use of 'different voices' in a text through a comparison of contemporary and historical scientific texts.

Despite the fact that these contributions could have important implications for the development of students' multiliteracies in science, it is not clear how such a pedagogy could actually be transferred to large undergraduate science classes at university. As was shown in the review of literature in Chapter 2, the preoccupation in undergraduate science is still with teaching disciplinary content and the concept of literacy remains fixed in the verbal mode, or at best, assumptions are made that students' already have or will acquire the multimodal literacies they need in the course of their studies.

3.4 Multimodality and intersemiosis: an overview

The literature on multimodality and intersemiosis within an SF framework has been expanding rapidly for over a decade. Building on the earlier work on the grammar of visual design (Kress & van Leeuwen, 1996; O'Toole, 1994), considerable advances in theoretical description and methods of analysis have taken place. Major contributions include O'Halloran's work on intersemiosis in mathematical texts (O'Halloran, 1999a, 1999b); corpus-based approaches to multimodal analysis in the multimodal concordancer (Baldry, 2000b); approaches to multimodal transcription (Thibault, 2000) and to multimodal discourse analysis (Martin, 2002a); 'multimedia semiotics' (Lemke, 2002b); and the dynamic modelling of genre in the Genre and Multimodality (GeM) project (Bateman, Delin, & Henschel, 2004). Related work undertaken in workplace contexts such as the NSW Department of Health has provided a complementary analytical perspective on multimodality, referring to the process of how meaning-making is translated from context to context or from practice to practice as 'resemioticisation' (Iedema, 2001b, 2003). This body of work has moved towards developing more comprehensive theoretical description and opened up new possibilities for research in a range of contexts. Recent volumes have built on this earlier work and added new dimensions to theory and analysis (O'Halloran, 2005, 2006; Ventola, Charles, & Kaltenbacher, 2004).

3.5 Issues in theory and analysis

In much of the work reviewed thus far, two significant approaches to multimodal research can be identified. One approach, found in the earlier work of Kress and van Leeuwen (1996) and O’Toole (1994), was to analyse various meaning-making systems separately and then study how they interrelate. The second, found in more recent work, is to attempt to directly analyse the interrelations among elements from different systems of meaning to search for common semiotic principles (Kress & van Leeuwen, 2001; Lemke, 1998b, 2002b; O'Halloran, 2005; Royce, 1998; Thibault, 2000). The challenge in the second approach is to take the total contribution of multiple systems of meaning into consideration, rather than adding up the singular contribution of each of the semiotic systems involved. This has meant extending various complementarities and hierarchies within SFL to push the boundaries of theory and description beyond language.

On a broad scale, many of the parameters for multimodal research can be found in the summary of SFL complementarities and hierarchies in Table 3.1, p. 40. Most researchers have used the metafunctional conceptualisation of meaning as an integrating principle for analysis. This principle has been used as a starting point to reason not only about other complementarities in multimodal meaning-making, such as synoptic and dynamic perspectives and typological and topological regions of meaning but also about how the hierarchies of rank, delicacy and realisation are played out in multimodal discourse analysis.

The purpose of the discussion in the remainder of 3.5 is twofold. Firstly, various issues related to SF complementarities and hierarchies, which have challenged key researchers, will be reviewed and secondly, it will be shown how their work has influenced the approach adopted in this study.

3.5.1 *Metafunctional complementarity*

Among researchers who have used to great advantage, the metafunctional principle as the cornerstone of their work, are Lemke (1998b), O'Halloran (2005) and Thibault (2000). Each has made distinctive contributions to the field, while highlighting some of the key issues in adopting metafunctional approach to description.

Thibault's (2000) multimodal description of a TV advertisement combines the analysis of sound, image, action and spoken language. There are interesting parallels in his metafunctional account with earlier work of Halliday (1978) and Martin (1992, pp. 10-13) on metafunctions and types of structure, which were discussed in section 3.1.2 of this chapter. Thibault argues that the experiential metafunction is characterised by the structural principle of constituency - the segmentation of the whole into its parts (as in process-participant relations in the clause). Similarly, in the visual, the perceiver segments the field into objects and lines of force (vectors). However, the temporal linearity of the syntagm in spoken language is not the same as syntagmatic principles of spatial adjacency in the visual, and in movement, the syntagmatic structuring will be non-linear and three-dimensional, rather than linear and two-dimensional (Thibault, 2000, p. 360). Nevertheless, he concedes there are similarities across modalities as they are all concerned with the whole and how the parts function within it. The fundamental meaning relation of the logical metafunction is that of (inter)dependency, concerned with part-part relations - equal and unequal - of cause, time, comparison etc. In the visual, there may be dependency relations between shots in a moving sequence or between images on a page, which may be akin to paratactic or hypotactic relations in the clause.

For Thibault (2000), a multimodal perspective on interpersonal meaning will be concerned with how interactants adopt and negotiate various speaking, writing, depicting, filming, listening, reading and viewing positions. For example, the visual semiotic can be modified by camera position, distance, angle etc or the way colour functions as a modality operator, while in movement, smiles, nods, gestures etc function as modifiers of larger actions or movement sequences. The textual metafunction relates to the organisation of the text and its parts and is concerned with principles of structure and texture, cohesion and coherence, foreground and background, and beginning-middle-end.

Despite Thibault’s concern that the metafunctional basis for analysis is too closely tied to the linguistic and that is has not been 'rigorously tested with respect to other semiotic systems' (Thibault, 2000, p. 359), he regards the metafunctions as a useful integrative, structural principle for analysis. If the metafunctional principle is adopted, Thibault claims, each modality is not analysed separately or independently of the others but as 'a full system of relations' (p. 362), in which the analyst will look at the metafunctional distribution of resources that are co-deployed across modalities. Thibault is careful to point out that there is no assumption that the principle of organisation of other semiotic modalities is the same as the linguistic (but there are parallels!) and he concedes that the theoretical notions and analytical principles are far from being fully worked out. His primary goal is to provide a dynamic account of multimodal meaning-making and 'a methodological and theoretical starting point' for analysis and as such it is an extremely valuable piece of work. Thibault’s (2000) analysis has been very informative in setting up the visual display of the multimodal content analysis in Stage 1 of my study and in reasoning about the complementarity of metafunctional meaning.

Reservations about extrapolating the metafunctional description of language to other forms of semiosis have also been expressed by Lemke (1998a, 1998b, 2002b). One of his concerns was to set up a framework for analysis of the ways in which verbal and non-verbal elements combine in 'multimedia genres' in science, i.e. those which are actional, conversational and written. Building on his earlier work and on that of Halliday's metafunctions, Lemke proposes three generalised semiotic functions. These are:

• presentational (creating or describing a world)

• orientational (taking a stance towards a presentation)

• organisational (defining parts and their wholes) (Lemke, 1998b, pp. 91-95).

Such a framework, he claims, is a powerful analytical tool which can be used to investigate what happens 'when the resources of multiple semiotic systems are co-deployed: 1) each semiotic can contribute componentially to each functional aspect of meaning;…2) each can internally cross-modulate meanings across functional aspects;… and 3) functionally specialised meaning resources in one semiotic combine with those for a different function in another semiotic to modulate any aspect of the meaning of the joint construct…', hence *multiplying* the set of meanings that can be made (Lemke, 1998b, p. 92). Lemke gives some explanation of how these processes are realised in multimodal texts but the actual methods of analysis are not made explicit and leave many questions unanswered. Moreover, demonstrating through analysis exactly what is meant by the 'multiplicative nature of meaning' in relation to modalities and metafunctions is not clear, although this concept is explored further in a later article on hypertexts (Lemke, 2002b). Nevertheless, his work is a highly significant contribution in articulating an alternative description of tri-functional meaning-making by shifting the focus beyond language. A number of aspects of his work will be explored further in this thesis. In particular, his categorisation of science images has been informative in determining the visual categories of this corpus in Chapter 4. In Chapters 4 and 5, Lemke's (1998b, p. 107) discussion of visual density in scientific research papers provides a useful guiding principle in setting up the analysis of visual density and the notion of redundancy (Lemke, 1998, p. 105) between visual and verbal elements in these genres has been informative in the metafunctional analysis of intersemiosis in Chapter 7.

O'Halloran's work also follows the basic premise of the metafunctional organisation of all forms of semiosis and is significant in advancing the grammatical description of the multiple systems of meaning which contribute to mathematical discourse, i.e. language, mathematical symbolism and visual display (O'Halloran, 1999a, 1999b, 2003, 2005). Contemporary mathematical symbolism, she argues, grew out of the lexicogrammar of natural language but as it evolved, 'it adopted only certain selections from the meaning potential of language' (O'Halloran, 1999b, p. 4), resulting in a contraction of this meaning potential. At the same time, this process of contraction allowed for semantic extensions which went further than the meaning potential of language. As a result of the process of expansion and contraction however, mathematical symbolism could not function alone without the co-deployment of language and visual display.

She illustrates the expansion of experiential meaning in the transitivity/ergativity system of mathematical symbolism through a category of what she calls 'Operative' processes. These processes have expanded the meaning potential of Material processes such as combining, increasing, decreasing etc to realise symbolically the arithmetical concepts of adding, multiplying, subtracting and dividing and other algebraic operations. She provides an example of a transitivity analysis of the following mathematical statement involving an Operative process,

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

which realises a Relational Identifying process through the = symbol. On the left, x is the Token (Agent) and the rest, to the right of the = symbol, is the Value (Medium). She argues that the right of the equation is an example of a rankshifted clause as it consists of nuclear configurations of a number of processes - addition, subtraction, multiplication, square root and division with participants *a, b, c,* 2, and 4, which means it can no longer be regarded as a single lexical item or Medium but consists of multiple Mediums. O'Halloran's analysis of mathematical discourse has provided many valuable insights into the field, particularly into the processes of intersemiosis.

3.5.2 Intersemiotic complementarity

Following the work of Kress and van Leeuwen (1996) on visual grammar, of Halliday (1985) on metafunctions, of Halliday & Hasan (1976, 1985) on cohesive relations and of O'Toole (1994) on the rank scale in images, Royce (1998) proposed a theoretical framework to analyse visual-verbal 'intersemiotic complementarity' in printed text, or the synergistic relationship whereby 'the visual and verbal modes semantically complement each other to produce a single textual phenomenon' (Royce, 1998, p. 26). As in the later work of Lim (2006), intersemiotic complementarity is conceptualised as a semantic 'space', visually represented at the interface between the visual semiotic and the verbal semiotic. The analytical framework, which is metafunctionally-based, is set out as a table of meaning systems, with visual meanings in the left column, intersemiotic meanings in the middle column and verbal meanings on the right. The meanings listed in the middle column are thus seen as integrating those on the left and right. Royce's frameworks are seen as 'a point of departure for the description of intersemiotic mechanisms' (O'Halloran, 2005, p. 165) and as such are a very useful starting point for the frameworks proposed in this thesis.

In viewing mathematics as a multisemiotic construction made up of language, mathematical symbolism and visual display, each with specific grammars, O'Halloran argues that this allows for the possibility of semantic expansions through the process of 'semiotic metaphor' (O'Halloran, 1999b, 2003, 2005). Through the interactions between the semiotic resources of language, mathematical symbolism and visual display (i.e. the process of inter-semiosis), semiotic metaphors involving semantic shifts are made possible as functional elements are re-construed in another semiotic. Meaning is thus realised not only within each semiotic but also through 'joint construction across codes' (O'Halloran, 1999b, p. 23), and the grammar of mathematical symbolism is intermediary between visual and verbal descriptions. More recently, O'Halloran (2005) has extended her work on intersemiosis in mathematical discourse but, since it forms part of the theoretical framework for the analysis of the thesis corpus, it will be explored in Chapters 6 and 7, rather than here.

3.5.3 Synoptic and dynamic complementarity

A crucial decision in multimodal analysis and transcription is selecting the appropriate unit for analysis. This raises the issue of static and dynamic approaches to description, which is also related to the type of text one is analysing. Whichever approach one chooses will also affect how one describes the units of analysis. One way is to describe the ‘levels’ or units of analysis as some form of hierarchy, moving from smallest unit/lowest level to largest/highest. Examples of this more static approach are Iedema's (2001a, p. 189) six levels of tele-film analysis, organised along the lines of a rank scale: *Frame, Shot, Scene, Sequence, Generic Stage* and *Work as a Whole*. A more dynamic perspective is Martinec’s (2000) hierarchical model of rhythm in multimodal texts, which he proposes for time-based semiotic modes (e.g. language, music and action), building on van Leeuwen’s (1999) analysis of rhythm in speech, music and action in film texts. His claim is that each ‘semiotic mode’ in a multimodal text has its own overall rhythmic hierarchy, coordinated by a ‘metric principle that synchronises their accents to different degrees in a particular text’ (Martinec, 2000b, p. 289). His basic proposition is that all time-based modes, including spoken language, ‘are rhythmically articulated at several levels at the same time’ (Martinec, 2000b, p. 289). The patterns at the various levels are called waves which he argues are ‘similar in kind but different in scale’ (p. 289), since higher level waves tend to be longer and more prominent than lower level waves. The levels are formed by waves and transitions (pauses or changes in tempo). Thus hierarchy is established by the relative prominence of the accents of the waves and the length of the pauses.

In hypertext and other moving texts, it is clear that multimodal meaning may cross both page and screen boundaries. The presence of hyperlinks on a screen ‘page’ certainly complicates the notion of a page as an analytical unit and static description. The hypertextual link is not a ‘neutral connection’ but performs different types of functions, allowing multi-sequential pathways to new pages containing different kinds of information and media. A dynamic meaning relationship is created, by means of activating the link, between the source page, paragraph, word, image etc and the target page. Clearly, on a screen page, the dynamic dimension of meaning will have to be accommodated in the selection of the analytical unit.

3.5.4 Hierarchies in multimodal analysis: rank and stratification

Two challenges for analysts are to do with conceptualising the hierarchies of rank and stratification for grammars other than language. For the grammar of mathematical visual display O'Halloran (1999a, 1999b, 2003, 2005) for example, adapts O'Toole's (1994) metafunctional framework organised according to rank, moving from Diagram/Graph (highest rank) to Episode/Figure and Parts (lowest rank). Each rank in the framework specifies different systems and functions in the spatial display of diagrams. For example, at the lowest rank of Parts in the diagram or graph, the experiential metafunction is realised by the functions of *Title, Axes, Scale, Arrows, Labels, Curves, Shading, Intersection of Points* and *Slope of Parts of the Figure* (O'Halloran, 1999b, pp. 16-17). In more recent work, other researchers in this tradition have continued to explore the possibility of a hierarchically organised rank scale for visual semiosis in various contexts (e.g. Kok, 2006; Lim, 2006).

While it is appealing for analysts to posit an image rank scale, the concept of rank, when applied to a unit of meaning which combines image and verbiage for example, remains problematic. A rank scale is hierarchically organised, but defining an intersemiotic unit at a given rank is difficult. The notion of composition underlying a rank scale presupposes a whole and its parts and so the question remains whether they are related in a constituency type of relationship, given that language and image are said to be incommensurable in the ways in which they make meaning. As multimodal researchers have pointed out (Kress & van Leeuwen, 2001; Lemke, 1998a, 2000a; Thibault, 2000), some modalities are 'better for doing some things than others'. Language has been described (e.g. by Lemke, 1998b) as making meaning more typologically, by classifying into mutually exclusive categories, while visual perception and spatial gesturing operate more topologically, by distinguishing variations of degree along continua of difference (e.g. speaking more loudly or softly, the use of colour in an image). Finally, the concept of a rank scale for an intersemiotic unit is further complicated in trying to capture dynamic perspectives on meaning-making in hypertext or moving texts, for example, as suggested in 3.5.3. This aspect was explored by Kok (2006), who posited 'orders of abstraction' of ITEM, LEXIA, CLUSTER and WEB, instead of a rank scale for hypertexts, arguing that these orders of abstraction are 'not necessarily related to each other by constituency' (Kok, 2006, p. 134). However, a notion of hierarchy still exists, as these elements range from the lowest (ITEM) to the highest order of abstraction.

Another problematic concept is that of stratification, particularly in articulating the content and expression strata of other forms of semiosis. In a significant collection of papers on grammatical metaphor, Ravelli (2003, pp. 43-44) and others in the same volume (e.g. O'Halloran, 2003) raised the possibility of extrapolating the principle of stratification to apply to other forms of semiosis. In their sketch of multimodal communication, this principle has also concerned Kress & van Leeuwen (2001), who outline four domains of practice, *discourse, design, production* and *distribution*, for making meaning in 'multiple articulations' in multimodal texts. They argue that multimodal resources are used to make meanings ‘in any and every sign, at every level, and in any mode’ (p. 4). This contrasts with meaning in language, in which meaning is made once as a 'double articulation' of form and meaning (i.e. not multiple articulations), or, in other words, of expression and content. Kress and van Leeuwen’s domains of practice are called strata, after the SFL stratally organised model of language, although, unlike Halliday, in Kress and van Leeuwen’s model, the strata are not hierarchically organised (Kress & van Leeuwen, 2001, p. 4). They argue that the content stratum can be further stratified into discourse and design and the expression stratum into production and distribution, although it is not clear how this translates into analysis.

More recent work which attempts to build a stratified ‘meta-model’ to describe the complex interaction of language and image is the Integrative Multisemiotic Model (IMM) proposed by Lim (2006). Here, the expression strata of language (typography) and visual image (graphics) contextualise the content strata of language and image (lexicogrammar/visual grammar and verbal and visual discourse semantics) through the Space of Integration (SoI), a ‘theoretical platform where intersemiosis occurs through contextualising relations’ (Lim, 2006, p. 223). Drawing on Thibault (2000), he identifies two types of contextualising relations in a multimodal text – converging or co-contextualising relations, where one modality ‘reflects’ the meaning of the other, and diverging or re-contextualising relations, where the meaning of one modality appears to be unrelated to the other (Lim, 2006, p. 239). It is in the SoI that intersemiotic meaning expansions take place through the mechanisms of Homospatiality (in which language and image share the same spatial coordinates on the expression stratum) and semiotic metaphor (on the content stratum). The IMM model is a bold attempt to build a much needed metalanguage to discuss the integrative principle of intersemiosis but clearly, and, as Lim (2006) admits, when other semiotic systems are brought into the picture, such as sound and moving text or image, a more dynamic model needs to be built to capture the increasing complexity and fluidity of the interacting systems.

From the discussion in 3.5 it could be concluded that the research field of multimodality has been dominated by research concerned with complementarities: metafunctions, intersemiosis, synoptic and dynamic perspectives but the hierarchies of rank and realisation have received some attention. Through highlighting various issues, the research reviewed has provided some interesting insights into current challenges of theory and description.

It has not been possible to do justice to all the significant developments in current multimodal research. The field continues to expand, with major contributions from Europe, Singapore and more recently, from Australia, and has become one of the exciting frontiers within SF semiotics. I hope to demonstrate in the following chapters how my research builds on the work reviewed in this chapter in developing a framework for multimodal analysis which could have applications in teaching multiliteracies for academic purposes.

CHAPTER 4

RESEARCH DESIGN AND STAGE 1 METHODOLOGY: MULTIMODAL CONTENT ANALYSIS

4.0 Introduction

This chapter will discuss the methodological framework for the analyses undertaken in the first stage of this research. There are three main parts to the chapter. Section 4.1 outlines the research design for the whole study, which is followed by a description of the context of the corpus in 4.2. Section 4.3 presents the methodology for Stage 1, in which further details of the corpus, the approach to analysis and a description of the categorisation of the content will be provided. The chapter concludes by pointing to some of the methodological issues which arose during Stage 1.

As stated in Chapter 1, the overall aim of this research is to provide an account of multimodal and multisemiotic meaning-making resources in print and computer-based teaching and learning resources in first year science at university and to consider the implications of such an account for students' multiliteracies for academic purposes. The materials to be investigated are both computer-based (CD-ROMs and online) and print-based (textbooks) resources, which are both typical of those used in undergraduate science courses and relevant to my professional context.

4.1 Research design

The research design consisted of two main stages, the first informing the selection of the texts analysed in Stage 2. Table 4.1 summarises the design, showing the principal stages of the research, the main activities undertaken and the methodology used for each stage.

Table 4.1

Research Design

Stage	Main activity	Methodology
Stage 1	*Preliminary search, classification and analysis of teaching and learning resources* Step 1: conduct search and sort resources Step 2: select from corpus texts for analysis Step 3: analyse multimodal content of the corpus according to format and discipline.	Multimodal content analysis
Stage 2	*Detailed analysis of Stage 2 corpus* Step 1: select corpus for Stage 2 based on a principled selection of texts from the Stage 1 corpus. Step 2: conduct a detailed analysis of Stage 2 corpus	Multimodal discourse analysis

Each stage necessarily employed different but complementary methodologies, which will now be outlined.

4.1.1 Stage 1: Step 1 Search and classification of resources

As discussed in Chapter 1, part of the motivation for this study is the relationship of the corpus to my professional context at the University of Sydney. Although this meant that the texts ultimately selected were those used only at this university, I was interested to establish how typical they were of those used in other ‘research-oriented’ universities in Australia. Information on first-year course content and teaching and learning resources in first year Biology, Physics and Chemistry was gathered from documents on the websites of the Universities of Melbourne, Monash, New South Wales and Sydney. Where possible, the textbooks in use from the four universities were borrowed from the library and examined. The resources from the four universities from first-year Biology, Physics and Chemistry were then classified into groups according to format. The results of the classification are shown in Table 4.2.

Table 4.2

Types of Learning Resources Found in Search, Classified According to Format

Format	Type of resource
Print	Textbook Laboratory book Lecture notes Handbooks and course outlines
Screen	Online learning modules CD-ROMs accompanying textbook ** Lecture notes (PowerPoint slides) Useful websites containing supplementary material **

Note. ** = optional resources outside the course

Most of the resources were integrated into the students' course of study and covered course content which was assessed, while others, shown as ** above, were outside the course and were offered as an optional set of learning resources students could access in their own time.

4.1.2 Stage 1: Step 2 Selection of corpus

The final selection of texts was made from those surveyed in Step 1. Permission was sought from the publishers to use the textbook chapters and CD-ROMs. A PDF version of both textbook chapters was provided by the publishers. The Stage 1 corpus consisted of physics and biology textbook chapters, interactive activities from two CD-ROMs accompanying physics and biology textbooks and activities from two websites designed for students in first-year chemistry and biology at the University of Sydney. Further details of the corpus will be given below in 4.2 on the context of the corpus.

Considerations in choosing the texts were that they should cover:

- the same topic or an aspect of the same topic in each discipline (e.g. fungi, mechanical waves, which were part of the course)
- a range of first-year resources used in science courses at the University of Sydney
- a range of pedagogical genres (e.g. textbooks, screen-based content learning modules and tests on content).

In addition, handbooks, course outlines and information from informal talks with science teaching staff at the University of Sydney were collected and examined in order to build up a more complete picture of the context of the corpus.

4.1.3 Stage 1: Step 3 Multimodal content analysis

As a basis for the detailed multimodal discourse analysis in Stage 2, content analysis of the textual, visual and other content of the corpus was carried out according to format (page or screen) and discipline. A rationale for the methodology chosen for Stage 1 and a description of the methods of analysis will be provided in 4.3.

4.1.4 Stage 2: Step 1 Principled selection of Stage 2 corpus

The main purpose of the very detailed approach to the multimodal content analysis in Stage 1 was to dissect the content, categorise it and examine it closely in order to select in a principled way the corpus for Stage 2.

4.1.5 Stage 2: Step 2 Multimodal discourse analysis of Stage 2 corpus

This step consisted of the in-depth analysis of multimodality and intersemiosis, which will be presented in Chapters 6 and 7.

Before outlining the methodology for Stage 1 and the rationale for its choice, the next section will situate the corpus in its context.

4.2 Context of the corpus

For the purposes of this discussion, no distinction will be made between the Stage 1 corpus and the Stage 2 corpus, since the Stage 2 corpus was a selection of texts from Stage 1. This section will briefly outline the context of the corpus under investigation in terms of how the texts are used in the different courses and give some background to each text.

4.2.1 Textbooks

Both the biology and the physics textbooks were used as the set texts in the first-year courses for each stream – for standard and advanced students.

Biology textbook

Like other tertiary level textbooks, the biology textbook, *Biology 2nd Edition* (Knox, Ladiges, Evans, & Saint, 2001), is a weighty tome, consisting of 45 chapters and 1276 pages, organised into seven parts. The seven parts cover broad themes such as *Cell Biology and Energetics*, *Reproduction and Development* and *Evolution and Biodiversity*. Each chapter follows the same format, with a table of contents for the chapter on the first page and at the end of the chapter, a summary of content, a key to the terms used in the chapter, a set of review questions, a set of extension questions and a list of suggested references for further reading. It is the prescribed textbook for first-year biology at the

University of Sydney. The textbook was chosen by lecturers because of its Australian content, which was considered important as most other biology textbooks are written and published in America and have minimal Australian content. This point was also instrumental in the book winning an Australian Publishers' Association excellence award for the best tertiary level textbook in 2001.

First-year biology is a 'service' course, serving other faculties such as Pharmacy, Nursing and Medicine, where students are required to do a unit of biology as part of their degree. In first year, approximately 1500 students enrol in one of several biology courses. The majority of these students do not proceed to second year biology and therefore do not tend to buy the textbook, relying instead on library copies or photocopies of extracts. The textbook is accompanied by a wealth of supplementary material for lecturers and students. For students there is a CD-ROM of interactive learning modules, an online multiple choice assessment package with built-in feedback and a website containing the *Online Learning Centre*, which includes learning objectives, key terms and other web links. For lecturers, there is an *Instructor's Resource Manual* with chapter outlines, teaching objectives, key terms, suggested answers to the end of chapter questions, extension exercises, references to other resources and notes to help integrate the book into an existing course. There is also visual material lecturers can use for their lectures, an online *Test Bank* and access to teachers' resources on the *Online Learning Centre*. According to the first-year lecturers at the University of Sydney, students do not use these resources much, as the content is presented differently from that in the lectures and laboratory sessions. They use instead the online resources specifically designed for them, which will be discussed in 4.2.3. The first-year lecturers also do not make much use of the huge number of resources provided by the publishers, preferring to compile their own material from a number of textbooks and websites.

Students are expected to read the set pages or chapters of the textbook to prepare for the lectures. For example, in the course ‘Concepts in Biology’, the chapter in this corpus, Chapter 36: Fungi, was set reading for Lectures 9-12 of a 24 lecture course. These four lectures cover the major groups of microorganisms, bacteria, protists, fungi and viruses. The content is organised around key concepts in microbiology such as diversity, nutrition, reproduction and competition. The lectures do not follow the sequence in the textbook and students are not tested on the textbook, although they use it to revise for exams, along with other material.

Physics textbook

Like biology, first-year physics is a service course attracting about 1200 students from a range of faculties, only 150 of whom go on to second year. Unlike biology however, students are ‘almost required’ to buy the textbook *University Physics 11th Edition* (Young & Freedman, 2004), which is much more integrated into their course. The lectures are based on the textbook and readings are set to support the lectures. Students are also assigned problems from the textbook, which they are expected to complete in their six hours of independent study per week. This differs from biology where students are not assigned any questions from the book. From Chapter 15: Mechanical Waves, the chapter analysed for this corpus, students are assigned specific text sections and examples, and are recommended to do specific questions, exercises and problems. The chapter is the basis for the course module on Waves, which consists of 12 lectures, three workshop tutorials and four three-hour laboratory sessions. The general goals of the module are ‘to understand the characteristics and causes of oscillations, using

Newton's laws and appropriate force laws and to gain a qualitative and quantitative understanding of wave motion in various media' (from Module outline: available on:

http://www.physics.usyd.edu.au/ugrad/jphys/units.html#1001).

Different editions of this textbook have been used in Physics for a number of years and the latest edition (2004) is now prescribed for first year and beyond. It consists of 44 chapters and over 1714 pages, organised into 6 main content areas. These cover topics such as mechanics, waves/acoustics, thermodynamics, electromagnetism and optics. The format for each chapter is the same, with chapter opening questions, chapter content interspersed by worked examples and problems, test questions at the end of each section, an end of chapter summary, described as a 'visual chapter summary', a list of key terms, answers to the chapter questions and further discussion questions and exercises. As in the biology textbook, the physics textbook has a substantial amount of online and printed supplementary resources for students and instructors. The online resources for students consist of an online tutoring and homework system, *MasteringPhysics*™, http://www.masteringphysics.com, developed specifically for courses using *University Physics* and providing students with individualised online tutoring and feedback which can also be monitored by course lecturers; *ActivPhysics OnLine*, http://wps.aw.com/aw_young_physics_11, which provides simulations and accompanying exercises, which are indicated in the textbook with an icon; the *Addison Wesley Tutor Centre*, http://www.aw-bc.com/tutorcenter, providing one-on-one tutoring via telephone, fax, email or the interactive website, by qualified instructors; and additional study material and discussions of topics not covered in the textbook available online. Print resources consist of a *Study*

Guide, emphasising problem solving strategies and a *Student Solutions Manual*, providing solutions to the odd-numbered exercises in the textbook. For lecturers, there is the *Instructor's Solutions Manual* in print and CD-ROM format; the *Test Bank,* also in both formats, of additional problems; a book on how to teach physics; a *Simulation and Image Presentation* CD-ROM, which contains the simulation applets from *ActivPhysics OnLine* and all the illustrations, except the photographs, all chapter summaries, problem solving boxes and key equations from the textbook; and a set of *Transparency Acetates* from the textbook for use in lectures. Most of the online resources for students outlined above are currently used as supplementary resources but this will change rapidly in the near future. For example, for the first time in 2004, *MasteringPhysics*™ online tutorial and homework system was used in one Physics course for tutorials and assignments. Publishers are also very keen to have physics departments at universities use the whole resource package accompanying the textbook.

4.2.2 CD-ROMs

The two CD-ROMs in the corpus were each part of a textbook package. Although they accompany different textbooks from those described above, they are regarded by staff as useful supplementary resources which students can use in their own time through the library copies. They were chosen for the corpus as they were largely standalone CD-ROMs and, although they were still representative of those which students may access, they were not as integral to students' courses as the other texts of the corpus, i.e. the textbooks and the websites.

<u>Biology CD-ROM</u>

The *Campbell Biology Student Media* CD-ROM (Campbell, 2002) accompanies the Campbell *Biology* textbook as part of the student ' media package'. The CD-ROM contains interactive activities for each chapter, quizzes on chapter content and a glossary of technical terms and interviews with scientists. It is also linked to a browser and the publishers' website, which enables access to extra resources such as chapter reviews, an electronic version of the textbook, instructor's resources, additional web links and references, art from the textbook and videos.

Physics CD-ROM

The *Your Personal Tutor for Physics: Version 2000* CD-ROM (Hecht, 2000) is also part of the Hecht *Physics: Calculus* textbook media package. Like the biology CD-ROM, it contains interactive activities for each chapter – *Warm-Ups* to review key concepts, *Walk-Throughs* to guide students through problems, and *Interactive Explorations* which use simulations to help students visualise physical phenomena. The *Further Discussions* also provided contain additional content and historical background to the physical concepts. The CD-ROM is also linked to a browser and the publishers' website and, although the additional resources are not as comprehensive as those on the Campbell *Biology* website, students have access to further websites and online quizzes.

4.2.3 Websites

The websites chosen for the corpus are integral to students' courses in first-year biology and chemistry at the University of Sydney and each contained interactive online materials. Since such materials were not part of the physics website, it was decided to choose the chemistry website instead. Neither chemistry nor biology can be described as online courses however, as they involve a substantial face-to-face component in the form of lectures, laboratory sessions and tutorials. Nevertheless, the course website is an essential resource students must access and is integrated into students' courses in different ways as will be explained below.

First-year Biology Virtual Learning Environment

Virtual Learning Environments (VLEs) were discussed in 2.1.2. The First-year Biology VLE is a 'one stop shop' for first-year students to access all course information, interactive learning resources, quizzes and course communication tools http://fybio.usyd.edu.au/VLE/L1. The design uses a building metaphor with images of doors, an elevator, desks, a noticeboard and computers etc hyperlinked to various aspects of the course content and administration. Students enter the site via the homepage, which is constructed as a virtual lobby with access to various materials, and help functions. Doors link to other 'rooms' labelled according to course code, where, with a password, students can access lecture notes and other material relevant to the lectures. Other doors take them to laboratory notes, seminar information and library links. An image of a computer takes them to computer-based learning modules, a man sitting at a desk takes them to course administrative assistance, a noticeboard to course notices and staff details and people sitting in armchairs to the discussion board and so on. The learning modules analysed for this corpus were developed specifically for first-year students at the University of Sydney with close involvement of academic staff and designers who had some disciplinary and pedagogical expertise. The modules are optional but strongly recommended, as they reinforce concepts from the course.

Chemistry website

In addition to course information, syllabus outlines, lectures notes, past exam papers and other links, the Chemistry website for first years (WebCT Chemistry online) enables access via password to ChemCAL online, (http://chemcal.chem.usyd.edu.au/), a series of self-help modules covering aspects of the first-year course. The modules are designed as interactive, self-paced and self-directed learning resources which students are required to complete prior to their laboratory work or to an assignment. They are thus seen as integral to the course, complementing the lectures, tutorials and laboratory sessions. Each module contains animations, questions with built-in feedback, a summary of the student's score and an opportunity to submit questions to a live tutor.

4.3 Methodology for Stage 1: Multimodal Content Analysis

In selecting content analysis (CA) as the methodology for Stage 1, I was concerned to adopt a quantitative approach which complemented the qualitative analysis of Stage 2. While clearly offering a different perspective on the corpus, what I hope to demonstrate in this section is that quantitative approaches can yield solid empirical data upon which to base further detailed analysis and that they enable a principled basis for selecting the corpus for this analysis. It is anticipated that adopting both coarse and fine-grained approaches to analysis will provide a multifaceted perspective on the texts, which can show both a level of generality and complexity.

4.3.1 General methodological considerations of content analysis

Content analysis is a very general approach to text analysis and recently, with computer-assisted techniques of analysis, the range of data types has widened (Bauer, 2000, p. 132). CA has been used to gather and examine content in written and multimedia material such as books, advertisements, films, song lyrics, photographs etc, and therefore its application in a multimodal corpus was worth investigating. It is a hybrid technique, bridging quantitative and qualitative analysis, and should be systematic, procedurally explicit and replicable (Bauer, 2000, p. 132). Bell (2001, p. 13) has defined CA as ‘an empirical (observational) and objective procedure for quantifying recorded ‘audio-visual’ (including verbal) representation using reliable, explicitly defined categories (‘values’ on independent ‘variables’)’. Bell’s study of the front covers of an Australian magazine over a period of 25 years is an explication of CA methodology when applied to visual content. The study also provides a useful insight into how content analysis can be linked to a semiotic model of the visual. It drew on Kress & van Leeuwen's (1996) visual grammar in formulating the hypotheses to be investigated and in defining the variables of social distance, visual modality and behaviour (Bell, 2001, pp. 27-31).

Content analysis research methodology involves decisions about research questions, about units of analysis, sampling procedures, variables and coding categories (Neuman, 2000, pp. 292-300). The unit of analysis can vary from a very small unit such as a word, phrase or single image to a very large unit, such as a page or chapter of a textbook or a series of screens on a website. Measurement in content analysis involves careful observation based on coding systems which can identify characteristics of the content such as: *frequency* (e.g. of text types or images) and *space* (e.g. devoted to text block or image). Sampling procedures in content analysis typically involve decisions about the field, scope and size of the corpus. The choice of sample clearly requires an understanding of how the sample relates to the specified variables. Variables should be clearly and unambiguously defined and assigned values. For example, if the variable is size of image, four values may be assigned: full page, half page, more than half page or less than half page. Finally, quality in CA can be enhanced by attention not only to reliability and validity but also to coherence in the system of categories and transparency through the coding procedures.

As suggested above, Stage 1 necessitated a methodology able to handle large quantities of data systematically in order to make generalisations and comparisons about the data. In selecting a complementary approach to the methodology in Stage 2, the research strategy adopted in this stage was to reveal the differences in content in terms of format, discipline and modality. It can be seen as the first level of description before the fine-grained multimodal discourse analysis of Stage 2. Aspects considered in the design of Stage 1 were the selection of the corpus, the description and theoretical underpinning of the categories, the coding tables and the coding process. These will be discussed in turn.

4.3.2 The corpus

After the preliminary search and classification of resources from the four universities the final corpus for Stage 1 was selected. Texts were those used in first-year biology, chemistry and physics at the University of Sydney at the time of selection in 2004 and were typical of the range surveyed. The range of texts consisted of textbook chapters, different types of interactive learning modules on CD-ROMs and online which were seen to be either teaching or testing content. As discussed, the corpus was selected for its relevance to my professional context but also for its currency and the range of text types represented.

Table 4.3 summarises the pages and screens analysed for Stage 1. A total of 71 pages and 156 screens were analysed. Some screens were displayed in the analysis tables but were not coded for content. These screens contained animations and were shown simply to record the unfolding of the animation in successive screenshots.

Table 4.3

Summary of Pages/Screens Analysed for Stage 1: Multimodal Content Analysis

Text Analysis	No. pages analysed	No. screens displayed in analysis tables	No. screens analysed
TEXTBOOKS			
Biology *1. Biology* (Knox et al) Chapter 36: Fungi	27	-	-
Physics *2. University Physics* (Young and Freedman) Chapter 15 Mechanical Waves	44	-	-
CD ROMS			
Biology *3. Biology* (Campbell textbook CDROM) Chapter 31: Fungi Activities 31 A and 31 B	-	24	17
Chapter 31 Campbell Quiz and Results Reporter	-	20	20
TOTAL		**44**	**37**
Physics *4. Physics Calculus* (Hecht Textbook CDROM) Interactive Exploration	-	15	15
Warm-up	-	25	24
Walk Through	-	11	11
TOTAL		**51**	**50**
WEBSITES			
Biology 5. Web-based materials for 1001: Concepts in Biology (Microbiological Concepts), University of Sydney	-	53	26
Self Assessment Module on Microbes	-	28	24
TOTAL		81	**50**
Chemistry 6. Chemistry 1001 ChemCAL module on Equilibrium, University of Sydney	-	28	**19**
TOTAL PAGES/SCREENS	**71**	**204**	**156**

<u>Textbook chapters</u>

1. Chapter 36: Fungi (from Part 7 *Evolution and Biodiversity*) (Knox et al., 2001). This chapter is one of the set readings for Lectures 9-12 in Biology 1001, 'Concepts in Biology', a 24 lecture, one semester course for first year students.
2. Chapter 15: Mechanical Waves (Young & Freedman, 2004). This chapter is

the basis for a module on Waves, one of the three foundation modules of Physics 1001.

CD-ROMs (supplementary media to textbooks)

3. Computer-based activities from Chapter 31: Fungi (Campbell, 2002; Campbell & Reece, 2002).
4. Computer-based activities from Chapter 11: Waves and Sound (Hecht, 2000).

Websites

5. First Year Biology website, Virtual Learning Environment, University of Sydney, http://fybio.bio.usyd.edu.au/VLE/L1/
6. Junior Chemistry website, University of Sydney (also a WebCT secure site): ChemCAL online module: Interactive tutorials and resources for first-year chemistry, http://chemcal.chem.usyd.edu.au/. The module on Equilibrium was selected as it is one of the key topics in first-year Chemistry courses.

4.3.3 Categorisation of content

One of the limitations of content analysis often cited is the 'un-theorised' content (Bell, 2001, p. 24; Neuman, 2000, p. 294). In this study, therefore, it was decided to draw on SF theory to inform the categorisation of the content. Accordingly, as will be demonstrated, the theoretical basis for the categorisation of the content drew on a broad conceptualisation of multimodality and the metafunctional orientation to meaning.

The content was first divided into categories for visual content, text blocks, animations and interactivity. Visual content, text blocks, and types of interactivity were also grouped according to which metafunctional meaning appeared to be foregrounded. A coding frame for the types of content within each category was devised. Table 4.4 shows an extract from the coding frame. The full coding frames can be found in Appendix A.

Table 4.4

Extract from Coding Frame for MCA

Types of visuals Colour	Proportion of visuals/visual blocks to text	Technology used for visuals	Location of visuals on screen	Types of text block	Font/ Size	Types of animation	Types/function of interactivity
1a = photograph 1aa = photo collage 1b = micrograph 1c = diagram/ drawing (scientific) col = colour b/w = black & white	* = less than half screen ** = half screen *** = more than half screen	T1: photography T2: microscope/y T3: SEM = Scanning electron microscope/y	T = top R = Right L = Left C = Centre B = Bottom	TX1 = running text TX2 = running text with technical term in italics TX3 = running text with technical term in bold TX4 = running text with technical term in bold and italics TX5 = running text with technical term as hyperlink	S = serif SS = sans serif 1 = very small 2 = small 3 = standard 4 = large 5 = extra large	A1 = Animated drawing, micrograph, graph, photo A2 = Animated text, numbers, values	INT1 = Click and drag/drop INT2 = Click image and enlarge INT3 = Click icon/button to return to top, go forward/ back/close window/get help, quit INT4 = Click button/icon/image/ hyperlink to start animation/activity

Table 4.5 shows the number of sub-categories for each category of content. Font and font size were collapsed into one column and coded together. For the screen texts, the coding table for the analysis was divided into eight columns, as shown in Table 4.4. The coding table for the textbooks was the same except for the last two columns.

Table 4.5

Number of Sub-Categories for Each Content Area

Content area	Number of sub-categories
1. visual type	10
colour or black/white	2
2. technology used to create visuals	7
3. location of visual on page/screen	18
4. proportion of text blocks to visuals/visual blocks on page/screen	3
5. text block type	27
colour or black/white	2
6. font }	2
7. font size }	5
8. animation	2
9. interactivity and its functions	14
Total number of sub-categories	**92**

Each of the ninety-two sub-categories represents a distinct unit of content and was assigned a code. What follows is a description of each content area and its categories, for each of the 8 columns of the coding table.

Column 1: Types of visuals/colour

Ten categories of visuals were identified and each visual was coded accordingly. The categorisation of visuals was informed by typologies of visuals in scientific text within social semiotics (e.g. Lemke, 1998b; Miller, 1998;

Thibault, 2001) and other areas of inquiry such as the sociology of scientific knowledge (Lynch & Woolgar, 1990b; Myers, 1990, 1992), as reviewed in Chapters 2 and 3. The categories were coded using lower case and were: (1a) photograph; (1aa) photographic collage; (1b) micrograph; (1c) diagram/scientific drawing; (1ct) cartoon; (1d) table; (1e) equation; (1f) icon (e.g. arrow, tick, logo); (1fhl) icon, button hyperlink; (1g) graph. Visuals were also tracked for colour with two codes only, col = colour and b/w = black and white. It was decided to distinguish between 1a (photograph) and 1aa (photographic collage) and 1b (micrograph), since, not only was each of these three categories seen to perform a different function, but also, different technology was used to create the images. Photographs were mostly used to depict the topic or field while photographic collage was a computer-enhanced collage of different parts of a photo or of different photos designed to add decorative interest to the page or screen, such as the visual backdrop in the screenshot in Figure 4.1 from the Physics CD-ROM.

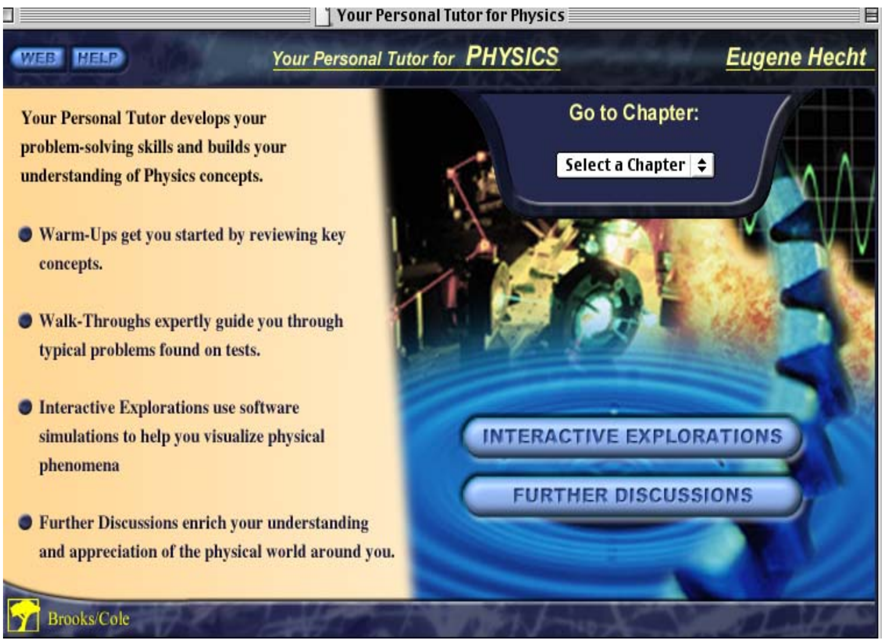


Figure 4.1. Screenshot from physics CD-ROM showing photo collage (Hecht, 2000).

Micrographs (1b) are typical of the discipline of biology. While on one level, they can be considered photographs, in that a camera may capture the image, the camera is affixed to a microscope and the image is taken through a microscope or similar device to show a magnified image of an item. This produces a highly technical image and unlike the photograph, tends to be recognisable only by a person with disciplinary knowledge. Equations (1e) were also included in visual content as, following Lemke (1998b) and O'Halloran (1999a, 1999b, 2005), they employ mathematical symbolism as a semiotic resource distinct from language. Also, they were often set off typographically from the verbal text or numbered and were thus regarded as forming visual rather than textual blocks. Category 1f (icon) and its hypertextual counterpart on the screen texts (1fhl) were also considered part of the visual display as they contributed visual rather than verbal content. Graphs (1g) were distinguished from scientific drawings and equations, since they serve a different function, although they often incorporated elements of each of these categories. If the image contained Cartesian coordinates (an x or y axis) it was coded as a graph rather than a drawing. Graphs in the physics textbook were either abstract visual representations of different types of mechanical waves (transverse, longitudinal and periodic, sinusoidal), their shape and motion over time, or representations of wave properties such as speed and energy. They were closely tied to the running text, the captions and labels and also to their relevant equations.

Finally, although not analysed metafunctionally in the coding tables, for the purposes of the discussion in Chapter 5, the visual categories were grouped metafunctionally. Table 4.6 shows how the ten categories of visuals were grouped according to their main purpose in the text and their orientation in the metafunctional organisation of meanings. Although it is acknowledged that all meanings select simultaneously from the metafunctions, at this point, Table 4.6 is an attempt to classify the visual categories according to which meaning systems appear to be foregrounded.

Table 4.6

Visual Categories Grouped According to Metafunctional Foregrounding

Topic focus: Experientially-oriented meanings		**User interest focus: Interpersonally-oriented meanings**		**Organisation focus: Textually-oriented meanings**	
1a	Photograph	* 1aa	Photo collage	1f	Logo, button or icon
1b	Micrograph	* 1ct	Cartoon	* 1fhl	Logo, button or icon as hyperlink
1c	Drawing				
1d	Table				
1e	Equation				
1g	Graph				

Note. * In screen texts only

Categories in the left column all contributed to the experiential content, creating the field-specific meanings and technicality. Categories in the middle column occurred only in the screen texts and were peripheral to the disciplinary content, adding ‘interest’ for the user in the form of cartoons or photo collage. Categories in the right hand column focus on the organisation of the text as a whole through forward or back buttons or as ‘anchoring’ logos (e.g. publishers’ logos), pointing the reader/user to other information or activities not visible on the active page or screen.

Column 2: Technology used to create the visuals

There has always been a close link between the evolution of science and the invention of technologies to understand it. It was therefore decided to track the type of technology used to create the visual to determine the relationship between the technology used, the type of visual and the technicality of the discipline. Seven categories of technology for creating visuals were identified; photography

(T1); light microscopy (T2); scanning electron microscopy (T3); scientific drawing (T4); mathematical drawing (T5); table drawing (T6); image editing software (T7).

Light microscopy and electron microscopy are two types of technology commonly used in biology, particularly to create micrographs (category 1b) in cell biology or cytology, but are less common in physics and chemistry. Light microscopes have a resolution limit of 250 nm (nanometers) with a magnification of around 800 times that of the naked eye (Knox et al., 2001). They work by passing light through the specimen and then through a series of glass lenses which project the magnified image to the eye, to a photograph film or to a video screen. Optical microscopy has reached its limits because of the wavelength of light. Electron microscopy however, is still developing and needs a much shorter wavelength. Electron microscopes such as the scanning electron microscope (SEM) focus a beam of electrons instead of light through the specimen or onto its surface, using electromagnets instead of glass lenses. They can attain a resolution of around 2nm, about 100 times better than light microscopes. The SEM has a large depth of focus and is useful for studying the surface of a specimen three-dimensionally via a video monitor (Campbell & Reece, 2002; Knox et al., 2001). Students learning biology at university need to develop expertise in using different forms of microscopy and ‘reading’ the micrographs. The technologies thus have a field-creating function, providing carefully selected visual evidence for the biologist’s observations and explanations of the natural world. Figures 4.2 and 4.3 from the biology textbook show micrographs taken with two different types of technology, the microscope and the scanning electron microscope.

Figure 4.2. Micrographs of fungal spores taken with a light microscope (Knox et al., 2001, p. 938).

Figure 4.3. Electron micrograph of fungal cell taken with a Scanning Electron Microscope (Knox et al., 2001, p. 939).

Drawing has been included as a type of technology used in creating visuals as it plays an important role in constructing field in biology, physics and chemistry, albeit in different ways. Historically, drawing in biology was regarded as an essential tool of the biologist's repertoire, giving foundation to his/her observations of the natural world. It is still considered an essential skill for students at university to be able to 'read' expert drawings and to produce drawings of specimens, dissections and prepared slides. At the University of Sydney, students are given some instruction in the skill of drawing and are expected to draw the results of their observations in the laboratory or field. Many of the drawings in the textbooks and on screen have been enhanced or assisted with computer drawing software, so that the traditional skills of biological drawing are less common. For students in physics and chemistry, apart from drawing graphs, drawing plays a lesser role, but may involve their representations of apparatus or experimental setups, of physical phenomena or of molecular structure. Even the latter may be reproduced by students using chemical drawing software such as ChemDraw. Also, image-editing software (T7) is used in some cases to produce an enhanced or altered image such as the photo collage (1aa) described above and shown in Figure 4.1.

Finally, mathematical equations, particularly in physics and chemistry, also produced using computer-aided software, are coded here for technology as mathematical drawings (T5). Tables (coded T6: Table draw) are produced by word processing or other similar software programs.

Column 3: Location of visuals on screen

Column 3 categories describe the total number of positions of visuals on the page or screen across the texts. It was decided to track location of visuals to determine whether there was any consistency in location and ultimately, how layout contributed to meaning. Eighteen different locations were identified which were combinations of the codes T = top; B = bottom; R = right; Left = left; C = centre. For example a visual located across the entire top half of the page from left to right was coded TLCR or coded TR if it was in the top right corner. Adding to the complexity of this area was the placement of equations which could occur at many different points on the page or screen.

<u>Column 4: Proportion of visuals/visual blocks to text</u>

Space allocated to visuals and their size may be related to constraints of page or screen design. This space assigned was considered important to analyse, firstly to determine their salience relative to text blocks and secondly, to get a sense of the visual ‘density’ of each page or screen. Three values were coded: * = less than half a page or screen; ** = half a page or screen; and *** = more than half a page or screen.

<u>Column 5: Types of text block/colour</u>

To complement the analyses of text elements in Stage 2, text blocks in Stage 1 were analysed partly from the perspective of typography (Tufte, 1997; Waller, 1987) and partly from the perspective of graphic design (Gillieson, 2003; Twyman, 1979). This was in order to understand aspects of the form of text elements as well as their function or purpose on the page or screen. For example, headings and sub-headings may be typographically distinguished by their size, type of font, colour or layout, while their function may be seen as organisational, to link coherent sections of text on the page or screen.

Considerable complexity was found in drawing up the categories of text blocks, with a total of 27 categories identified initially, compared to 10 categories of visuals. The main criterion used to delineate one text element from another was if it could be seen to perform a distinct function on the page or screen or was distinguishable by some typographical feature such as bold type or italics. Upper case was used for the codes. Text blocks also differed according to print or screen format, in that some elements were found only in the screen texts while others only in the print texts. The size of text block categories varied, ranging from a single word element, such as a single word heading hyperlink (TX18), a summary consisting of one or more sentences (TX13) or one or more paragraphs of running text (TX1).

Despite the large number of categories, it was decided in the first instance to use the full 27 categories in the analysis tables and summarise the results accordingly. The full table of text block categories can be found in Appendix A, Table A1.2. However, in collating the results for the 27 categories, it was found that such a fine level of distinction between some of the categories was unnecessary, since many categories were not found in the majority of the texts. The 27 categories were therefore collapsed to 19. Categories TX2-TX6 in the full table (Table A1.2), which all code technical terms, were collapsed into one category (TX2 = technical term in running text in italics, bold, colour or as hyperlink), since the finer distinctions in typographical variation were not found to be of sufficient importance at this point. Similarly, categories TX21 and TX22 (multiple-choice question and multiple-choice answer) were represented as one category (TX15) and TX24 and TX25 (question and question as a hyperlink) became TX17). The categories were also coded for colour (col). The descriptors for each of the 19 categories are set out in Table 4.7.

Table 4.7

Description of 19 Categories of Text Blocks

Code	Category descriptor
TX1	running text
TX2	technical terms in running text in italics, bold, colour or as hyperlinks
TX3	heading/sub heading
TX4	button label/ hyperlink
TX5	visual caption (active or inactive)
TX6	label (active or inactive)
TX7	summary running text
TX8	chapter contents/ chapter summary/revision/review/extension questions/key terms
TX9	footer
TX10	table text
TX11	text hyperlink
TX12	heading hyperlink
TX13	pull-down text menu
TX14	key to visual
TX15	multiple choice question/answer
TX16	problem/solution/worked example
TX17	running text questions/test your understanding (active or inactive)
TX18	Activated text box (glossary term/explanation)
TX19	warning

As with the visual categories, to provide a metafunctionally-oriented perspective on the reporting of results, the text block categories were grouped according to which metafunctional meanings were foregrounded. Table 4.8 shows how the nineteen categories were grouped.

Table 4.8

Groups of Text Block Categories According to Metafunctional Foregrounding

Topic/content focus: Experientially-oriented meanings		**User/reader focus: Interpersonally-oriented meanings**		**Organisation focus: Textually-oriented meanings**	
TX1	running text	# TX15	multiple choice question/ answer	TX3	heading/sub heading
TX2	technical terms in running text in italics, bold, colour or as hyperlinks	# TX16	problem/ solution/ worked example	*TX4	button label/ hyperlink
TX5	image caption (active or inactive)	# **TX17	running text questions/test your understanding	**TX8	chapter contents/ chapter summary/ revision/ review/ extension questions/key terms
TX6	image label (active or inactive)	# **TX19	warning	TX9	footer
TX7	summary running text			*TX11	text hyperlink
TX10	table text			*TX12	heading hyperlink
*TX13	pull down text menu				
TX14	key to visual				
*TX18	Activated text box (glossary term/explanation)				

Note. * = in screen texts only, ** = in textbooks only, # = categories with dual focus

Categories in the left column all focus on the topic, serving to create field through categories such as the main text, image captions and labels and technical terms and are thus experientially-oriented. Categories in the central column are interpersonally-oriented and involve interaction with the reader/user, engaging them in some pedagogical activity such as answering different types of question or working through a problem. Categories in the right column are oriented toward the textual metafunction and focus on the organisation of the text as a whole, either internally through headings or summaries or externally, pointing the reader to other information or activities not visible on the 'active' page or screen.

Column 6: Font and font size

The typographical features of font and font size were designated as separate areas for content analysis to establish how they co-varied with text block categories, with colour or with page and screen format. While these are important decisions for a graphic or screen designer and appear to be of little interest to the analyst, the choice of font type and size also affects how students read and interact with the page or screen. Typographical features such as font size and type also serve a textual metafunction in creating unity and coherence. Font was categorised with two values only: SS = sans serif (such as Arial or Helvetica) and S = serif (such as Times Roman). Font Size was given 5 values: 1 = very small; 2 = small; 3 = standard; 4 = large; 5 = very large. The two areas were coded together in one column.

Column 7: Types of animation

This area was a feature of the screen texts and involved moving images and image parts or text or numbers which moved, often as a result of the user activating these elements. Despite the potential for the screen texts of this corpus to include a large range of animations, only two categories were identified: A1 = animated visual (e.g. drawing, micrograph or photo); A2 = animated text, numbers or values. Animations could co-occur with interactivity and visual and verbal modalities. For example, the biology CD-ROM contains an animated drawing of the reproductive cycle of fungi. The student is directed by a voice over the text to click on a section of the drawing (the gills of the mushroom) in order to observe the structures that produce spores. The gills then move and become enlarged, revealing their structure.

Column 8: Types and functions of interactivity

Interactivity in the content analysis is defined as an instance in which the user/student could be directed from the screen to carry out some activity related to the content on the screen. The 'direction' to the student could be in the visual mode, for example when the student clicks a button to start an animation or activity, or in the verbal mode, for example when the student clicks a text hyperlink to change to a different activity, or a combination of both visual and verbal modes, for example when a text hyperlink appears below an image, directing the student to enlarge the image.

Fourteen types of interactivity were identified which are described in Table 4.9.

Table 4.9

Categories of Interactivity and Codes

Code	Description
INT1	Click and drag/drop
INT2	Click image and enlarge
INT3	Click icon/button to return to top, go forward/ back/close window/get help, quit
INT4	Click button/icon/image/hyperlink to start animation/activity
INT5	Click correct answer (MCQ), solution
INT6	Click, select from pull down menu to change activity/give answer
INT7	Enter/activate numbers, values, symbols to balance equation, to change parameters on graph
INT8	Click HL to go to glossary/ explanation
INT9	Click to check answer or explanation/hint
INT 10	Fill in form
INT 11	Click to send (to internet)
INT 12	Click hyperlink to change to different activity
INT 13	Type in answer, comments
INT 14	Click HL to go to intra/internet

Some categories (INT3, INT12, INT14) play an important navigation role, interacting with the visual and verbal content to guide students through the current activity, to direct them to another activity on the same website or CD or to link them to another website either on the intranet or the internet. Other categories are tied to the pedagogical activity ‘going on’ on the screen, rather than the navigation aspects. Categories INT 1, INT2, INT5, INT6, INT7, INT8, INT9, INT13 all engage the student in the experiential content on the screen, directing him/her to perform some action related to that content. All these types of interactivity however, differ in the type of action needed and in whether the student needs to interact with the visual or verbal mode.

4.3.4 Coding process

A table was set up for each text showing an image of the full page or scrollable screen, the areas of content analysed and the coding results of each area per page or screen. Full tables of the analysis can be found in Appendix B. For the textbooks the analysis tables were set out with 10 columns as in Table 4.10.

Table 4.10

Extract from Multimodal Content Analysis of Textbook Page Showing Content Areas and Coding

Page	Page image	Visual No	No Visuals per page	No each type col/b/w	Technology used	Location of Visual	Prop Visuals :Text	Type of text block/ colour	Font size/ Type
2 (938) *		36.1 36.2(a) 36.2(b) 36.2(c)	4	1c col 1b col 1b col 1b col	Draw Micro Micro Micro	BL TR CR BR	***	TX1 TX3 (4) TX7 col (2) TX9 col (4) TX11 b/w	3S 3S 2S,4SS 2S 1S, 2S

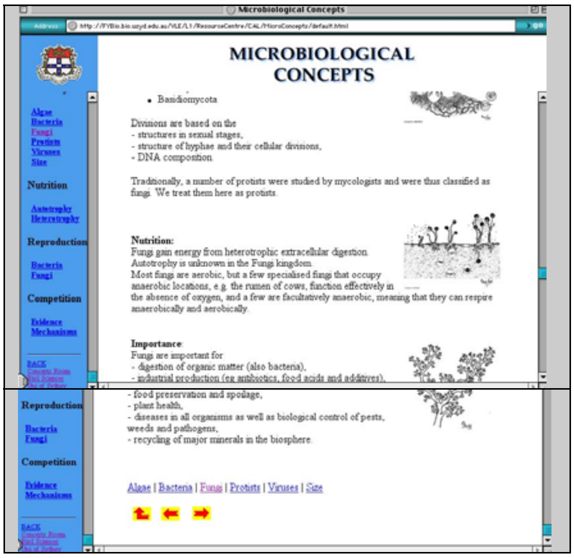
Note. * = page in textbook

For the screen texts the analysis tables were set out similarly but with two extra columns for Animation and Types/function of Interactivity;

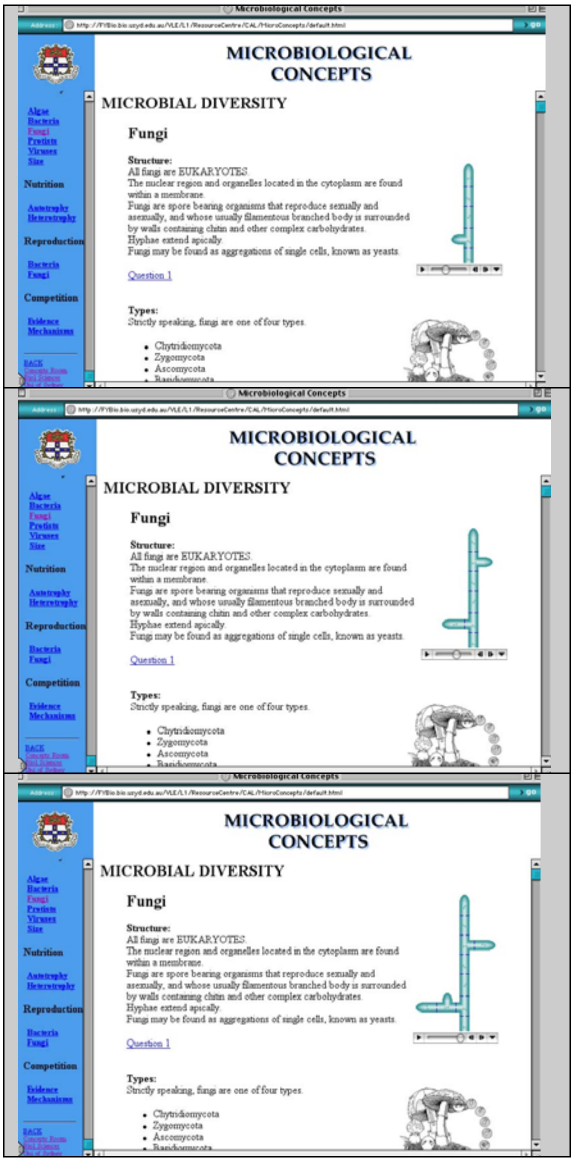
The analysis tracked the range and frequency of all sub-categories within each content area and summarised the results in tables and graphs in order to show patterns of distribution of categories across texts, disciplines and modalities. All summary tables and graphs can be found in Appendix B.

<u>Images of page and screen: the unit of analysis</u>

As seen from the analysis tables above and in Appendix B, Tables B1.1 to B1.11, the unit of analysis was an image of the page or screen. All images were screenshots of the pages of the textbook or of the CD-ROMs and websites. The textbook chapters were obtained in PDF format and screenshots taken of each page. For the screen texts, a screenshot was taken of what was visible on the active screen. If it was possible to scroll to a continuation of the active screen, a new screenshot was taken and separate analysis was carried out. For example, the following screenshots from the biology website were analysed as two screens as they contain different content.



Screens which contained animations were analysed once only for the type of animation but were displayed as successive screenshots showing the unfolding of the animation. For example, the following animation from the biology website of fungal hyphae extending (the coloured drawing on the right) was displayed with 3 screenshots in the analysis table to show the steps of the animation.



4.3.5 Limitations of content analysis

Quality in content analysis derives in part from coherence of the coding frame and from transparency of the categories (Bauer, 2000). In the approach I have outlined in this chapter I hope to have demonstrated both these criteria in the conceptualisation of the multimodal content and in the description of the categories.

There are however, a number of limitations of content analysis. In yielding primarily quantitative data from which generalisations can be drawn, the qualitative or interpretive dimension of the analysis cannot be fully explored. Another major limitation mentioned above is that the content may be un-theorised and the categories may be based on a ‘commonsense’ understanding of social context (Bell, 2001, p. 24). Coding categories may end up by being overly subjective or decontextualised. It is also difficult to make inferences from the data as they do not go beyond the content to reveal the intentions of the designers of the content or the impact on the ‘readers’ of the content. There will clearly be different readings of visual and verbal content, for example, depending on reader knowledge and expertise. Categorisation of content tends to favour a typological perspective on meaning through the breakdown of content into micro elements. This process may overlook clines or shades of variation – i.e. more topological perspectives. Finally, by focussing on discrete areas of content intermodal meanings may be difficult to see. However, I believe the value of a multimodal content analysis lies in its generation of quantitative and empirical data upon which to base the selection of texts for further fine-grained analysis, such as that proposed for the MDA in Stage 2, which will be presented in Chapter 6. The next chapter presents the results of the multimodal content analysis.

CHAPTER 5

STAGE 1 RESULTS AND DISCUSSION (MCA)

5.0 Introduction

The main purpose of the detailed approach to the multimodal content analysis of Stage 1 was to break down the content, categorise it and examine its distribution across modalities in order to provide a principled basis for the selection of texts for Stage 2. This chapter will present the results for Stage 1 and discuss their significance, focussing on the variation between page and screen texts and on the ways in which the multimodal content is distributed across disciplines.

5.1 Results of multimodal content analysis

Appendix B presents the multimodal content analysis and the tables and graphs which summarise all results for Stage 1. These tables and graphs will form the basis for the discussion of the results and where appropriate, will be reproduced in the following pages.

The results of the nine areas of multimodal content analysis (MCA) will be discussed as follows:

<u>Section 5.2 Visuals</u>

1. types and colour of visuals
2. technology used to create the visual content
3. location of visual on page/screen
4. proportion of text blocks to visuals/visual blocks on page/screen

<u>Section 5.3 Text</u>

5. types and colour of text blocks

6. font
7. font size

Section 5.4 Animation and Interactivity

8. animation *
9. interactivity and its functions *

   * = only in screen texts

Each section will present the results of the six texts of the corpus and discuss their significance. The chapter will conclude with some general observations on the Stage 1 results, thereby paving the way for the multimodal and multisemiotic analysis of Stage 2 presented in Chapters 6 and 7.

5.2 Visual content analysis

Tables and graphs for all four areas of the visual content analysis can be found in Appendix B. Tables B3.1.1 to B3.1.4 and Figures B3.1.1 to B3.1.5 summarise all features of the visual content analysis. Results for the types of visual, the technology used to create the visual, visual density, the proportion of visual blocks to text blocks per page/screen and the location of the visual on the page/screen will be discussed in turn.

5.2.1 Types of visual

The range of categories of visual for each text and the proportion of each category of the total number of visuals for each text is presented in Table B3.1.1 and Figures B3.1.1 and B3.1.2 in Appendix B. The differences are marked and show variation according to both discipline and text. The physics CD-ROM and the biology website showed the greatest range of categories of visuals with seven of the full range of ten visual types represented. This implies that these two screen texts are more ‘visually’ oriented than the others. However, when the function of the visuals and their relationship with other content areas is examined, the results become more meaningful. Chapter 4 presented a categorisation of visuals based on metafunctionally oriented groups in Table 4.6, p. 84. To determine which of the metafunctional groupings of visuals was dominant the total contributions for each group of visuals was calculated. The results are shown in Figure 5.1.

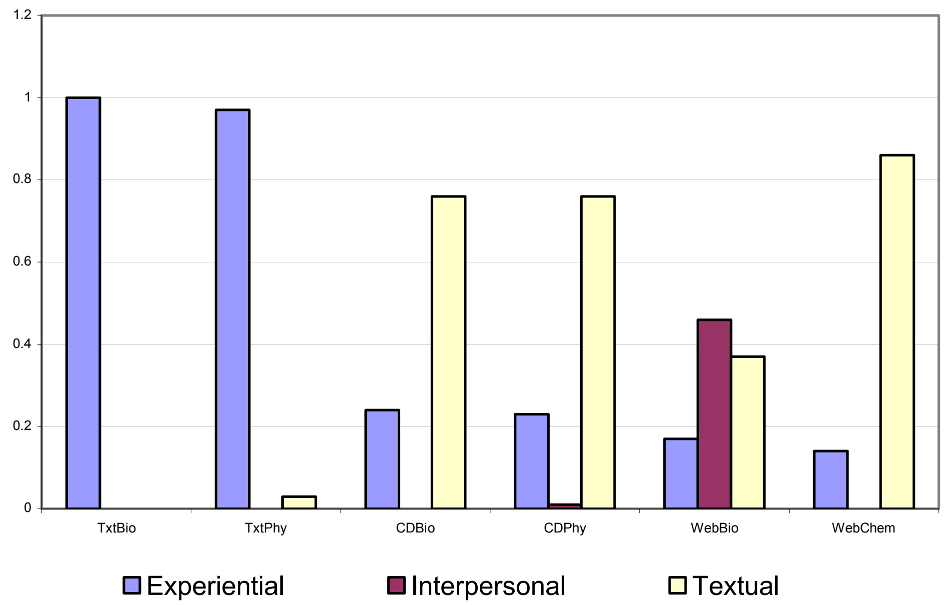


Figure 5.1. Comparison of metafunctional groupings of visuals across texts.

Figure 5.1 shows that different groups of visuals predominate in different formats. In the textbooks experientially-oriented categories far outweighed the other two groups while in the screen texts navigational or textually-oriented categories were dominant. The page and screen texts selected different types of visuals, resulting in the foregrounding of different metafunctions. The screen texts depended more on navigational types of visuals to orient the user to the organisation of the subject matter and pedagogical activities, while the textbooks were more concerned with visuals oriented towards the subject matter. Finer analysis of the metafunctional groupings of visuals revealed that there was also variation according to discipline, as will be demonstrated next.

Experientially-oriented categories

Table 5.1 shows the relative proportions of experientially-oriented categories for each text and the proportion of these categories of the total number of visuals as a percentage. There is a marked variation in the range and distribution of these categories according to both format and discipline.

Table 5.1

Proportions of Experientially-oriented Visual Categories across Texts

	Exp categories %	1a	1b	1c	1d	1e	1g
Textbook Biology	100	0.39	0.37	0.22	0.02	0	0
Textbook Physics	97	0.05	0	0.22	0	0.61	0.09
CD Biology	24	0	0	0.24	0	0	0
CD Physics	23	0	0	0.04	0.005	0.14	0.04
Web Biology	17	0.03	0.03	0.08	0.03	0	0
Web Chemistry	14	0.01	0	0.03	0	0.09	0.01

Note. 1a=Photograph, 1b=Micrograph, 1c=Drawing, 1d=Table, 1e=Equation, 1g=Graph

When represented as a graph in Figure 5.2 the differences become clear.

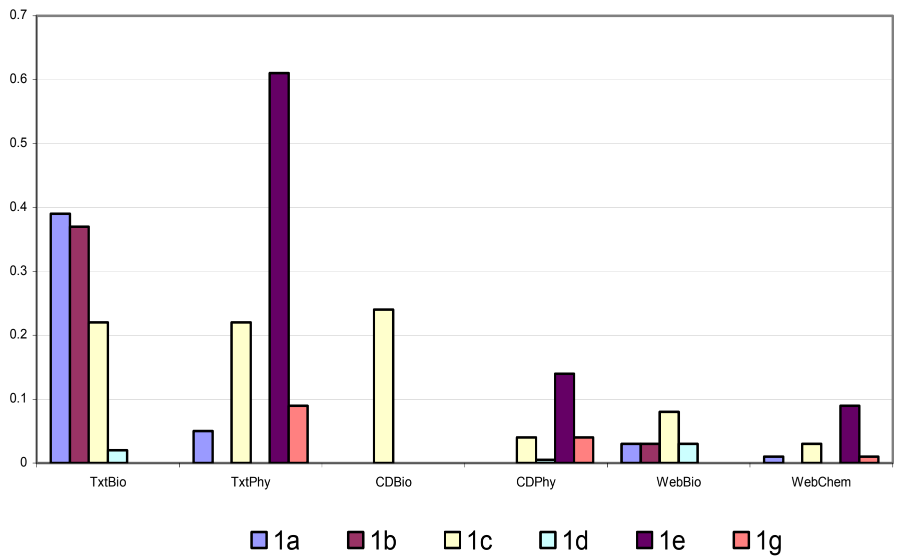


Figure 5.2. Range and distribution of experientially-oriented visual categories per text.

One notable difference between the textbooks and the screen texts is the considerably higher proportions of the experientially-oriented visuals in the textbooks, corresponding to the findings of Unsworth (2004) in children's learning materials. All visuals (100%) in the biology textbook fell into this group and 97% in the physics textbook, compared with 24% on the biology CD-ROM, 23% on the physics CD-ROM, 17% on the biology website and 14% on the chemistry website. This is perhaps not surprising however, and can be attributed in part to the affordances of page and screen formats. The depth of subject matter coverage per page in the textbooks was far greater than that found on a scrollable screen in these screen texts, which only focussed on a very narrow aspect of the topic.

Also interesting was the fact that disciplinary variation in the types of visuals occurred regardless of format. The biology textbook used the categories of photograph and micrograph in almost equal proportions, which together made up about three quarters of the total number of visuals for the chapter, while the physics textbook used a small proportion of photographs and no micrographs. In the screen texts micrographs were found only on the biology website, accounting for just 3%. Although four of the texts used photographs, they did so in a different way metafunctionally. In the biology textbook, the numerous photographs and micrographs of fungi served to construct the experiential content of the discipline by showing 'how the world is' according to the biologist/photographer. On the biology website the smaller number of photographs was used in the same way. In the physics textbook and on the chemistry website the photographs were more interpersonally-oriented. In the physics textbook for example, a photograph of an earthquake is used as a 'chapter opener' for the chapter on mechanical waves to show the effect of seismic wave action and a photograph of a girl playing the violin accompanies the text input on sound waves. These photographs, while related to the topic in a broad sense, serve more to engage the reader by adding interest in the otherwise abstract visual world of physics. Similarly, on the chemistry website, the 1% of photographs actually consisted of two photo clips, one of the sky and the other of some glass flasks of chemicals, again possibly used to add visual interest for the student user. They contribute very little however, to the experiential meaning of the module on equilibrium.

In the physics and chemistry texts, on the other hand, equations (1e) and graphs (1g), both of which were not found in the biology texts, are the important field-creating visuals. Equations were particularly important in the physics textbook where they made up 61% of the visuals for the chapter. Although they occurred far less on the physics CD-ROM (14%) and the chemistry website (9%), they were still important in creating field. Less significant in proportion but not so for their role in constructing field in physics and, to a lesser extent in chemistry, were graphs (category 1g). In physics they accounted for 9% of visuals in the textbook chapter and 4% on the CD-ROM. Examples of graphs in the physics textbook were abstract visual representations of different types of mechanical waves - transverse, longitudinal and periodic, sinusoidal - their shape and motion over time, or representations of wave properties such as speed and energy. They interact with the verbal text and with mathematical symbolism as they are closely tied to the running text, the captions and labels and also to their relevant equations. Their role in intersemiotic relations will be discussed further in Chapter 7.

Drawings (1c) mostly served to convey experiential content in the three disciplines and were used in the same proportion in both textbooks (22%). In the screen texts, however, there were some differences. In biology, drawings accounted for 24% and 8% of the total number of visuals for the CD-ROM and website respectively, while in physics they made up only 4% for the CD-ROM and 3% on the chemistry website. Tables (1d) also contributed to the experiential content but occurred in very small proportions, accounting for only 6% of visuals on the biology website, 2% in the biology textbook and 0.5% on the Physics CD-ROM. The only table in the biology textbook chapter (Table 36.1 on p. 947) gives taxonomic information about four of the six phyla of fungi and a comparison of their characteristics.

<u>Interpersonally-oriented categories</u>

Table 5.2 shows the proportions of the two interpersonally-oriented types of visuals across the texts, photo collage (1aa) and cartoon (1ct) and the proportion they contribute to the total visuals as a percentage.

Table 5.2

Proportions of Interpersonally-oriented Visual Categories across Texts

	Int categories %	1aa	1ct
Txtbk Biology	0	0	0
Txtbk Physics	0	0	0
CD Biology	0	0	0
CD Physics	1	0.01	0
Web Biology	46	0	0.46
Web Chemistry	0	0	0

Note. 1aa= photo collage, 1ct= cartoon

The two categories in this group occurred only in the screen texts and were peripheral to the disciplinary content, adding interest for the user in the form of cartoons or photo collage. The photo collage that appears on the physics CD-ROM, shown in Figure 5.3, is the introductory screen for the activities and plays a similar ‘user interest’ role to the chapter opening photos in the textbooks. This highly coloured visual is designed to suggest physical phenomena such as waves and circular motion and engage the user in the activities which follow.

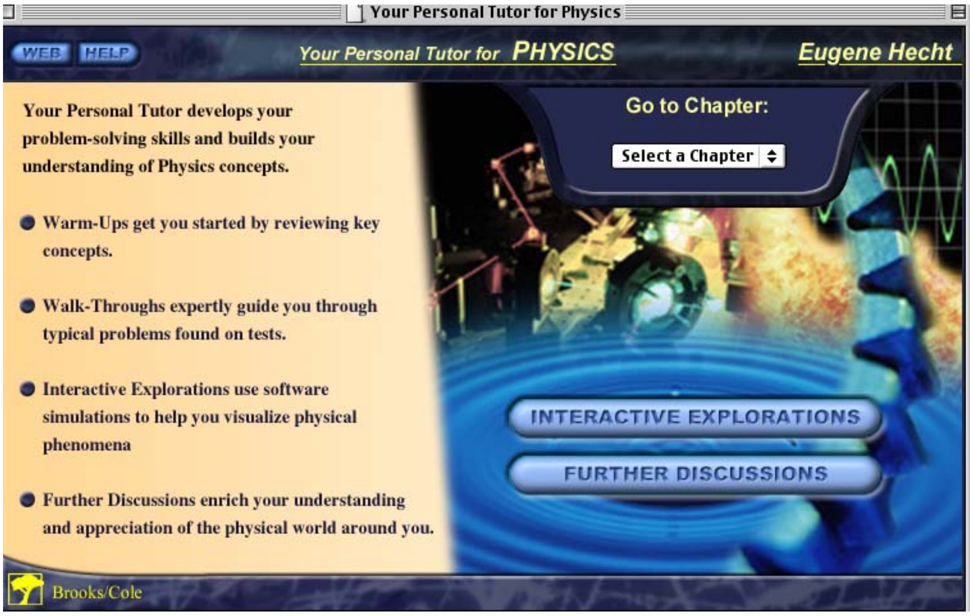


Figure 5.3. Opening screen of the Physics CD-ROM activities showing photo collage (Hecht, 2000).

Category 1ct (cartoon) occurred only on the biology website but it accounted for 46% of the total number of visuals for this text. It served a dual function however, partly interpersonal and partly navigational. As discussed in 4.2.3, p. 74, the website is designed to suggest a virtual learning ‘space’ and the cartoon drawings suggest that this will be a friendly and helpful environment to navigate. Many of the cartoon figures are active hyperlinks and guide the student through the website to other screens with information on the course, the computer modules, the staff, the lectures etc., as in the screenshot in Figure 5.4.

Figure 5.4. Screenshot of the introductory screen to the Student Resources Centre on the biology website

On the same website, however, cartoon drawings also appeared as part of the experiential content, as in the screenshot in Figure 5.5.

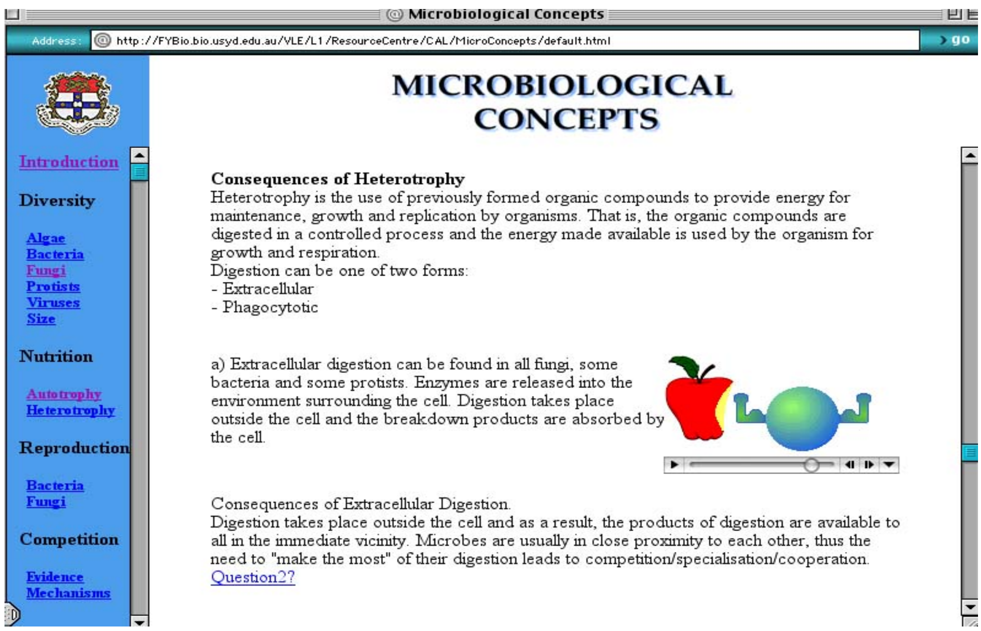


Figure 5.5. Screenshot of the biology website showing a ‘content-oriented’ cartoon drawing of an apple being consumed by microbes.

Where the image was functioning in this way, it was classified as a scientific drawing (1c) rather than a cartoon (1ct). It could be argued that in drawings, there is a cline of 'cartoonness' or a cline of 'scientificness', depending on their role in the text. This highlights one of the limitations of content analysis which focuses on the categorisation of content, thereby foregrounding typological rather than topological perspectives on meaning.

Textually-oriented categories

Categories in this group foreground the textual metafunction, focussing on user navigation and the organisation of the text as a whole. Table 5.3 shows the proportions of the two textually-oriented types of visuals, icon (1f) (e.g. arrow, tick, logo); and icon/button hyperlink (1fhl), across the texts and their relative percentages.

Table 5.3

Proportions of Textually-oriented Visual Categories across Texts

	Textual categories %	1f	1fhl
Txtbk Biology	0	0	0
Txtbk Physics	3	0.03	0
CD Biology	76	0.76	0
CD Physics	76	0.18	0.58
Web Biology	37	0.18	0.19
Web Chem	86	0.11	0.75

Note. 1f= icon, 1fhl= icon, button hyperlink

These two categories made up the majority of the visuals in all four of the screen texts, contributing a high 86% of the visual content on the chemistry website and 76% on the biology CD-ROM. The relatively high proportion of these categories in the screen texts is interesting. Category 1f and its hyperlink counterpart, 1fhl, serve to orient the user/reader to the sequencing of the content and the activity on the 'active' page or screen, such as the forward/back button links in the screen texts, or the logos which point the reader to the existence of online activities in the physics textbook. Other instances of 1f or 1fhl were the publishers' logo on the biology and physics CD-ROMs and the ChemCAL logo on the chemistry website. They clearly do not contribute to the visual meaning in the same way as the experientially-oriented categories but are crucial for navigation, playing an important sequencing and orienting role for the user.

5.2.2 Types of technology used to create visuals

Table B3.1.3 and Figure B3.1.5 in Appendix B summarise the results for this feature. There is a close relationship between the technology used to create the visual, the type of visual and the discipline. Of the seven types of technology, (T1 to T7) the biology textbook had the greatest range with five out of eight types. In this text, the three types of technology crucial to the discipline, photography (T1), light microscopy (T2) and scanning electron microscopy (T3) made up 77% of the types of technology used, matching the proportion of photographs and micrographs found. Interestingly, these three categories were little used in the biology screen texts. On the biology website only 6% of the images were reproduced using photography or light microscopy, while on the biology CD-ROM none of the images were reproduced in this way. The latter text, used image editing software to produce 76% of the images, which were all related to the publishers' promotion of the book. These consisted of a small image of the front cover of the textbook, located in the top right corner and a faded image of part of the cover used as a backdrop for the publishers' hyperlinks for the book on the left, shown by the arrows in the screenshot in Figure 5.6.

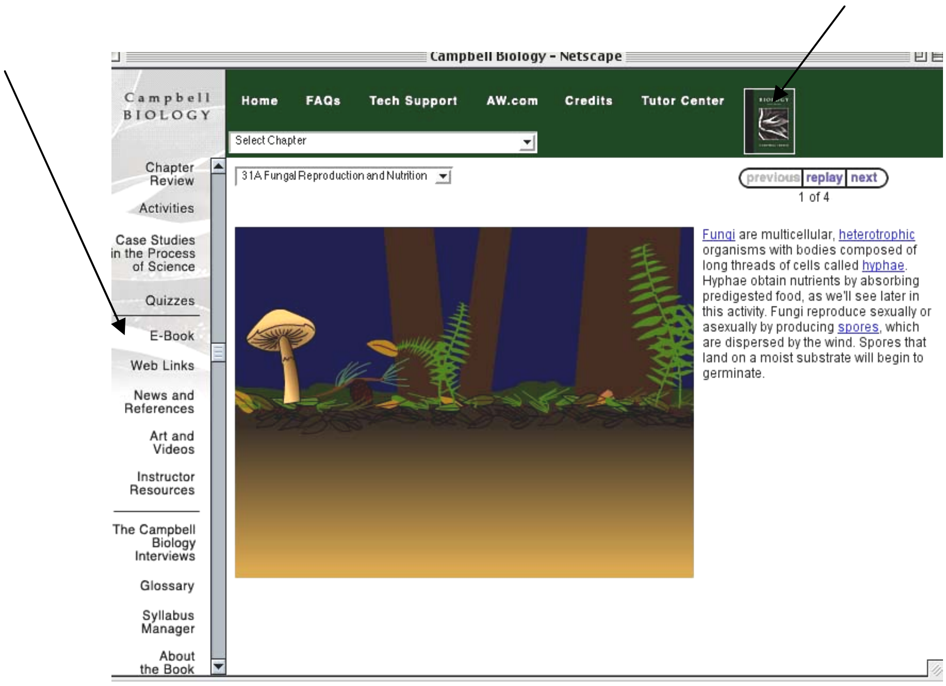


Figure 5.6. Screenshot of Biology CD-ROM activity showing images produced by image editing software (Campbell, 2002).

The 24% of the field specific images were rather crude drawings rather than the highly technologised drawings found in the textbook.

In the physics and chemistry texts, the types of technology used are very different. Mathematical drawing (T5), used to create equations and graphs, was the predominant category used in the physics textbook (68%), while it was used for only 18% on the physics CD-ROM, 10% on the chemistry website and not at all in the biology texts. The relatively small proportions in the physics and chemistry screen texts of this category was skewed by the high use of drawing (T4) used to create the logo and icon categories of visuals.

5.2.3 *Visual density and proportion of visual blocks to text blocks*

Two analyses of visuality of the corpus were carried out, visual density and the proportion of visual blocks to text blocks. The measure for visual density (VD) was calculated as the total number of visuals counted for each text divided by the number of pages/screens analysed. Because of the high proportion of navigation visuals in the screen texts a second measure of visual density (VD1) was calculated to give a more accurate representation of the visual density of the disciplinary content of the texts. VD1 refers to the total number of visuals without the icon/button/logo categories (1f) and (1fhl), the navigational cartoons (1ct) and the photo collage images (1aa). Table 5.4 compares the visual density across the texts in terms of two values, VD and VD1.

Table 5.4

Comparison of Visual Density and Visual Density 1 across Texts

	VD	VD1
Txtbk Biology	1.89	1.89
Txtbk Physics	3.48	3.39
CD Biology	2.62	0.62
CD Physics	4.26	0.96
Web Biology	3.62	0.6
Web Chemistry	10.15	1.42

The highest VD was for the chemistry website while the lowest was for the biology textbook. This pattern changes for VD1, where both textbooks showed a higher visual density than the screen texts. This finding accords with Unsworth (1999), who also found visual sparsity in screen texts. It seems that the bulk of the work being done by the visuals is for navigation rather than representation of disciplinary content.

In order to determine how much space was devoted to visuals and text blocks per page or screen three categories were used: category 1: *** = more than 1/2 page/screen, category 2: ** = 1/2 page/screen; and category 3: * = less than 1/2 page/screen. The values shown in Table 5.5 represent the proportion of pages/screens per category of the total number of pages/screens analysed for each text.

Table 5.5

Proportion of Visual Blocks per Page/Screen across Texts

	Category 1	Category 2	Category 3
Txtbk Biology	0.5	0.05	0.45
Txtbk Physics	0.16	0.07	0.77
CD Biology	0.43	0.27	0.3
CD Physics	0	0.24	0.76
Web Biology	0.08	0.13	0.79
Web Chemistry	0.11	0.47	0.42

There was considerable variation across the texts. In the biology textbook, the biology CD-ROM and the chemistry website the visuals occupied the most space, since the majority of pages or screens occupied half a page/screen or more (categories 2 and 1). The biology website, the physics textbook chapter and the physics CD-ROM showed that more space was assigned to text blocks than to visuals. However, the salience of many of the images in the textbooks, through their size, also needs to be taken into account, since many of them occupied a full half page. This aspect, along with other aspects of visuality, will be discussed further in the Stage 2 analysis in Chapter 7.

5.2.4 Location of visuals on page and screen

The location of visuals on the page and screen was tracked to determine whether there was any consistency in layout which would be a useful starting point to analyse information value in Stage 2. Both the textbook and screen text visuals occupied a large number of locations on the page and screen, ranging from 18 in the physics textbook to 6 on the biology CD-ROM. This may be explained by the fact that the physics textbook has a high proportion of equations, which need to occupy a wide variety of positions on the page, since they are integrated more closely than other visual types with the running text. Visuals such as photographs, micrographs or drawings have fewer positions which they can occupy due to page/screen size and design constraints. Moreover, the space that these three categories occupy tends to be larger than that for equations, particularly in the case of textbook visuals. Other aspects related to the location of visuals on the page will be taken up further in the discussion of the Stage 2 analysis in Chapter 7.

5.3 Text block content analysis

The content analysis comprised categories of text block and typographical features such as font and font size. Text block categories were determined according to the function they performed and the typographical features they displayed. Before discussing these analyses, it is worth commenting on the space allocated to text blocks compared with that for visuals.

Kress (2003) has claimed that both page and screen texts today are being influenced by the mode of image and the 'logic of space' rather than the mode of writing. In the visual content analysis it was found that in three of the six texts - the biology website, the physics CD-ROM and the physics textbook chapter - more space was assigned to text blocks, i.e. the written mode than to images.

5.3.1 Types of text block

The initial categorisation of text blocks found 27 distinct categories and all texts were coded accordingly. Results of the full coding can be found in Table B3.2.1 in Appendix B. However, as explained in 4.3.3, the finer categorisation was done to account for every distinct category, and, following the principles outlined on p. 90, the 27 categories were collapsed to 19. Like the visual analysis, the text block analysis will be presented according to metafunctional groupings of the 19 categories, as shown in Table 4.8, p. 91.

Figure 5.7 presents a summary of the results of the distribution of each group of categories across the texts.

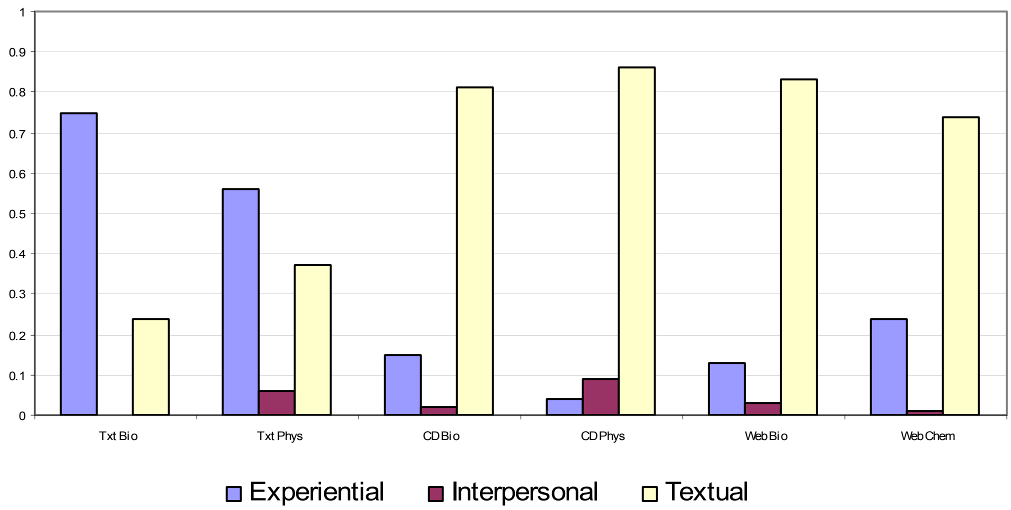


Figure 5.7. Comparison of metafunctional groupings of text block categories across texts.

Figure 5.7 clearly shows that the main concern of the verbal content of the screen texts is to orient the user to the organisation of the content (textual categories) while the textbooks are more concerned with the presentation of the topic (experiential categories). This suggests that the verbal text on screen is carrying the ideational load. The following sections will discuss the results for each of the metafunctional groups, thereby exploring this issue further.

<u>Experientially-oriented categories and technicality</u>

Table 5.6 presents the results for this group, showing the total percentage

contribution of these categories and the distribution of each category.

Table 5.6

Proportions of Experientially-oriented Text Block Categories across Texts

	%	TX1	TX2	TX5	TX6	TX7	TX10	TX13	TX14	TX18
Txtbk Biology	75	0.07	0.44	0.16	0.04	0.04	0.003	0	0	0
Txtbk Physics	56	0.08	0.27	0.1	0.11	0	0	0	0.003	0
CD Biology	15	0.01	0.04	0	0.01	0	0	0.04	0.005	0.04
CD Physics	4	0.03	0.01	0	0	0	0.001	0.001	0	0
Web Biology	13	0.03	0.002	0.03	0.02	0	0.009	0	0	0.04
Web Chemistry	24	0.09	0.1	0.005	0.02	0	0	0	0.01	0.01

Note. TX1= running text, TX2 = technical term, TX5=caption, TX6=label, TX7=text summary, TX10=table text, TX13=pull-down text menu, TX14=key to visual, TX18=glossary explanation

From Table 5.6 it can be seen that, as in the visual content analysis, the experiential categories occurred in much higher proportions in the textbooks than in the screen texts. This was particularly the case in areas such as highlighting technical terms (TX2), the use of captions (TX5) and labels (TX6). It should be noted however, that the measures show frequency of occurrence per page/screen rather than the amount of page/screen space taken up by text blocks. The comparatively high measures of technical terms (TX2) in the textbooks merely indicate that this feature occurred relatively frequently when compared to the full range of categories and frequencies.

Technicality in the visual content analysis was seen in the types of technology used to create the visuals as well as in the type of visual. In the verbal content, one aspect of technicality can be seen from the way in which technical terms are typographically distinguished (e.g. bold or italics). This aspect varies according to format. Typographically marked technical terms occur most frequently in the biology textbook chapter, accounting for 44% of the total instances of text blocks types, and then in the physics textbook for 27%. The screen texts use this feature far less frequently. As was found in the visual analysis, the coverage of the topic in the screen texts was far less than that in the textbooks. There was less space taken up by main text and more ‘white space’, so less opportunity to introduce technical terms. Only one of the five screen texts uses the hyperlink feature to define or add more information about technical terms. On the biology CD-ROM technical terms are hyperlinked to a pop-up screen with an explanation from a database glossary of terms. It is surprising that only one of the screen texts does this, since it could be argued that in texts of this nature an ideal use of hypertext would be to link students to further explanations about technical terms. If this was done, far more explanatory text about the technicality of the discipline could be included so that explanations and definitions do not have to take up screen space on the active screen or appear as part of the main text. It would also give the student the option of reading or skipping over the explanations and definitions.

Another aspect of technicality found in the text blocks is the naming and identification of phenomena on the images through captions (TX5) or labels (TX6). Here, interaction between the verbal and the visual systems of meaning can be observed in the way written text is used to identify what the image represents and what its components are. Finer analysis in Stage 2 will show more precisely how this works and how the images, captions and labels also interact with the main text.

Again, the differences in these categories were according to format rather than discipline. The textbooks generally used captions and labels more frequently than the screen texts. Captions made up 16% and 10% of the text block instances for the biology and physics textbooks respectively, while on the physics and biology CD-ROMs there were no captions and very small numbers on the screen texts. There was a similar pattern for labels (TX6), with the screen texts showing far fewer visuals labelled. It appears that in supporting the images on the screen the main text plays a more important role than captions or labels in identifying and naming the image and its parts. This is supported by Unsworth (2004), who reported a similar finding for school science textbooks and CD-ROMs.

Interpersonally-oriented categories

Table 5.7 presents the results for the categories in this group, showing the total percentage contribution of these categories and the distribution of the categories across the texts.

Table 5.7

Proportions of Interpersonal Text Block Categories across Texts

	Int categories %	TX15	TX16	TX18	TX19
Txtbk Biology	0	0	0	0	0
Txtbk Physics	6.5	0	0.04	0.02	0.005
CD Biology	2	0.02	0	0	0
CD Physics	9	0.09	0	0	0
Web Biology	3	0.02	0	0.01	0
Web Chemistry	1	0	0	0.01	0

Note. TX15=MCQ/answer, TX16=problem/solution, TX18=question, TX19=warning

The interpersonally-oriented categories formed a small proportion of the total for each text, with the highest proportion occurring in the physics CD-ROM. The distribution of these categories did not appear to vary much according to format or discipline. This group also comprised categories which had a dual focus, contributing at the same time to the subject content and to the pedagogical activities on the page or screen. The main purpose of the use of text blocks in this group of categories was to introduce the reader/user to problems (TX16), to multiple choice questions and answers (TX15) or to ask questions on the main text (TX17). The biology textbook did not use these categories at all. In this text the main focus was on presenting subject matter. Given that the overall purpose of the corpus texts is instructional, it is surprising that there was not more use of the verbal component to set up pedagogical activities. This is certainly a general feature of science textbooks at university, which have an overriding concern to cover as much content as possible, while the ‘real’ pedagogical activity may be said to occur in the laboratory or tutorial classes.

Textually-oriented categories

Table 5.8 presents the results for the categories in this group, showing the total percentage contribution of these categories for each text and how the proportions of each category are distributed.

Table 5.8

Proportions of Textually-oriented Text Block Categories across Texts

	Textual categories %	TX3	TX4	TX8	TX9	TX11	TX12
Txtbk Biology	24	0.23	0	0.01	0	0	0
Txtbk Physics	37	0.34	0	0.03	0	0	0
CD Biology	81.2	0.08	0.04	0	0.002	0.03	0.66
CD Physics	86	0.17	0.27	0	0.06	0	0.36
Web Biology	83.4	0.19	0.21	0	0.004	0.02	0.41
Web Chemistry	73.5	0.18	0.09	0	0.09	0.005	0.37

*Note.*TX3=sub/heading, TX4=button label, TX8=chapter contents/summary, TX9=footer, TX11=text hyperlink, TX12=heading hyperlink

As Table 5.8 shows, there are marked differences in this group of categories according to format. In the screen texts this group contributed a significant proportion to the verbal component, while in the textbooks the experientially-oriented categories contributed the greatest proportion.

The designer’s task of dividing up the given space on the page or screen between text and image, and structuring the information clearly for the student is a challenge. Layout of the page and screen can be observed through the choice of headings and sub-headings. This aspect differed quite markedly in the printed and screen texts, not only in terms of typographical features such as font and font size, but also in purpose and in the use of hypertext and colour. Headings and sub-headings (TX3) and headings as hyperlink (TX12) functioned to structure the content on the page and screen both intratextually, within the boundaries of the page or screen and intertextually, linking the student to content beyond the page or active screen. While the headings in the textbooks were category TX3, which are mostly used intratextually, guiding the reader through the experiential content within the chapter, on the screen, the headings were both categories. However, compared to the textbooks, smaller proportions of headings and sub-headings were used in the screen texts to structure the disciplinary content on the active screen. The headings in these texts were predominantly heading hyperlinks (TX12) of different kinds, with high proportions occurring on the biology CD-ROM, where they formed 66% of the total text blocks, and 41% on the biology website. This type of heading had a navigation role rather than one which organised the disciplinary content. It was used to link the student to different learning activities elsewhere on the CD-ROM or website, to information on related websites or webpages, or to more commercially-oriented information on the publisher's website. The heading hyperlink thus serves to frame and contextualise the screen activities for the student on the CD-ROMs and the websites and assists in navigation. The other category which performed an important navigation role on the biology website and the physics CD-ROM was the button hyperlink (TX4). This category is similar in function to the button hyperlink (1fhl) and the button (1f) in the visual analysis but contains written text on the button, such as ‘back’ ‘forward’. The results of all navigating categories in the visual and verbal content showed that some screen texts preferred the visual mode for the navigating buttons while others preferred the verbal mode.

5.3.2 Font and font size

These features were analysed to establish their co-patterning with text block categories and colour and how they contributed to overall design. The results of either a serif (S) or sans serif (SS) font and the font size of each text block are presented in Tables B3.2.3 and B3.2.4 and Figure B3.2.2 and B3.2.3 in Appendix B. Five values of font size were analysed: 1 = very small; 2 = small; 3 = standard; 4 = large; 5 = extra large.

From a graphic or web design perspective, the choice of font size and type would be expected to vary consistently according to the function of the text block. Design consistency in these variables occurred in all texts but there was more variation in font size in the textbooks. The font size of headings and sub-headings on the biology textbook page, varied from the size 5, in the chapter title to 2 in the chapter header, reflecting the hierarchy in the organisation of content. Most of the headings were size 4 and font type indicated whether they were second or third order headings. Colour was also used to distinguish headings from main text. Size 2 was used consistently for captions and size 1 for labels in both textbooks. The screen texts tended to prefer a sans serif font to a serif for most text blocks, possibly because a sans serif font such as Arial, Verdana or Helvetica is easier to read on the screen. Apart from the chemistry website, the screen texts also tended to select size 3 for headings, the same size as for the main text and mainly varied between sizes 3 and 2.

5.4 Interactivity and animation content analysis

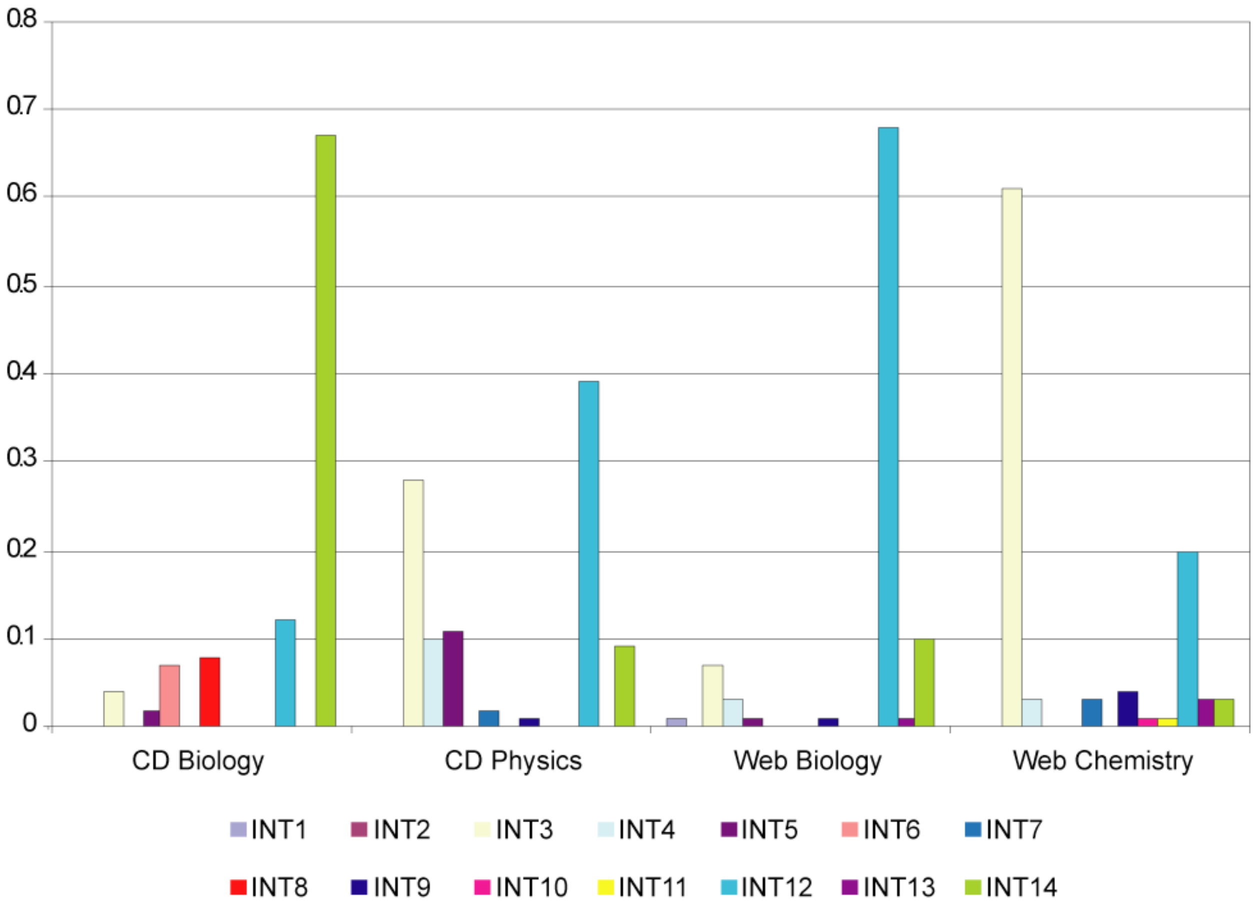
This section discusses the results of the multimodal content analysis for patterns of interactivity and animation found in the screen texts. In 4.3.3, p. 93, interactivity was defined as an instance in which the user/student could be directed from the screen to carry out some activity related to the content on the screen. Interactivity and animation were analysed for a number of features:

- the range of categories per text
- proportions of each category per text
- categories of animation

Tables and graphs presenting the results of these analyses can be found in Appendix B.

5.4.1 Interactivity

Table B3.3.2 and Figure B3.3in Appendix B show the number of instances of each category, calculated as a proportion of the total number of categories of interactivity per text. To frame the following discussion, Figure 5.8 presents the results for the 14 categories of interactivity per text. For reference, the category descriptors and codes are reproduced in the key.



Key to categories of interactivity and codes

INT 1	Click and drag/drop
INT 2	Click image & enlarge
INT 3	Click icon/button to return to top, go forward/back/close window/et help/quit
INT 4	Click button/image hyperlink to start animation/activity
INT 5	Click correct answer (MCQ), solution
INT 6	Click, select from pull-down menu to change activity/give answer
INT 7	Enter/activate numbers, values, symbols to balance equation, to change parameters to graph
INT 8	Click hyperlink to go to glossary/explanation
INT 9	Click to check answer or explanation/hint
INT 10	Fill in form
INT 11	Click to send (to website)
INT 12	Click hyperlink to change to different activity
INT 13	Type in answer, comments
INT 14	Click hyperlink to go to intranet/internet

Figure 5.8. Proportions of interactivity categories per text.

There was not much difference between the CD-ROM and web texts in the range of interactivity types found. The largest range, 10 of 14 types, was found in the biology CD-ROM, followed by the chemistry website with 9 types, the physics CD-ROM and the biology website with 8 types each. Four of the categories related to navigational aspects, eight to the subject content and the pedagogical activity and two to peripheral aspects such as filling in forms and sending quiz results or feedback to another website. The three most frequently occurring categories, INT 3, INT 12, INT 14, were found in varying proportions in all texts, ranging from 94% on the biology website to 76% on the physics CD-ROM. These three categories play an important navigation role, interacting with the visual and verbal modes to guide students through the current activity, to direct them to another activity on the same website or CD-ROM or to link them to another website either on the intranet or the Internet.

To show the important contribution of different modes to navigation in the screen texts, the proportions of these three interactivity categories were compared with two other navigation categories in the verbal analysis - button hyperlink with text (TX4), and heading hyperlink with text (TX12) and the button hyperlink (1fhl) in the visual analysis (Table 5.9). Values are given as a proportion of the total instances of the six categories for each text.

Table 5.9

Proportion of the Six Navigation Categories in Visual, Verbal and Interactivity Analysis

	Visual	Verbal	Interactivity	Total
CD Biology	0	0.36	0.37	0.73
CD Physics	0.08	0.30	0.28	0.66
Web Biology	0.02	0.35	0.31	0.68
Web Chemistry	0.28	0.18	0.21	0.67

Table 5.9 shows that a considerably high proportion of the visual, verbal and interactivity content is taken up by categories contributing to navigation. Some texts clearly preferred one mode over the other. The biology CD-ROM used the verbal and interactivity categories but not the visual while the chemistry website preferred the visual more than the verbal for navigation.

Despite this however, as was found in the discussion of the visual and verbal content analysis, some of the categories of interactivity do relate to the subject content and to the pedagogical activity ‘going on’ on the screen, rather than the navigation aspects discussed above. Eight of the fourteen types fell into this group, although their proportions were relatively small. INT 1, INT2, INT5, INT6, INT7, INT8, INT9, INT13 (see Figure 5.8, p.121 for descriptors) all engage the student in the experiential content on the screen, directing him/her to perform some action related to that content. All these categories differ in the type and complexity of action needed and in whether the student needs to interact with the visual or verbal mode, as the following examples illustrate.

An example of a simple type of interaction is INT 1, which only occurs on the biology website in the Self-Assessment Module on microbes. Here the student interacts with the verbal mode and is directed to click on a word in the Phrase Bank and drag and drop it into the correct space in the sentences above. This action is illustrated in the screenshot in Figure 5.9.

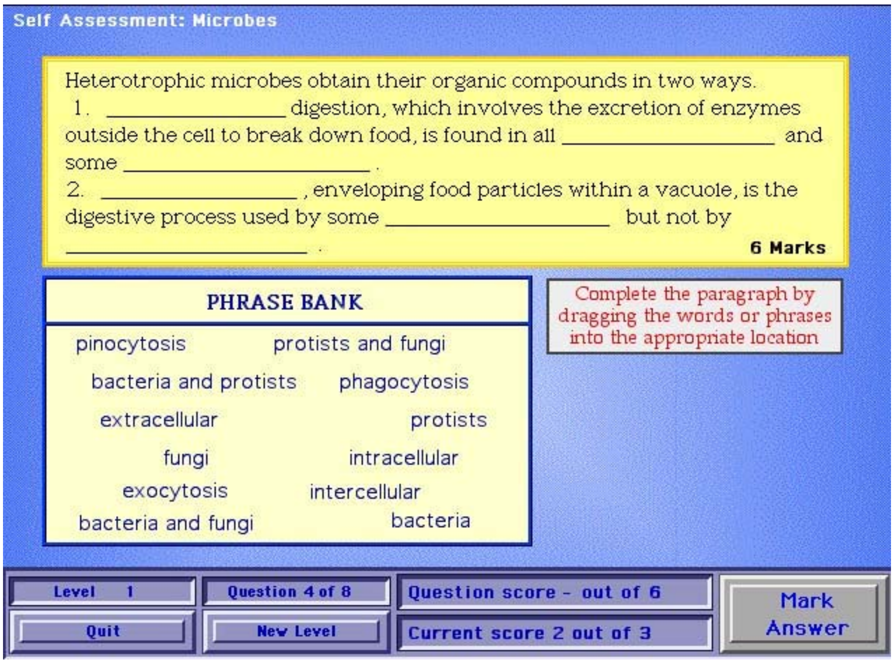


Figure 5.9. Screenshot of a Self Assessment Module on the biology website showing an example of a simple interactivity category (INT1).

A more complex type of interactivity is INT 7. This engages the student in an action which involves both visual and verbal modes as well as mathematical symbolism. This category does not appear in the biology screen texts but occurs on the physics CD-ROM and the chemistry website in similar proportions (2% and 3% respectively). The screenshot from the chemistry website in Figure 5.10 shows a complex interaction of visual and verbal modes and interactivity. In order to calculate the equilibrium conditions for a certain chemical reaction, the student has to follow the on-screen written instructions to use the Equilibrium Simulator in the bottom panel. By moving the sliders to adjust the values in the small panels above the sliders, the student can observe the effect of this action on K_p (the equilibrium constant), before clicking the coloured button labelled ‘equilibrate’ which brings the system to equilibrium. These actions can be repeated a number of times at the student’s leisure before moving on to the next screen or elsewhere in the module.

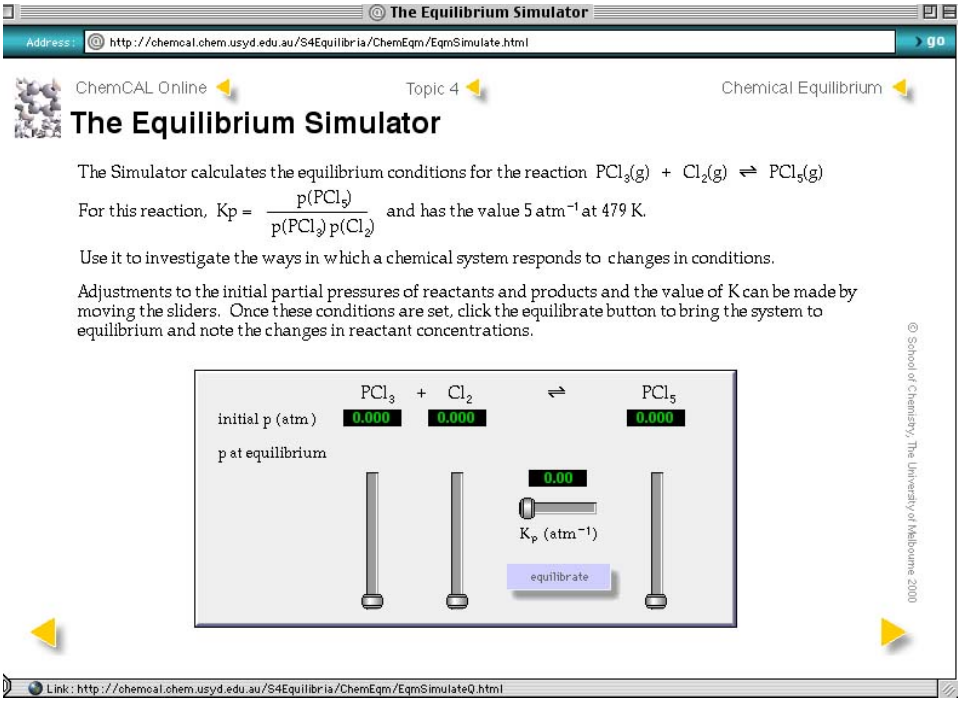


Figure 5.10. Screenshot of more complex type of interactivity (INT7) on the chemistry website.

In summary, the 14 types of interactivity hyperlinks identified in the Stage 1 corpus can be seen from both an intermodal and functional perspective. Most hyperlinks were related to navigation rather than to the learning activity. In either case the interactivity categories co-occurred with the visual and verbal mode. All texts selected hyperlinks in either mode and no pattern could be found according to format or discipline.

5.4.2 Animations

Although animation did not form a significant proportion of the total content, this content area was analysed for its contribution to other modes. Animation co-occurred with visual and verbal modes and with interactivity. The two types of animations identified in this corpus, the animated drawing or graph

(A1) and the animated text, numbers or values (A2) were found in varying proportions in the screen texts, as Table 5.10 shows (see also Table B3.3.1 and Figure B3.4 in Appendix B).

Table 5.10

Proportions of Animation Types found in Screen Texts

Text	No of screens analysed	A1	A2
CD Biology	37	0.16	0
CD Physics	50	0.36	0.18
Web Biology	50	0.14	0
Web Chemistry	19	0.16	0.11

The biology texts used one type of animation, the animated drawing (A1) and the chemistry website and the physics CD-ROM used both types. In each case they added another dimension to the subject content and the interactivity. For example, in the screenshot in Figure 5.11 from the physics CD-ROM, the verbal text instructs the student to start the animation by clicking a button labelled ‘transverse on a string’ in the grey block on the left of the screen.

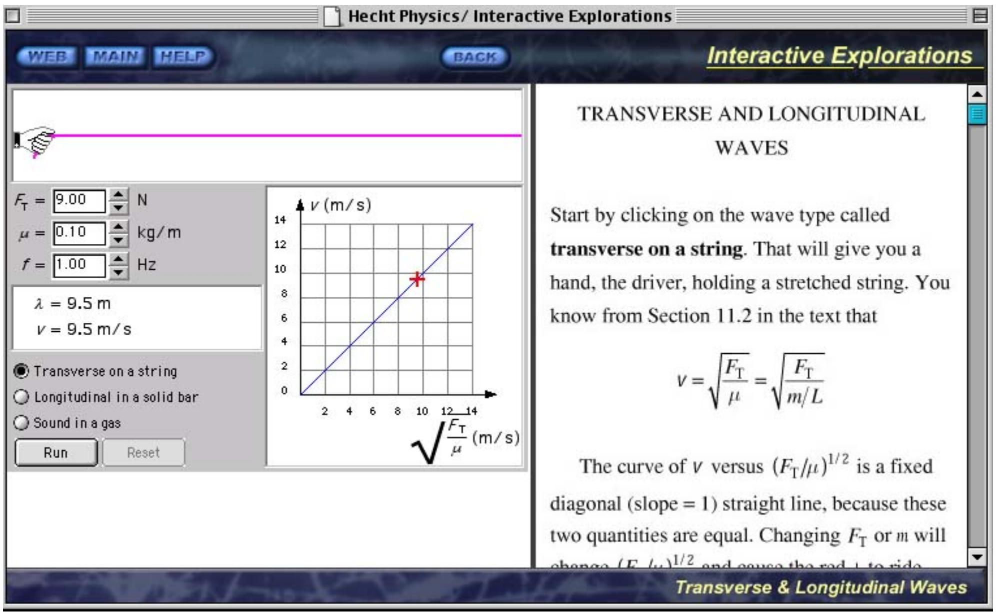


Figure 5.11. Screenshot from Physics CD-ROM showing animation before student activates it (Hecht, 2000).

After the student has clicked on the button, the hand moves the string up and down to illustrate a transverse wave, as shown by the curved string in the screenshot in Figure 5.12.

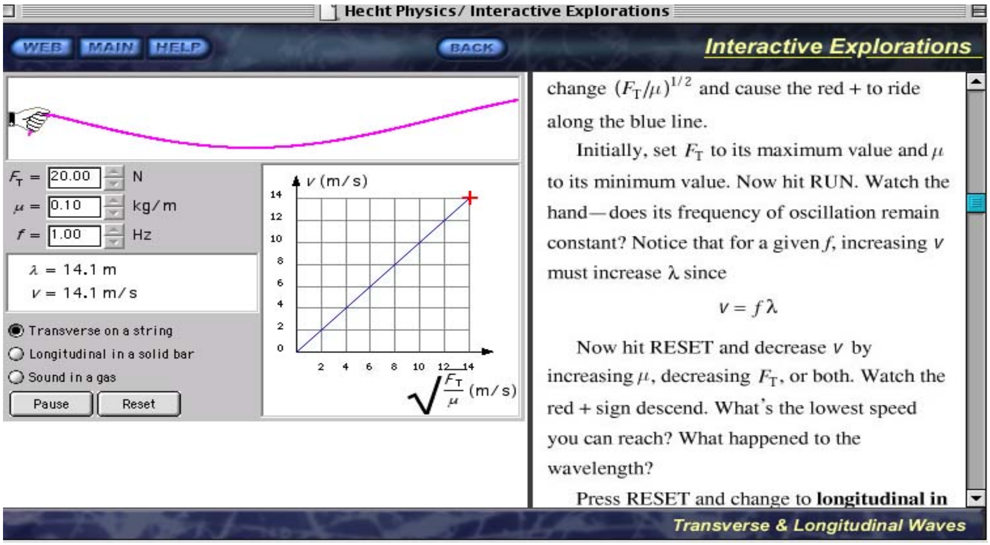


Figure 5.12. Screenshot from Physics CD-ROM showing animation after student activates it (Hecht, 2000).

The animation co-occurs with other actions the student has to perform, thereby interacting simultaneously with the visual display, the verbal text and mathematical symbolism. Finer analysis in Stage 2 will show more precisely how these modes interact and expand the meaning potential.

5.5 Concluding comments

This chapter has presented the results of the multimodal content analysis, largely from a metafunctional perspective and discussed the key points arising from the results. It has been claimed that the textbook is being influenced by the logic of the screen (Kress, 2003, pp. 7-8) and that compared with forty years ago the functional load of textbooks is now carried by the image. The above discussion of the results of Stage 1 of this study presents evidence which challenges this claim in part. In terms of experiential content, the visual density was higher in the textbooks and a higher proportion of visuals contributed to the subject matter than in the screen texts. Moreover, many of the visuals in the textbooks were highly salient, displaying a complexity and intricacy which has been achieved by employing advanced technologies in their production. The high proportion of non-content oriented visuals in the screen texts means that the visual mode was used more for navigation than for teaching content, thereby foregrounding the textual metafunction. Compounding this finding was that the majority of the work being done by the interactivity was related to the navigational function rather than to the pedagogical activity or to the subject content. Finally, the location of visuals was more variable on the page than on the screen and both are clearly influenced by the design grid underlying the page and screen format of these texts.

Text blocks were generally allocated more space than visuals on the screen and there was more variation in the range of types of text blocks than in the range of visuals. Interestingly, there was clear disciplinary variation in the types of images consistent in both page and screen texts but this was not the case with the verbal content. Variation in text block categories tended to relate more to format than to discipline. This could be explained by design constraints since each format should be designed to best use the affordances of page and screen. What is perhaps surprising is that page and screen are not more differentiated in types of text block. Most of the categories which occur in the printed texts could have been used in the screen texts. Overall, the main concern with the verbal content in the screen texts was to orient the user to the organisation of the content while the textbooks were more concerned with the presentation of the topic.

The multimodal content analysis has yielded some solid empirical data on the distribution of text, image and interactivity and their variation according to format and discipline. On the basis of these data it was observed how discipline and format can determine visual and verbal content. While acknowledging the limitations of content analysis discussed in 4.3.5, p. 96, the approach adopted in this research can be justified on a number of grounds. It has provided an entrée to the multimodal corpus, which has served the dual purpose of becoming well acquainted with the corpus while managing the daunting task of analysis. It has given a comprehensive account of the multimodal content of the texts which has moved beyond the impressionistic. Finally, as will be shown in the next chapter, it provides a set of principles on which to make an informed selection of texts for the in–depth multimodal discourse analysis of Stage 2.

CHAPTER 6

STAGE 2 METHODOLOGY: MULTIMODAL DISCOURSE ANALYSIS

General theoretical principles of a social semiotic theory of multimodality have been outlined in Chapter 3. This section will first describe the principles of selection for the Stage 2 corpus, the analytical framework for multimodality and intersemiosis and the methods of analysis.

6.0 Principles of selection for the texts in Stage 2

The selection of the texts for Stage 2 was based on principles emerging from the Stage 1 analysis. The Stage 2 texts represented:

- the page format and the two different formats of the screen texts (CD-ROM and website)
- the full range of the 10 multimodal content areas described in Stage 1
- the full range of the 92 categories of content described in Stage 1
- the full range of pedagogical tasks i.e. those which were testing disciplinary content and presenting disciplinary content
- the three disciplines, biology, physics and chemistry
- the contemporary teaching and learning context of first-year university science.

The principles were therefore the typicality, validity, relevance and currency of the texts. First, they were typical of the range of texts from the initial survey in Stage 1. They were valid in that they represented the full range of multimodal content areas, multimodal categories, disciplines and formats found in the Stage 1 corpus. Second, the texts were relevant to my professional context at the University of Sydney, to the course of study of current students and to the current pedagogical context.

6.1 The Stage 2 corpus

Table 6.1 shows the texts analysed for Stage 2. Because of the number of analyses undertaken and their level of delicacy, the Stage 2 corpus was smaller than that for Stage 1. Although the table shows the number of clauses analysed, i.e. the verbal component, analysis was also done of the interaction of the verbal component with elements from other semiotic resources, as will become evident in the discussion of the methods of analysis.

Table 6.1

Summary of Pages, Screens and Clauses Analysed for Stage 2: Multimodal Discourse Analysis

Text	No. pages	No. clauses	No. screens
Biology (Knox, 2001) Chapter 36: Fungi	4	94	N/A
Biology (Campbell 2002) Textbook CD-ROM) Chapter 31: Fungi Activities 31 A and 31 B		134	14 activity screens + 25 glossary screens
Biology Web-based materials for 1001: USyd Concepts in Biology (Microbiological Concepts)		215	19
Physics Calculus (Hecht, 2000) Textbook CD-ROM) Chapter 11 Interactive Exploration: Transverse and Longitudinal Waves Walk-through 11.1		56 54	9 activity screens 8
University Physics (Young and Freedman, 2004) Chapter 15 Mechanical Waves	5	168	N/A
Chemistry University of Sydney Chemistry 1001 ChemCAL module on Equilibrium		166	20
Total pages/clauses/screens	**9**	**887**	**95**

The proportion of the total number of clauses analysed corresponded roughly to how many formats were analysed per discipline. In biology all three formats (textbook, CD-ROM and website) were analysed (50% of the clauses), in physics there were two formats (textbook and CD-ROM - 31%) and in chemistry, one format (the website – 19%). As explained in 4.2.3, the chemistry website was included as a comparison to the biology website, as there were no interactive learning modules on the University of Sydney physics website. A chemistry CD-ROM was not included in the corpus, because there was no CD-ROM recommended for the course, as students used the online interactive modules instead. In addition, a chemistry CD-ROM and textbook were not included in the corpus because of the need to limit the corpus to a manageable size.

6.2 Introduction to Stage 2 methodology

As discussed in 3.5, the current challenge in multimodal analysis is to take the multimodal totality into consideration and to search for common semiotic principles across modes. Adopting the metafunctional organisation of meaning as a unifying and abstracting principle of analysis means that each modality is not analysed separately or independently of the others. Such an approach attempts to understand the various complementarities and hierarchies of multimodality on a macro scale through an exploration of the expansion and contraction of the meaning potential. Such an approach will also be concerned to describe combinatorial principles and mechanisms and the co-patterning of interacting systems. Drawing on the work of Lemke (1998b), O'Halloran (2005), Thibault (2000) and others, the approach adopted in this thesis, is to take as a starting point the concept of multimodality as a macro-system of meaning potential and describe principles of intersemiosis from a metafunctional perspective. Because the corpus consists of learning resources in science, a particular focus in this study will be how abstraction and technicality are realised intersemiotically.

6.2.1 The conceptual and analytical framework

The rationale for the metafunctionally based, multisemiotic approach to analysis has been established in Chapter 3. Of concern at this point is a theoretical framework for analysis which has as its integrating principle the metafunctional organisation of meanings in a stratified model of semiosis. The analytical and conceptual framework adopted in this thesis is based firstly on that of O'Halloran (2005) for intersemiosis across language, mathematical symbolism and visual display in mathematical discourse. O’Halloran’s (2005) metafunctionally-based framework is organised according to the discourse, grammar and display strata for experiential, logical, interpersonal and textual meaning. Given the nature of the corpus under discussion here, the adoption of a framework which has been developed to describe intersemiosis in a science discipline such as mathematics seems appropriate, since the physics and chemistry components of the corpus contain mathematical discourse. It is also an opportunity to test the theoretical framework in other contexts and disciplines such as biology. Secondly, the analytical and conceptual framework attempts to extend Martin’s (1992) discourse semantic systems of ideation, negotiation and identification in relation to intersemiosis.

In setting up her framework, O'Halloran (2005, pp. 166-7) identifies four major aspects which need to be considered:

a) the mechanisms through which intersemiosis occur. These mechanisms account for meaning arising ‘through choices from systems functioning as interlocking networks’, such as the mechanism of semiotic cohesion, where elements of the text cohere across semiotic resources.

b) the description of the metafunctionally-based intersemiotic systems in a stratified model.

c) the semantics of intersemiosis in terms of co-contextualising and re-contextualising relations.

d) the metaphorical expansions which take place through semiotic metaphor. Semiotic metaphor on the grammar stratum is concerned with the transitions which occur either through shifts in the functional status of transitivity relations across semiotic resources or through the introduction of new processes, participants or circumstances (O'Halloran, 2005, p. 179). The extent to which the aspects and mechanisms of intersemiosis can be found to apply to the thesis corpus will be explored through the discussion of results in Chapter 7.

6.3 Preliminary analyses

Preliminary SF analysis was undertaken as a basis for building an understanding of the texts and as a pathway into the analysis proper and into the more unfamiliar territory of multimodal discourse analysis. The preliminary analysis used the *Systemics* 1.0 coder (O'Halloran & Judd, 2002), which has the major systems for experiential, interpersonal and textual meaning at the rank of word, word group, clause, clause complex, paragraph and text from Halliday's *Introduction to Functional Grammar* (1994) and Martin's *English Text* (1992) pre-programmed into the software. This enabled me to conduct analyses for Transitivity/Ergativity, Mood, Speech Function and Theme on a selection of the texts to establish to what extent they displayed some of the features of scientific discourse outlined in Chapter 3.

6.4 Analysis of technicality, grammatical metaphor and lexical density

As a precursor to the analysis of visual abstraction and technicality, each text was then analysed for technicality, grammatical metaphor and lexical density. Martin (1986, pp. 20-22) has identified grammatical resources which contribute to technicality, which have to do with the semantics of elaboration and taxonomic relations among participants. Based on this, and following Jones (1989, 1991), a table of categories of technicality was set up and a measure obtained for each text by dividing the number of instances of these categories by the number of ranking clauses. The measure included grammatical resources and field-specific technical terms. The table of categories for technicality and the codes used for each category are presented in Table 6.2, along with examples taken from the texts for each category. Examples are shown in blue, with the category underlined where appropriate, and the source of the example and clause number are in bold.

Table 6.2

Table of Categories for Technicality with Examples from Corpus

Category	**Lexicogrammatical resource and example**
1	**ELABORATION**
1A	*paratactic nominal group complex (apposition) 1 = 2*
	Bio txtbk: 50 The ascomycetes and basidiomycetes evolved regular septa in their mycelium and a dikaryotic (cells with two nuclei, p. 943) phase.
1B	*identifying relational clause (Token/Value)*
	Bio txtbk: 66 A mass of branched and apparently tangled hyphae is a mycelium.
1C	*embedded clause (defining relative clause)*
	Chem web: 46 that systems adjust in a direction that tends to reduce the change in conditions.
1D	*elaborating clause complex (non-defining clause complex)* $\alpha = \beta$
	Bio txtbk: 32-33 They may be saprophytes, which play a crucial role in litter decomposition and nutrient recycling,
1E	*elaborating clause complex (text reference) 1 = 2*
	Bio web: 79-83 Microbes must be at or close to the surface of a body of water//to photosynthesise.//This is//so that they can gain adequate radiation // to trigger photosynthesis.

1F	*internal conjunction - implicit or explicit - i.e. or e.g.*
	Phys txtbk: 79-80 Second, the medium itself does not travel through space; its individual particles undergo back-and-forth or up-and-down motions around their equilibrium positions.
2	**POSSESSION**
2A	*attributive relational process of possession or circumstance: e.g. 'X has a Y' or 'X includes Y'*
	Chem web: 129 The reaction in Equation 16 has an equilibrium constant of 5.0 atm^{-1} at 600°C.
3	**PROJECTION**
3A	*projecting verbal process*
	Chem web: 65 Le Chatelier's Principle predicts
	TAXONOMIES - NOMINAL GROUP STRUCTURE
ET	*Epithet ^ Thing*
	Bio txtbk: 90 only to separate spores, sexual reproductive structures or old hyphae from the actively growing mycelium.
CT	*Classifier ^ Thing*
	Phys CD-ROM: 92 The speed of a transverse wave on a string varies ...
PT	*Pre-Thing*
	Bio txtbk: 65 this type of tip growth,
PDT	*Possessive-Deictic Thing*
	Chem web: 65 Le Chatelier's Principle predicts
TT	*Technical term*
	Phys txtbk: 105 periodic waves with simple harmonic motion are particularly easy to analyze;

A total of 887 clauses were analysed for instances of technicality. Many clauses contained multiple instances. The analysis and results are summarised in for each text (see Appendix D, Tables D1.1.1 to D1.6.2).

Grammatical metaphor analysis was carried out in a similar way with a table of categories of metaphor set up to track these through the texts. The table of categories extends those proposed by Jones (1989) and Ravelli (1985/1999) and is set out in Table 6.3. Each section of the table is illustrated by examples for each category in red from the texts. The full analysis can be found in Appendix D, Tables D2.1.1 to D2.6.2).

Table 6.3

Table of Categories of Grammatical Metaphor with Examples from Corpus

Cat No	Semantic Choice	Metaphorical Realisation Function/Class and example	Congruent Realisation/Class
1a	*material process*	*Thing/nominal gp*	verbal gp
	Chem web: 1	Many chemical **reactions** apparently 'stop' well before **completion.**	
1b	*mental process*	*Thing/nominal gp*	*verbal gp*
	Bio web: 3	…apply the **concepts** to any practical situation.	
1c	*relational process*	*Thing/nominal gp*	*verbal gp*
	Bio web: 48	DNA **composition**	
1d	*verbal process*	*Thing/nominal gp*	*verbal gp*
	Bio CD-ROM: 11	there are **reports**	
1e	*behavioural process*	*Thing/nominal gp*	*verbal gp*
	Chem web: 3	this module describes the quantitative **behaviour**…	
2a	*material process*	*Epithet, Classifier/adjective*	*verbal gp*
	Chem web: 13	The reaction occurs quite quickly at **elevated** temperatures.	
2b	*mental process*	*Epithet, Classifier/adjective*	*verbal gp*
	Phys CD-ROM: 85	A wave travels at a **known** speed along a taut rope of specified length.	
2c	*relational process*	*Epithet, Classifier/adjective*	*verbal gp*
	Bio CD-ROM: 15	…**defining** feature of the Ascomycota division of fungi.	
2f	*existential process*	*Epithet, Classifier/adjective*	*verbal gp*
	Bio txtbk: 75	The vesicles and their contents fuse with the **existing** membrane	
2g	*material process*	*quality of a process/adverb*	*verbal gp*
	Bio CD-ROM: 4	A filament that **collectively** makes up the body of the fungus	
3a	*quality of a Thing*	*Thing/nominal gp*	*adjective*
	Phys txtbk: 31	called normal-mode **frequencies**	
3b	*quality of a process*	*Epithet, Classifier/adjective*	*adverb*
	Phys CD-ROM: 52	the **forward** thrust causes compressions	
3c	*quality of a process*	*Thing/nominal gp*	*adverb*
	Chem web: 94	that both the reaction and its **reverse** are occurring simultaneously	
3d	*quantity of a Thing*	*Thing/nominal gp*	*adverb*
	Bio CD-ROM: 20	..has reduced the **amount** of leaf litter	
4a	*modality*	*Epithet/adjective*	*adverb (modal)*
	Phys CD-ROM: 54	How would you create the longest **possible** wavelengths?	
4b	*modality, modulation*	*Thing/nominal gp*	*adjective, passive verb*
	Bio web: 118	thus the **need** to 'make the most' of their digestion leads to competition	
5a	*logical connection*	*Thing/nominal gp*	*conjunction*

	Bio txtbk: 65	As a **consequence** of this type of tip growth	
5b	*logical connection*	*Process/verbal gp*	*conjunction*
	Phys CD-ROM: 52	how the forward thrust **causes** compressions	
5c	*logical connection*	*circumstance/prep phrase*	*conjunction*
	Bio web:72	that an energy rich carbon compound is formed **as a result of** the process.	
6a	*circumstance*	*process/verbal gp*	*prep phrase*
	Bio txtbk: 57	They **contain** all the usual eukaryotic cell machinery except chloroplasts.	
6b	*circumstance*	*Epithet, Classifier/adjective*	*prep phrase*
	Bio CD-ROM: 33	The mushrooms that we find in the forest are the reproductive structures of large **underground** mycelia.	
6c	*circumstance*	*Thing/nominal gp*	*prep phrase*
	Bio CD-ROM: 16	they release digestive enzymes into their **surroundings.**	
7a	*participant (Thing)*	*Epithet/Classifier/adjective*	*nominal gp*
	Phys txtbk: 9	Ripples on a pond, musical sounds, seismic tremors triggered by an earthquake - all these are **wave** phenomena.	
7b	*participant (Thing)*	*Thing/nominal gp*	*nominal gp*
	Bio txtbk: 57	They contain all the usual eukaryotic cell **machinery** except chloroplasts.	
7c	*participant (Thing)*	*quality of a process/adverb*	*nominal gp*
	Bio web: 34	Hyphae extend **apically.**	
8a	*expansion*	*Act, def relative clause/embedded clause*	*ranking clause*
	Phys CD:2	(start)… by clicking on the wave **called transverse on a string.**	
8b	*expansion*	*Epithet/Classifier/adjective*	*ranking clause*
	Phys txtbk: 91	The tension in the string restores its **straight-line** shape	
8d	*expansion*	*Thing/nominal gp*	*ranking clause*
	Phys txtbk: 129	The speed of propagation equals the product of **wavelength** and frequency.	
9c	*process (phase)*	*quality of a process/adverb*	*verbal gp*
	Bio txtbk: 67	A mass of branched and **apparently** tangled hyphae is a mycelium.	

Following the analysis for each text, tables of the range and frequency of each category of grammatical metaphor were made (Appendix D). Summary tables and graphs of the range and frequency of categories of technicality and grammatical metaphor across all texts were then made. (Appendix D, Table D4.2, Figure D4.2 and Table D4.3 and Figure D4.3). Next, a measure for lexical density was calculated by counting the number of content words per ranking clause and dividing by the number of clauses in each text (Appendix D, Tables D3.1 to D3.6). The three measures were presented on a graph to examine the interrelationship of lexical density, technicality and grammatical metaphor as co-varying patterns (see Appendix D, Figure D4.1). The remaining sections of this chapter will present the methodological approach for the MDA. The analytical procedures will be outlined and examples of the analyses displayed. Issues pertaining to the analysis will also be highlighted and then taken up again in the discussion of results in Chapter 7.

6.5 Summary of analyses for intersemiosis and multimodality

This section outlines the analyses of intersemiosis and multimodality, as they relate to the research questions. Analyses carried out are summarised in Table 6.4, arranged according to metafunction and register variable, texts analysed and location of analyses in the Appendices. Also shown are the research questions relating to each metafunctional area of analysis.

Table 6.4

Summary of Analyses for Intersemiosis and Multimodality

Analysis	**Texts analysed**	**Location of Analysis**
Ideational Metafunction/Field ***Research questions*** *1. How is content knowledge represented in conventional page format and on the computer screen through different modes and forms of semiosis?* *2. How do images and language work together to construct technicality?*		
• Visual and verbal technicality	All texts	Appendix D
Intersemiotic and multimodal ideation: • activity sequences across text and image and animation	Bio/phys textbooks Bio CD-ROM	Appendix E

• experiential cohesive relations across text and image • logico-semantic relations in activity sequences across text and image on screen • logico-semantic relations in text and image complexes	Bio/phys textbooks Bio CD-ROM Bio CD-ROM Bio/phys textbooks	Appendix E Appendix E Appendix E
Interpersonal Metafunction/Tenor ***Research questions*** *3. How are pedagogical roles such as reader/viewer/learner and writer/teacher/designer/knower constructed in the multimodal learning environment of the page and screen?* *4. How does the notion of interactivity compare in page and screen formats?* *5. How is the notion of scientific realism constructed across text and image?*		
• interactivity and negotiation (exchange structure) across text and image on screen • scientific realism - mood in text and its relationship to modality in image	Bio CD-ROM Phys CD-ROM Bio textbook	Appendix E Chapter 7 7.5.3
Textual Metafunction/Mode ***Research questions*** *6. How do layout and organisational structure contribute to meaning on the page and screen?* *7. How do images and language work together to construe abstraction on the page and screen?*		
• Visual and verbal abstraction • Intersemiotic identification across text and image • Location of text and image on the page	All texts Bio/phys textbooks Bio/phys textbooks	Appendix D Appendix E Appendix C

6.6 Ideational metafunction

Intersemiosis of the ideational domain of meaning concerns the content and the field of discourse and how this is construed across semiotic resources. In this section the analyses for intersemiotic ideation (O'Halloran, 2005, p. 168) will be presented in the order shown in Table 6.4.

6.6.1 *Visual and verbal technicality*

In constructing the technicality of a discipline, language alone is not the only meaning system involved. The concept of technicality also includes an understanding of how multimodal meaning resources, such as image, typography and animation contribute to technical meaning. A microscopic image of a spore in a textbook or animated on the screen is read or viewed in conjunction with a definition or explanation in the text. A technical term may be highlighted in a text through typographical resources such as colour, bold face or italics. On screen, the technical term may be hyperlinked to a glossary which defines and explains the term or to a databank of images.

To extend the analyses of technicality of the verbal component, the relationship between visual and verbal technicality was analysed to determine if there were any patterns of co-variation. First, in order to track the relationship between verbal and visual technicality, the number of instances of the six categories contributing to technicality and field-specific meaning – photos (1a), micrographs (1b), drawings (1c), tables (1d), equations (1e) and graphs (1g) - was counted. This was calculated as a proportion of the total number of visuals relating to the text. This proportion was then compared with the measure of technicality for the verbal text. For example, in the biology website text, the total number of visuals found was 54. Only 15 of these (0.28) fell into the six technical visual categories. The measure for verbal technicality of the same text was 2.02. This measure included instances of grammatical resources used to create technicality (as outlined in Table 6.2, p. 135) and lexical items which were technical terms calculated as a proportion of the total number of clauses for the text. These two measures were then summarised in a table and plotted on a graph to compare visual and verbal technicality across formats and discipline.

Calculations were done for each text and the results displayed on a graph (Appendix D, Table D4.4, Figure D4.4 – see also Figure 7.4 in Chapter 7.).

6.6.2 Intersemiosis and multimodality in activity sequences

Intersemiotic ideation at the discourse stratum (O'Halloran, 2005, p. 168, pp. 174-175) involves expectancy relations between activities in activity sequences (see also Martin 1992, pp. 321-4 and Wignell et al. 1993, pp. 156-159), which involve more than one semiotic resource. For example, in the physics textbook (Young & Freedman, 2004, p. 550), the activity sequence in the verbal component of the main text, reproduced below in Figure 6.1, depends for its interpretation on the activity sequence in the graph in Figure 15.3 of the textbook, which contains mathematical symbolism. The activity sequence is thus depicted visually and verbally, thereby integrating linguistic, mathematical symbolism and visual resources.

Extract from main text

Figure 15.3 shows the shape of a part of the string near the left end at time intervals of 1/8 of a period, for a total time of one period.

Activity sequence in main text

1. The wave shape advances steadily toward the right,
2. as indicated by the short red arrow pointing to a particular wave crest.
3. As the wave moves,
4. any point on the string (the blue dot, for example) oscillates up and down about its equilibrium position with simple harmonic motion.

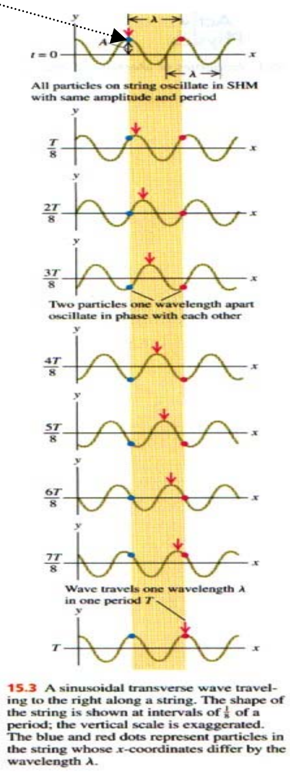


Figure 6.1. Example of activity sequence in the physics textbook integrating verbal text, mathematical symbolism and visual display (Young & Freedman, 2004, pp. 549-550).

Activity sequences spanning text and still image and animated image were analysed in the biology and physics textbooks and biology CD-ROM. Analyses can be found in Appendix E, Table E1.1. As shown in Figure 6.1, in the verbal text each activity sequence was bracketed as a numbered sequence of clauses. The verbal activity sequence was connected with lines to its corresponding visual activity sequence.

6.6.3 Intersemiotic experiential cohesive relations

Intersemiotic cohesive relations may occur across labels, captions, images and main text, establishing ties between linguistic elements and their visual representations, as in the following example for ‘string’ from the physics textbook shown in Figure 6.2.

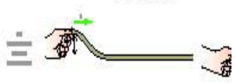
Image : Fig 15.1(a)	**Image label**	**Image caption**	**Main text**
	(a) transverse waves on a string	15.1 (a) The hand moves the string up and then returns producing a transverse wave.	In Fig 15.1a the medium is a string or rope under tension.

Figure 6.2. Example of intersemiotic cohesive relations in image, label, caption and main text from (Young & Freedman, 2004, p. 548).

Captions and labels may also use more than one semiotic resource. For example, the caption and labels for Figure 15.3 in the physics textbook, reproduced in Figure 6.1 use linguistic and mathematical symbolism.

Intersemiotic experiential cohesive relations were analysed for the textbooks and the biology CD-ROM. This involved analysis of the composition and classification taxonomic relations occurring both in the activity sequences and in the remaining visual and verbal text. Analyses were displayed in Excel tables with columns set up for the image element (both still and animated for the biology CD-ROM), the image label, the image caption and the main text lexical item identified by its clause number. Each relationship was analysed according to the relations of intersemiotic hyponymy, intersemiotic meronymy and intersemiotic correspondence. Lines were drawn connecting the related elements and the relationship marked in bold, as shown in the analysis extract in Figure 6.3. Full analyses can be found in Appendix E, Tables E2.1 to E2.3.

Still image shows	Animated image shows	Main text: Screen 2
Image of forest floor	Long branching hyphae	The spores that land on a moist
	corr	**corr**
with 2 spores on ground	growing from 2 spores on the ground	substrate grow into long branching hyphae

Figure 6.3. Extract from the intersemiotic experiential cohesion analysis of screen 2 of the biology CD-ROM, showing relations of correspondence between main text, animated image and still image.

Correspondence was preferred as a term to synonymy or repetition to more accurately describe the relationship between a visual and verbal element as the meaning constructed in the visual semiotic does not ‘repeat’ meaning in language, although there is a correspondence. An image of a hand moving a rope up and down, for example, corresponds very closely to the words: ‘the hand moves the string up and then returns’. However, as Lemke (1998b, p. 110) argues, semiotic resources are ‘essentially incommensurable: no verbal text can construct the same meaning as a picture, no mathematical graph carries the same meaning as an equation...’ – it is their ‘joint co-deployment’ that creates the tie.

Finally, on the display stratum, juxtaposition, font and colour realise intersemiotic experiential meaning through the use of space and position in the spatial relations among images, labels, captions and main text, the use of small italics for symbols or bold type for technical terms and the use of colour to represent particles in the physics diagrams as blue and red dots. These aspects will be highlighted in the discussion of the examples in Chapter 7.

6.6.4 Logico-semantic relations across text and image in the textbooks

To complement the analyses of experiential meaning, intersemiotic logical meaning was explored through analysis of logico-semantic relations across image and text and inter-image for some activity sequences in the biology and physics textbooks and for the biology CD-ROM. Analyses can be found in Appendix E, Tables E3.1 and E3.2. Following Martin (1992 p. 323), in activity sequences expectancy relations – *and/then* where activity a) is *probably* followed by activity b), are distinguished from implicational ones – *if/then* where activity a) is *necessarily* followed by activity b). The latter is typically found in science in explanations of physical and biological phenomena (see also Unsworth, 1999; Wignell et al., 1993). Intersemiotic logico-semantic-relations and interdependency at the grammar stratum function to link text and image through relations of elaboration or extension. In elaborating relations, for example, some part of the main text, caption or label may expand an aspect of an image or vice versa by restating or representing the same thing in a different semiotic resource, specifying an aspect in greater detail, refining it or making something more specific. For example, in Figure 15.1a from the physics textbook, shown in Figure 6.4, the main text elaborates the image implication sequence of a transverse wave on a string over six consecutive clauses (clauses 1-6). All parts of the image are explained in the main text and a ‘reduced’ version of the implication sequence is also found in the caption.

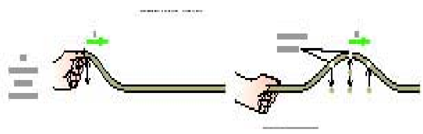
Figure 15.1a	Caption	Main Text clauses
	Transverse waves on a string. …. (a) The hand moves the string up and then returns, producing a transverse wave.	1. In Fig 15.1a the medium is a string or rope under tension. 2. If we give the left end a small upward shake or wiggle 3. the wiggle travels along the length of the string. 4. Successive sections of string go through the same motion that we gave to the end, but at successively later times. 5. Because the displacements of the medium are perpendicular or transverse to the direction of travel of the wave along the medium, 6. this is called a transverse wave.

Figure 6.4. Example of an intersemiotic implication sequence (O'Halloran, 2005, p. 170, p. 176) showing elaboration across image, caption and main text from the physics textbook (Young & Freedman, 2004, p. 548).

In the same way, extending relations between text and image and also between images were explored. In these instances, either the text or the image/image part added a new element either in the visual or verbal text. Enhancing relations were not analysed under ideational meaning, as it is difficult to reason about relations of cause, time, purpose etc between text and image. As was shown in the content analysis, some images were found to contribute little to ideational meaning, serving a purely decorative or motivating function. These were images such as the photos at the beginning of the textbook chapter, or the photo collages on the websites or CD-ROMS. In this way, the image could be seen to enhance the text but it was decided not to include them in this analysis, as they were more interpersonally oriented.

Following Halliday (1985, pp. 193-227), interdependency relations may be paratactic - linking two like elements of equal status, one initiating and one continuing – or hypotactic – one element modifying the other in a relationship of unequal status, where one element is dominant and the other is dependent, forming clause or group complexes, for example. In the analysis of logico-semantic relations across text and image, i.e. in complexes made up of image and text, the issue of taxis and the directionality of relations were problematic. Since each semiotic system can make meaning in its own right, independent of the other, it is difficult to determine which element is dominant and which is dependent. Moreover, given that some relationship of interdependence does exist, is this relationship unidirectional, where it is clear which element is initiating and which is continuing or is the relationship bi-directional? To overcome this issue, it was decided to analyse interdependence in image/text complexes as bi-directional, where neither element can be seen to be dominant or dependent (see also (Cheong, 2006) and the notion of the 'bi-directional investment of meaning' in print advertisements). In these texts, where the purpose is pedagogic, a more useful question may be whether the image can stand alone and be understood without its caption, label or relevant main text.

For the textbook analysis, tables were set up with columns for the number of the image, image label, image caption and main text clauses. Bi-directional arrows were drawn connecting the image/text complexes which were related logico-semantically and the relationship was labelled for elaboration (=) and extension (+). The textual element of the complex was labelled T, the whole image was labelled Im and the part of the image, Im (part), as set out in the example below.

Image Number	Image label	Image caption	Relevant clause Number(s)
1	Im (part) =T	Im = T	Im = T (6-7)

6.7 Interpersonal metafunction

The interpersonal dimension of the texts was analysed in terms of number of interrelated parameters which reflect its interactive and evaluative meanings and how these are realised across semiotic resources:

- Intersemiotic negotiation (O'Halloran, 2005, p. 169, pp. 175-176): Speech function and exchange structure across semiotic resources
- Reader/viewer roles in exchanges
- Mood and modality (truth value) in verbiage
- Coding orientation in image and scientific realism (Kress 1996, pp. 163-180).

Intersemiotic negotiation at the discourse stratum was tracked in the screen texts in interactive activities, such as quizzes through the analysis of speech function and exchange structure. Through an analysis of the discourse moves of such activities and of other aspects of interpersonal meaning such as the coding orientation of images and the modality values of text and image, student roles can be compared with teacher roles and the power relations they embody.

6.7.1 Intersemiotic negotiation: exchange structure analysis

While the interpersonal domain was not the primary focus of the analysis, I was interested to explore how pedagogical roles such as reader/viewer/learner and writer/teacher/designer/knower were being constructed in the learning activities in the screen format. This was to understand how students are instructed to engage with the screen content and secondly, to explore the claim made by publishers that learning through pedagogical tasks on screen is both engaging and interactive (Campbell, 2002; Campbell & Reece, 2002; Hecht, 2000; Knox et al., 2001). In the biology and physics CD-ROMs, intersemiotic exchange structure was analysed to establish how pedagogic roles were being played out across text and image throughout the sequence of interactive moves on the screen during an on-screen activity such as a problem-solving task or multiple choice question.

Following Martin (1992, pp. 31-91), exchanges were analysed as either knowledge exchanges - those which are oriented towards information - or goods and services exchanges - those oriented towards action. Moves in the exchange were analysed for speech function and sequence in the exchange. The speech function system network adopted for the analysis is based on the networks in Martin (1992, pp. 44-70) and is shown in Figure 6.5. The full analysis of exchanges is located in Appendix E, Tables E4.1 and E4.2.

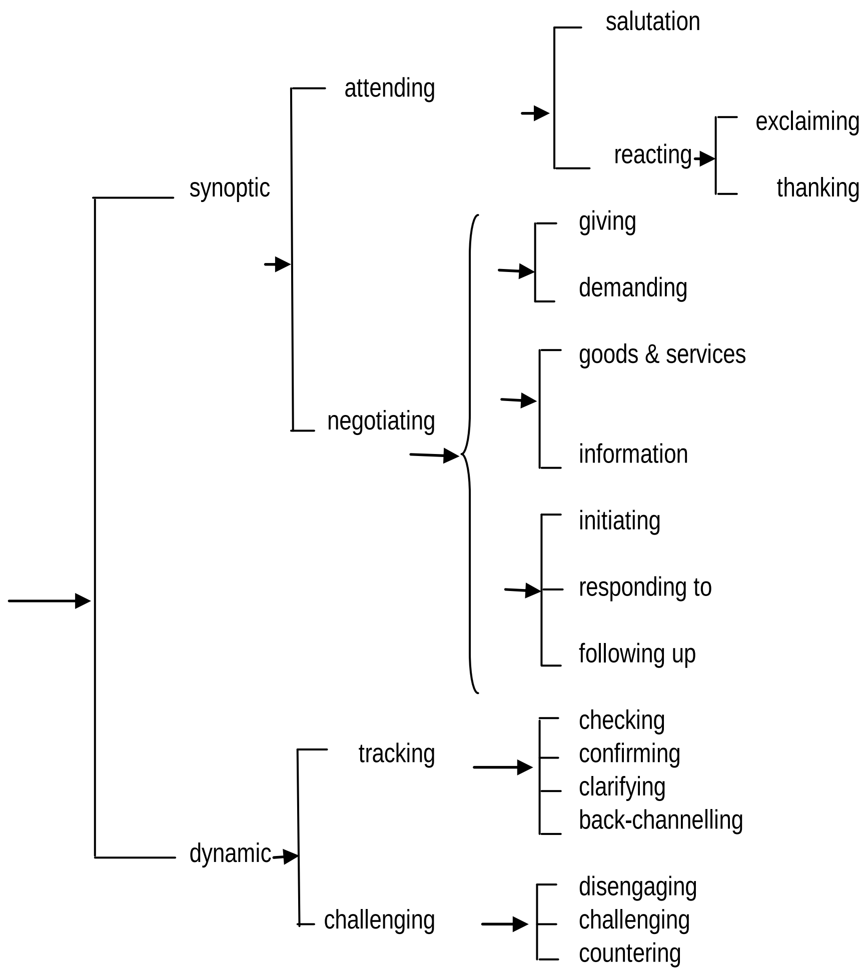


Figure 6.5. Speech Function network used for analysis, adapted from Martin (1992).

The network recognises at primary delicacy a system of *synoptic* versus *dynamic* moves. The distinction here is between moves which anchor the exchange, giving it its underlying structure, and moves which interrupt and prolong the initial sequence by opening it up for further negotiation. The system of synoptic moves recognises attending versus negotiating moves and these are the key systems which underlie the basic adjacency pairs. *Dynamic* moves have been classed here as *tracking* moves or *challenging* moves. *Tracking* moves can be either *back-channelling* moves which serve to monitor the exchange, reassuring the participants that someone is 'listening' or those which interrupt the exchange, by *checking*, *confirming* or *clarifying* the experiential content being negotiated. *Challenging* moves on the other hand, have the potential to suspend or abort the exchange. During the course of an on-screen activity the student can be instructed to carry out some action related to the image and has the option of complying or not complying with the command. The exchange structure analysis was set up on a spreadsheet with six columns. From left to right, the first column identified the number of the exchange structure; the second divided the text into moves; the third described the image the student needed to view and/or the action the student needed to perform in relation to the text and/or image; the fourth showed the intersemiotic exchange structure analysis – K1, K2 for knowledge exchanges and A1, A2 for goods and services exchanges, constituency and dependency relations of the exchanges and which moves involved the image or the action; the fifth column analysed the Speech Function and the sixth column indicated who carried out the move – the teacher or the student. Figure 6.6 shows an example of how the analysis was set out.

Exch No	Text	Image/ action	Intersemiotic exchange structure analysis	Speech Function	Role
2	Initially, set *FT* to its maximum value and u to its minimum value.		A2	Command	T
		S adjusts FT and u value buttons	A1	Resp to comm:comply	S

Figure 6.6. Example of intersemiotic exchanges structure analysis from the physics CD-ROM.

6.8 Textual metafunction

Textual meaning relates to composition and the distribution of meaning across semiotic resources, which is manifest in the use of layout, framing and ordering of visual and verbal elements. In scientific discourse reference is also crucial to identify and keep track of visual and verbal participants and contributes to texture, and hence to mode and the textual metafunction. Visual abstraction is another dimension of mode which contributes to textual meaning.

6.8.1 Visual and verbal abstraction

Complementing the notion of visual technicality is the notion of visual abstraction, which was discussed in Chapter 2 from different disciplinary perspectives. In the visual mode, an image may be represented in increasingly more abstract ways, when a photograph is compared with an abstract drawing or a graph, for example. Drawing on the discussion of scales of abstraction in images from Chapter 2 (Arnheim, 1969; Bastide, 1990; Lynch & Woolgar, 1990b), the analyses will explore how different types of images may be seen to move along scales of abstraction. Abstract images were taken to be those which involved a shift from concrete reality, removing them from familiar representations of events, participants and places in the concrete world. Aspects of form, function, setting and other detail are removed to render the whole image or elements of the image abstract. The categorisation of images in this corpus coded graphs as both technical and abstract, while a photograph was coded as technical (see also 6.6.1, p. 141).

Four categories of images were considered to be abstract - drawings (1c), tables (1d), equations (1e) and graphs (1g). The number of instances of the four categories was counted and a measure was obtained by calculating the proportion of abstract visuals to the total number of visuals for each text. To track the relationship between verbal and visual abstraction, this proportion was then compared with the measure of grammatical metaphor for the verbal text. For example, in the biology website text, the total number of visuals found was 54.

Ten of these (0.19) fell into the four abstract visual categories. The measure for grammatical metaphor of the same text was 1.34. These two measures were then summarised in a table and plotted on a graph to compare visual and verbal abstraction. Calculations were done for each text and the results compiled (Appendix D, Table D4.5 and Figure D4.5). Finally, to establish if there was any co-variation between visual and verbal abstraction and visual and verbal technicality, all four measures were collated (Appendix D, Table D4.6 and Figure D4.6.

6.8.2 Intersemiotic identification

Under intersemiotic identification (O'Halloran, 2005, p. 167, pp. 173-174) the concern is with reference systems across semiotic resources and with understanding how identifying relations are set up across the main text, the captions, labels and the images. In the reference system the basic opposition is that between new participants - presenting reference - and known participants - presuming reference (Martin, 1992, p. 110). The other system which cross-classifies with presenting/presuming reference is that of generic/specific. In generic reference the whole of an experiential class of participants is referred to, while specific reference refers to a specific example of that class. In the realisation of reference across text and image there may be a shift from generic to specific. Those items whose identity can be retrieved from the context are called phoric and those whose identity is new are called non-phoric.

The analysis was concerned with how participants are identified and tracked across semiotic resources and how these identifying relations are set up across the main text, the captions, labels and the images in the biology and physics textbooks. The analysis was set out as in Figure 6.8. The text and image extract for this segment of the analysis are shown in Figure 6.7.

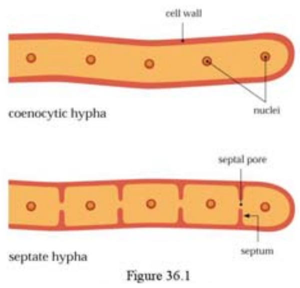
Image No	Image label	Image caption	Clause No/Main text
	cell wall coenocytic hypha nuclei septal pore septum septate hypha	Fig. 36.1 Coenocytic and septate fungal hyphae	6 The body of a fungus, the mycelium, generally grows as filamentous hyphae (sing. hypha), 7 which are microscopic tubes of cytoplasm bounded by tough, waterproof cell walls (Fig. 36.1). 8 Hyphae extend apically, 9 [they] branch 10 and, theoretically, [they] have an unlimited life.

Figure 6.7. Text and image extract for analysis of intersemiotic identification in Figure 6.8 (Knox et al., 2001, p. 938).

Image/image element	**Image label**	**Image caption**	**Main text**
whole image →		Fig 36.1	7 Fig 36.1
top image →	X Coencytic hypha →	X Coencytic and X septate hyphae	8 Hyphae ↑
			9 [they] ↑
			10 [they]
image part: cell wall →	X cell wall		

X shows generic/presenting reference

Figure 6.8. Analysis of intersemiotic identification of extract shown in Figure 6.7.

The direction of the chain depends on where the item is being introduced, for example, in the main text, caption or label. The analysis can be found in Appendix E, Tables E5.1 and E5.2. In the extract from the analysis in Figure 6.8 the arrows indicate the cohesive ties and direction of the relationship across text, caption, label and image or image element or the main text.

6.8.3 *Layout and information value*

Building on the content analysis, which tracked the various locations of visual and verbal blocks on the page and the relative salience of these blocks (5.2.3) and Appendix B, diagrams of page layout showing the location of elements from different semiotic resources were drawn for the biology and physics textbooks. These are discussed in 7.6.2. This was to determine the relationship between information value and the meaning arising from the location of visual and verbal elements. The effect of salience of these components on page and screen and the interplay with typography and colour will be discussed in the results.

6.9 Concluding comments

The overall concern of the metafunctionally-based analyses of multimodality and intersemiosis outlined in sections 6.4 to 6.8 is to test the conceptual and analytical framework. In the course of the analysis it is anticipated that some of the mechanisms of intersemiosis proposed by O'Halloran (2005, p. 165), namely those which capture the nature of contextualisation and complementarity between interacting semiotic systems, will be explored. The extent to which the two types of contextualising relations described by Lim (2006), reviewed in 3.5.4, will also be examined.

There were significant challenges posed by the multimodal discourse analysis in Stage 2. Managing the quantity of data generated, selecting an appropriate unit for analysis and transcribing and presenting the analyses were among these challenges. Although the notion of ‘the multimodal page’ has provided the foundation for units of analysis for this corpus, the issue of what constituted ‘an intersemiotic unit’ of analysis remained a challenge throughout. In the effort to capture and describe an integrated account of multimodality and multisemiosis, an overriding issue was that of the selectivity of the analysis and the trade-off between comprehensibility and delicacy. For the researcher who does not have access to multimodal concordancing, the problem of transcription and presentation of a multimodal corpus may seem overwhelming. In attempting to solve this problem I asked whether 'static' transcriptions were sufficient to capture data of such complexity and how I could represent the dynamic aspects with a static transcription. Ultimately however, the methodological approach adopted depends on the researcher's purpose and the corpus to be analysed and will be affected by contextual considerations and constraints.

CHAPTER 7

STAGE 2 RESULTS AND DISCUSSION (MDA)

7.0 Introduction

The theoretical principles underpinning multimodality and intersemiosis have been outlined in Chapter 6, together with the analytical framework and the principles of selection for the Stage 2 corpus, comprising all pedagogical texts – the two textbooks, the two CD-ROMs and the two websites. This chapter will present the results of the Stage 2 analysis and discuss their significance. The chapter is divided into seven main sections. Section 7.1 discusses the results for lexical density, technicality and grammatical metaphor of the verbal text as a prelude to the analysis of visual technicality and abstraction in section 7.2 (research questions 2 and 7). The remaining sections, 7.3, 7.4, 7.5 and 7.6 address research questions 1, 3, 4, 5, and 6, through an exploration of the metafunctional analyses for intersemiosis and multimodality. These will be set out as in Table 6.4, p. 139. Section 7.7 will conclude the chapter by revisiting the research questions in the light of the discussion of the analysis.

7.1 Lexical density, grammatical metaphor and technicality as co-varying patterns

One finding from the verbal content analysis was the complexity of text block categories. As discussed in Chapters 3 and 6, SFL formulations of complexity in scientific discourse are reflected in the measures of lexical density, technicality and grammatical metaphor. In order to determine whether there was any pattern of co-variation among these features, and whether this variation related to discipline or format, measures of lexical density, technicality and grammatical metaphor were calculated for a total of 887 clauses. For the number of clauses analysed per text see Table 6.1 p. 131. The methods of calculating the three measures were outlined in 6.4, together with examples of the grammatical categories of technicality and grammatical metaphor from the corpus. The analysis can be found in Appendix D. Table 7.1 shows the results of the analysis arranged according to format.

Table 7.1

Summary of Results for Lexical Density, Grammatical Metaphor and Technicality

	Lexical Density	Grammatical Metaphor	Technicality
Txtbk Bio	5.7	1.4	2.7
Txtbk Phy	5.5	1.48	2.5
CD Bio	5.4	1.43	3.25
CD Phy	3.3	0.8	1.46
Web Bio	5.0	1.34	2.03
Web Chem	3.8	1.26	2.11

The three measures were also plotted as co-varying patterns on a graph and are shown in Figure 7.1.

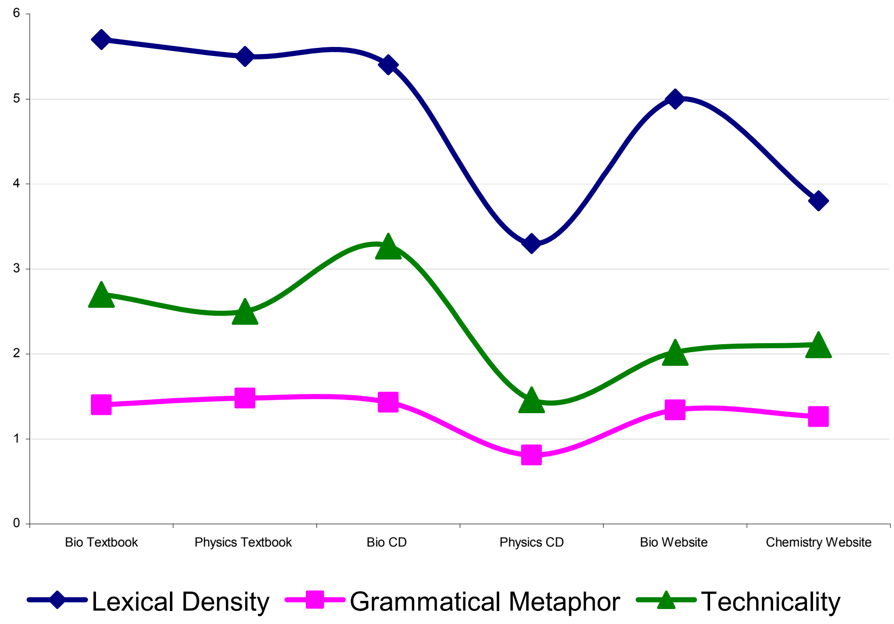


Figure 7.1. Results for measures of lexical density, grammatical metaphor and technicality showing co-variation.

Table 7.1 and Figure 7.1 show that the three measures tend to occur as co-varying patterns in all texts. High lexical density was associated with high measures of technicality and grammatical metaphor, for example in the biology textbook, and low lexical density with low measures of grammatical metaphor and technicality, for example in the physics CD-ROM. From these overall measures, variation appears to be associated with format rather than discipline. Apart from the biology CD-ROM, the screen texts had lower measures of lexical density, grammatical metaphor and technicality than the textbooks. One reason for the high measures on the biology CD-ROM is that it consists of interactive activities supported by a glossary of technical terms, hyperlinked to the running text. This glossary distorts the three measures as without it, the measures are much lower and similar to the other screen texts in lexical density and grammatical metaphor. Lexical density becomes 4.7, grammatical metaphor 1.16 and technicality 1.2. The texts do not appear to vary much in the overall measures according to discipline, since both biology and physics textbooks display similar measures of lexical density and grammatical metaphor, although technicality is higher for all biology texts. It may be that in the distribution of categories of grammatical metaphor and technicality, which will be discussed in sections 7.1.2 and 7.1.3, variation according to both format and discipline becomes more apparent. At this stage, the discussion has focussed on the three overall measures and their tendency to co-vary. The more precise ways in which lexical density, grammatical metaphor and technicality are interrelated and how this interrelationship impacts on visual semiosis will be explored further in 7.2.

7.1.1 Technicality and technical terms

As explained in 6.4, a measure of technicality including technical terms was calculated for each text. Table 7.2 shows the technicality measures and the proportion of technical terms of this measure.

Table 7.2

Measures of Technicality and Proportion of Technical Terms

	Technicality	Proportion of technical terms: technicality
Txtbk Bio	2.7	0.52
Txtbk Phy	2.5	0.59
CD Bio	3.25	0.5
CD Phy	1.46	0.49
Web Bio	2.03	0.49
Web Chem	2.11	0.57

A high proportion of technical terms were found in all texts. It could be argued that, because these are pedagogical texts, designed to teach students the technicality of the discipline in their first year of university, the high proportion of technical terms and the relatively high measure of the grammatical resources needed to set them up, are not unusual. Moreover, in the content analysis it was noted that the introduction of technical terms in each text co-occurred with typographical resources such as bold type, italics or underlining in hyperlinks, which would not be a feature of more expert genres such as scientific research articles. Thus in pedagogical texts, different semiotic resources need to work closely together to set up technicality. This will become more apparent when the role of images in technicality is considered.

7.1.2 Distribution of technicality across texts

Table 6.2, p. 135 details the categories used to track technicality in the texts. The analysis was based on the grammatical resources needed to name, define and explain technical terms so that they can be classified into field-specific taxonomies. The range of grammatical resources for technicality did not vary according to format or discipline. The highest range, 11 of the 12 sub-categories, occurred on the biology website while the lowest range was on the physics CD-ROM, with 6 sub-categories. The two textbooks had 10 sub-categories and the biology CD-ROM and chemistry website 9. However, the distribution of these resources did show some variation. Table 7.3 shows the distribution of the sub-categories across the texts. The measures for each text relate to the frequency of occurrence of each sub-category, obtained by dividing the number of instances of each sub-category by the number of ranking clauses.

Table 7.3

Distribution of Grammatical Categories of Technicality across Texts

Category	Txtbk Bio	Txtbk Phy	CD Bio	CD Phy	Web Bio	Web Chem
1A	0.05	0.01	0.04	0.01	0.004	0.01
1B	0.04	0.16	0.19	0.31	0.06	0.28
1C	0.16	0.16	0.16	0.2	0.18	0.07
1D	0.07	0.03	0.05	0	0.004	0.01
1E	0.01	0.01	0	0	0.01	0
1F	0	0.006	0	0	0.004	0
2A	0.07	0.04	0.06	0.03	0.06	0.03
3A	0	0	0.004	0	0.02	0.01
CT	0.39	0.47	0.35	0.23	0.45	0.46
ET	0.2	0.1	0.14	0.21	0.18	0.11
PT	0.01	0.03	0.02	0	0.02	0.01
PDT	0.01	0	0	0	0	0.01

The categories which occurred in the highest proportions in all texts were Classifier^Thing (CT) and Epithet^Thing (ET) in the nominal group structure, and the sub-categories of category 1, those to do with the semantics of elaboration. These three categories constituted 90% or more of the total for each text. Classifier^Thing structures, which set up field-specific superordination taxonomies and Epithet^Thing structures, describing attributes of the Thing, together accounted for about 60% of occurrences in the biology textbook and websites, about 50% in the physics textbook and the biology CD-ROM and 44%

on the physics CD-ROM. Categories of elaboration ranged from 26% on the biology website to 52% on the physics CD-ROM. These results showed that the variation among the categories could not be attributed to format or discipline.

In all texts identifying relational clauses (1B) and embedded clauses (defining relative clauses) functioning as Qualifiers in the nominal group (1C) were crucial in setting up definitions of technical terms. Typically, technical terms and their definitions or explanations were realised by Token/Value structures in identifying relational clauses, as in examples **[7.1]** and **[7.2]** from the biology texts. Technical terms are marked in bold.

[7:1]

Cl	BIOLOGY TEXTBOOK		
67	A mass of branched and apparently tangled **hyphae**	is	a **mycelium**.
	Value	Pro:rel:id	Token

[7:2]

Cl	BIOLOGY CD-ROM: Glossary for Activity 31A		
8	A **mycelium**	is	the densely branched network of **hyphae** in a fungus.
	Token	Pro:rel:id	Value

Definitions of technical terms in identifying relational clauses were often further elaborated by embedded clauses functioning as Qualifiers in the nominal group (category 1C), as in **[7:3]** from the physics textbook.

[7.3]

Cl	PHYSICS TEXTBOOK		
41	A **mechanical wave**	is	a disturbance [[that travels through some material or substance [[called the **medium** for the wave]]]].
	Token	Pro:rel:id	Value

Disciplinary variation however, was found in the way in which technicality was realised intersemiotically. This occurred in the physics and chemistry texts when the verbal grammar worked together with the grammar of mathematical symbolism to set up definitions. The equation in the clause in **[7:4]** below from the physics CD-ROM is an identifying relational clause in which the participants of Token and Value are realised by the mathematical symbols '*v'*, which means 'wave speed', '*f*', which means 'frequency', λ which means 'wavelength' and the relational process by the symbol '='.

[7:4]

Cl	PHYSICS CD-ROM: INTERACTIVE EXPLORATION			
30	Note the **wavelength** (distance peak-to-peak) in each case;			
31	again,	*v* Token	= Pro:rel:id	*f* λ Value

wave speed | frequency | wavelength

Both the Token (Agent) and Value (Medium) consist of technical terms, realised in this case by mathematical symbols, but already introduced in the verbal grammar as the participants 'wave speed', 'wavelength' and 'frequency'. So in this equation, the wave speed, *v,* equals the product of wavelength, λ, and frequency, *f*. Here, '*f*λ*'* as Value consists of an Operative process (O'Halloran, 2005), which involves multiplying the wavelength with the frequency of oscillation, *f*. Thus at clause rank in the grammar of mathematical symbolism, the equation is a nuclear configuration of an Operative process and two key participants, *f* and λ, involving simultaneous expansion and contraction of meaning.

Other layers of complexity are added in this example on the display plane in the use of typographical resources, such as italics for the symbols *v* and *f*, and in spatial positioning, by centering the equation on the next line apart from the main text, as shown by the green arrow in the screenshot in Figure 7.2.

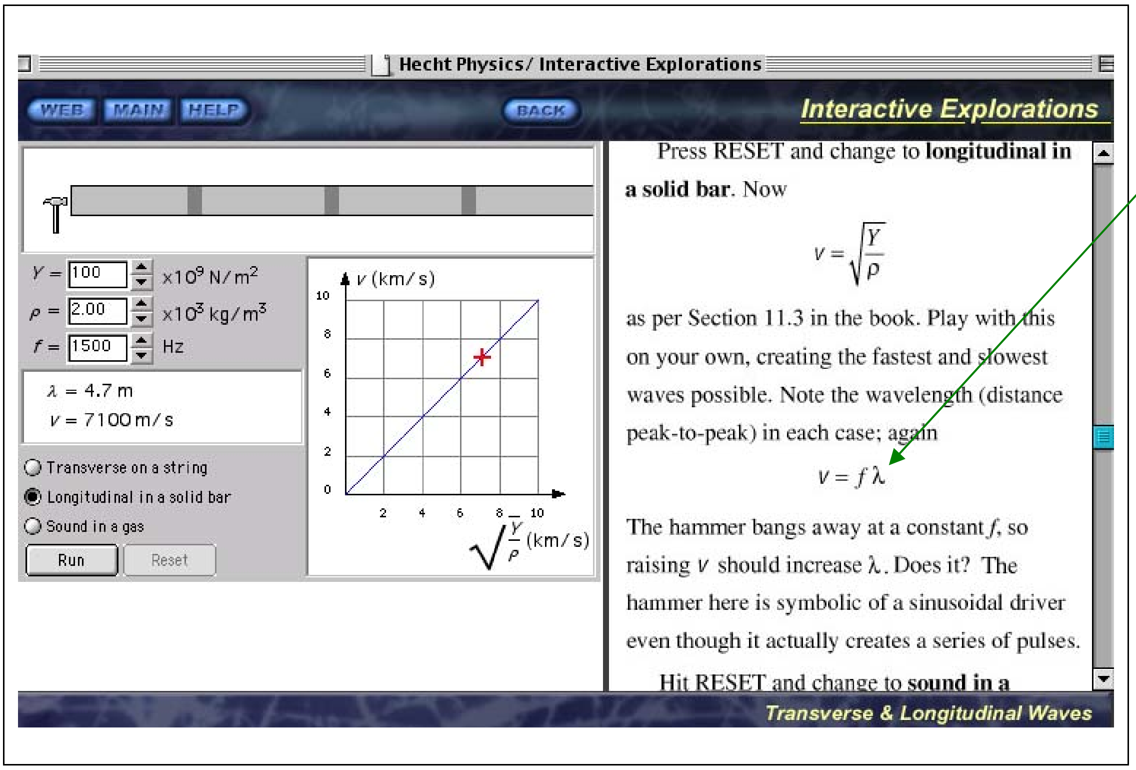


Figure 7.2. Screenshot of physics CD-ROM page showing the interplay of mathematical symbolism, typographical resources and spatial positioning in an equation (Hecht, 2000).

Once technical terms have been defined, they can be organised into technical taxonomies which reflect the uncommonsense reality of science. This process frequently involved Classifier^Thing structures, marked in blue in **[7.5]** to **[7.7]**, and the resources of grammatical metaphor, which will be discussed in 7.1.3.

[7:5]

CI	CHEMISTRY WEBSITE
98	For an exothermic reaction, K always decreases with increasing T.
99	For an endothermic reaction, K always increases with increasing T.

[7:6]

CI	PHYSICS TEXTBOOK
51	this is called a transverse wave.
56	We call this a longitudinal wave.
106	we call them sinusoidal waves.

Composition (part/whole) taxonomies set up through category 2, Possession, were less common in all texts, accounting for fewer than 10% of instances. The biology texts showed slightly higher frequencies than the physics and chemistry texts, as **[7:3]** from the biology textbook illustrates.

[7:7]

CI	BIOLOGY TEXTBOOK
25	Their vegetative cells usually contain more than one haploid nucleus,
26	and the diploid state is less common and in most species very brief.

These two clauses are an example of composition and classification taxonomies working together, as the Classifier^Thing structures (in blue) set up types of cell (*vegetative*) and types of nucleus (*haploid* and *diploid*) at the same time as a part of a vegetative cell, the *nucleus* (in red). In addition, both kinds of taxonomies in the verbal text were found to be working intersemiotically by interacting with visual representations of the same phenomena (e.g. in images of cells and their parts in biology and of types of mechanical waves in physics). This aspect will be taken up further in the discussion of intersemiosis and ideational meaning in 7.4.

7.1.3 Distribution of grammatical metaphor

Grammatical metaphor analysis was carried out to obtain a measure of the level of abstraction of the verbal text but also to explore its role in setting up technicality. Halliday (1998) argues that the two 'pay-offs' of grammatical metaphor are taxonomising and reasoning.

> *'[t]wo distinct metafunctional environments for grammatical metaphor: one textual - creating reasoned argument through managing the information flow of the discourse; the other ideational- creating ordered taxonomies of abstract technical constructs. I used different, though overlapping, (lexical) metaphors for the two: packaging and compacting for the former, and (following Martin) condensing and distilling for the latter'(Halliday, 1998, p. 221).*

At this stage it is the latter process which is of concern here in the interplay between technicality and grammatical metaphor.

Table 6.3, p. 137 shows the categories used to track grammatical metaphor. The bias of the table is towards metaphors of transitivity and hence ideational meaning. This reflects the main focus of the analysis in this thesis on ideational meaning and the fact that the interrelationship between grammatical metaphor and technicality is of particular interest in exploring the scientific discourse of the thesis corpus. The full analysis of grammatical metaphor and tables of results can be found in Appendix D. The distribution of the nine major categories of grammatical metaphor across the texts is shown in Table 7.4 and Figure 7.3.

Table 7.4

Proportions of Major Categories of Grammatical Metaphor across Texts.

Major category *	Txtbk Bio	Txtbk Phy	CD Bio	CD Phy	Web Bio	Web Chem
1	0.15	0.3	0.2	0.26	0.37	0.59
2	0.14	0.07	0.2	0.07	0.05	0.07
3	0.04	0.15	0.005	0.24	0.03	0.04
4	0.02	0.004	0.005	0.02	0.02	0.005
5	0.02	0.02	0.01	0.06	0.04	0
6	0.04	0.01	0.05	0	0.02	0
7	0.44	0.27	0.27	0.1	0.26	0.24
8	0.15	0.17	0.27	0.24	0.2	0.06
9	0.01	0	0	0	0	0

*** Explanation of major categories**
1 = nominalisation of processes
2 = processes as Epithet/Classifier
3 = Quality/Quantity as Thing
4 = modal adjunct as Thing
5 = logical connection as Thing or Process
6 = Circumstance as Process/Epithet or Thing
7 = Thing as Epithet/Classifier/Quality
8 = expansion as Act/Epithet/Classifier/Thing
9 = Process (phase) as Quality

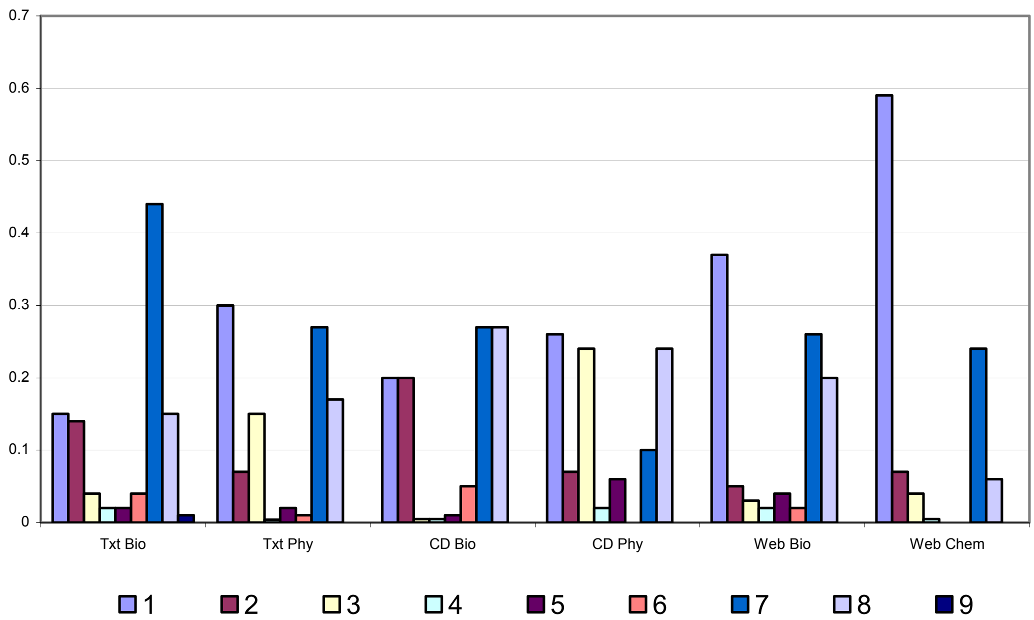


Figure 7.3. Distribution of major categories of grammatical metaphor.

As Table 7.4 and Figure 7.3 show, the distribution of grammatical metaphor across texts showed little variation according to discipline or format. The three most frequently occurring categories, Categories 1, 7 and 8 were found in all texts, accounting for 89% of the total instances on the chemistry website, 83% on the biology website, 74% in the textbooks and on the biology CD-ROM and 60% on the physics website. Category 1, nominalisations of processes, ranged from 59% on the chemistry website to 15% in the biology textbook. Category 7, to do with metaphorically reconstruing transitivity relations in the nominal group, was the second most frequent category, ranging from 44% in the biology textbook to 10% on the physics CD-ROM. Category 8, where ranking clauses are realised metaphorically as rankshifted clauses functioning as Qualifiers, Epithets, Classifiers or Things, ranged from 27% on the biology CD-ROM to 6% on the chemistry website.

Of the 29 sub-categories the biology website had the greatest range, with 22, the biology textbook with 19, the physics textbook 17, the biology CD-ROM 16, the chemistry website 12 and the physics CD-ROM 10. Apart from the physics CD-ROM, which had the lowest measure of grammatical metaphor and the lowest range of categories, there was no relationship between the number of sub-categories deployed and the measure of grammatical metaphor. For the results of proportions of each sub-category see Table D4.3 and Figure D4.3 in Appendix D. The analysis shows that nominalisations of material processes (Category 1a) and Things metaphorically realised as Epithets or Classifiers (category 7a) were the two most frequently occurring sub-categories in all the texts. In the chemistry website module on chemical equilibrium, Category 1a accounted for over half the measure of grammatical metaphor. It was used to build up the technicality about the behaviour of chemical reactions as they approach equilibrium. Technical terms *reaction, reactant, product, concentration, pressure* are all instances of nominalised material processes, shown in bold in **[7:8]**.

[7:8]

Cl	CHEMISTRY WEBSITE: CHEMICAL EQUILIBRIUM MODULE
4	Some chemical **reactions** continue
5	until one reagent is effectively completely consumed.
19	The **reaction** has reached a condition where the **reaction** of **reactants** forming **products** (left to right) is occurring at exactly the same rate as the breakdown of **products** to re-form the **reactants.**
72	Although **concentrations** can be used,
73	in describing gaseous **reactions**
74	it is quite common
75	that the equilibrium law is written in terms of the partial **pressures** of the substances taking part in the **reaction.**

In the same text about one quarter of the instances were Category 7a, Things realised as Epithets or Classifiers, which also contributed to technical taxonomies through Classifier^Thing structures, as in the words in bold in the clauses in **[7:9]**.

[7:9]

Cl	CHEMISTRY WEBSITE: CHEMICAL EQUILIBRIUM MODULE
31	and K is called the **equilibrium** constant.
116	and note the changes in **reactant** concentrations.
137	The **reaction** quotient is a useful expression which allows us to predict the direction in which the equilibrium will adjust to achieve equilibrium.

In clause 116 and clause 137 in **[7:9]**, another characteristic of grammatical metaphor, that of recursion is apparent (Ravelli, 1985/1999), thereby adding a further layer of complexity. When one semantic configuration is realised metaphorically, it may open up the potential for that realisation to pass through the network a second time and again be realised metaphorically. *Reactant* and *reaction* are, in their first metaphorical realisation, nominalised processes of the Process *react* but here are realised as Classifiers in the nominal groups *reactant* *concentrations* and *reaction quotient*. Halliday (1998, p. 214) argues that any metaphoric shift may 'reverberate throughout the clause' and that 'grammatical metaphors tend to occur in *syndromes*: clusters of interrelated transformations that reconfigure the grammatical structure as a whole'. Thus, at the micro level, structures such as *reactant concentrations* are counted as two instances of metaphor, i.e. categories 7a and 1a. However, Ravelli (1988) notes that at the same time they can be seen as one 'macro level' metaphor, since 'one occurrence of grammatical metaphor is syntagmatically dependent on another process of metaphor' and, as such they are interdependent. The interaction of these two categories was a feature of all texts, as shown in **[7.10]** and **[7:11]** and was a significant aspect in the technicalisation of the discourse.

[7:10]

Cl	BIOLOGY TEXTBOOK
33	which play a crucial role in **litter decomposition** and **nutrient recycling**, 7a 1a 7a 1a

[7:11]

Cl	PHYSICS TEXTBOOK
59	a **wave disturbance** travels down the length of the channel. 7a 1a
97	Then each particle in the string also undergoes **periodic motion** 7a 1a

Thus the 'technical grammar' (Halliday & Martin, 1993, p. 6), which helps to create the scientific discourse in these texts, enables the shift from commonsense to uncommon sense knowledge. Lexical density, technicality and grammatical metaphor clearly occur as co-varying patterns in these texts, regardless of discipline or format. Through the interrelationship of the grammatical resources deployed in technicality and grammatical metaphor, experience is reconstrued as discipline-specific and highly abstract knowledge. Halliday (1998) sums up the effect of this reconstrual in metafunctional terms:

'*Ideationally, the nominalising grammar creates a universe of things, bounded, stable and determinate; and (in place of processes) of relations between the things. Interpersonally, it sets itself apart as a discourse of the expert, readily becoming a language of power and technocratic control'* (Halliday, 1998, p. 228).

7.2 Visual and verbal technicality and abstraction

If a reconstrual of experience occurs through the grammar of technicality and abstraction in scientific discourse what kinds of reconstruals are taking place in the images which accompany the text? Clearly, on the page or screen in scientific texts, technical, abstract discourse co-occurs with technical and abstract images. The following section will extend the reasoning about co-variation in technicality and abstraction in language to co-variation in technicality and abstraction in images (research questions 2 and 7).

7.2.1 Visual and verbal technicality

In the process of technicalisation and abstraction of scientific discourse, the accessibility of verbal meanings becomes restricted to members of an increasingly expert discourse community. Images are also caught up in this shift from commonsense to uncommonsense knowledge, both in their own right and in their interaction with verbiage. As an extension to the analysis of technicality in the verbal text, the notion of technicality in visuals was investigated a) to determine whether it co-varied with verbal technicality and b) to establish whether any variation was related to format or discipline. In the first instance, this was done by comparing two measures – one for technicality in the verbal text and the other for images considered to contribute to technicality and field-specific meaning. The measure of technicality for the verbal text was discussed in 7.1.2. The second measure consisted of the number of the six categories of 'technical' images in each text – photos contributing to subject content, micrographs, drawings, tables, equations and graphs - calculated as a proportion of the total number of images for that text. These two measures are summarised in Table 7.5 and presented in Figure 7.4. Table 7.5 also describes the relative level of each measure as high, medium or low, to indicate how the measures co-varied.

Table 7.5

Measures for Visual and Verbal Technicality

Text	Proportion of visuals contributing to Field/Technicality	Technicality	Visual measure	Verbal measure
Txtbk Bio	1.0	2.7	high	high
Txtbk Phy	0.8	2.5	high	high
CD Bio	0.33	3.25	low	high
CD Phy	0.44	1.46	med	low
Web Bio	0.28	2.03	low	med
Web Chem	0.14	2.11	low	med

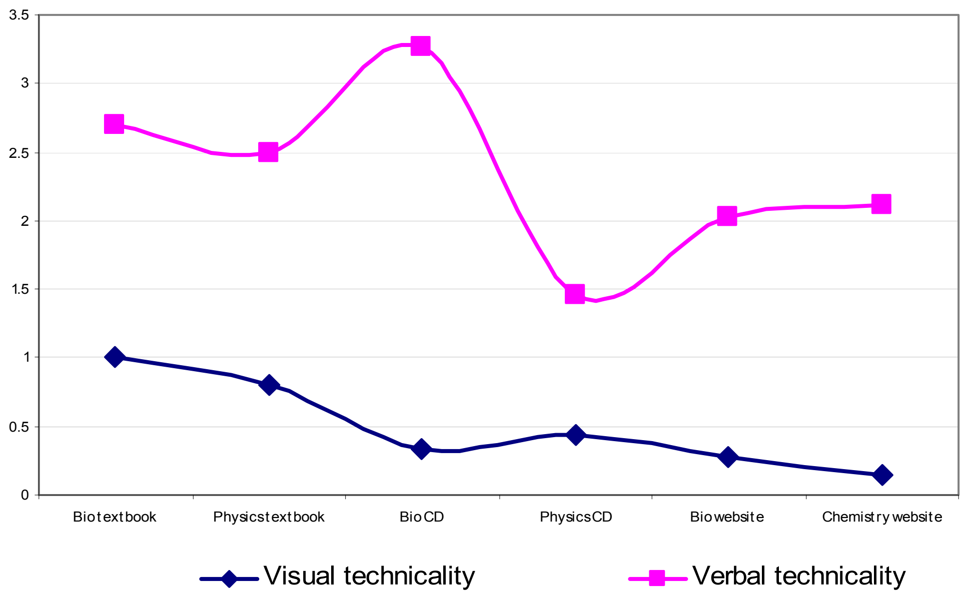
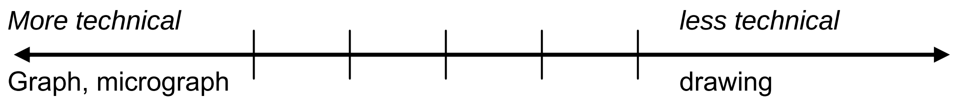


Figure 7.4. The relationship between visual and verbal technicality.

Table 7.5 and Figure 7.4 show that there was some degree of co-variation between the two measures. In the textbooks, high measures of verbal technicality co-vary with high measures of technical images and on the biology CD-ROM a low measure of technical images corresponds to a high measure of verbal technicality. The relationship is less clear in the other texts. The screen texts all have lower measures of images contributing to technicality but, apart from the physics CD-ROM, the visual measure does not correspond to low measures of verbal technicality. This lack of correspondence can be partly explained by the fact that, in the screen texts, the visuals are doing more navigation work than field-oriented work, as discussed in the content analysis in Chapter 5. The CD-ROMs have higher proportions of visuals than the websites, which have the lowest proportion. The relatively high measure of verbal technicality for the biology CD-ROM was explained in 7.1 as resulting from the use of a glossary of technical terms with hyperlinks to the term and its definition or explanation. Interestingly, the glossary is not elaborated in the visual mode, resulting in a relatively low proportion of technical images. Thus, in the textbooks the images appear to play a much more significant role in constructing field than in the screen texts.

Although these broad measures are interesting, by adopting a topological perspective on technicality in images, a finer distinction can be made in describing the degree of technicalisation of the images. The level of technicality of an image can be ranged topologically along a cline from less to more technical, according to the level of expertise needed to read it and what it is trying to depict. A certain drawing may be placed at the less technical end and a graph at the other, while in another case, a highly complex drawing or diagram may be placed towards the more technical end.



Where an image is placed along such a continuum will depend on other aspects such as whether technical elements appear with naturalistic elements from the material world, what kind of processes and participants are represented and what other forms of semiosis it draws on. For example, the image of a periodic wave in Figure 7.5 from the physics textbook would be placed in the centre of the continuum. It depicts an action process of drops of water falling into a pool. The image combines elements with a degree of naturalism, such as the drops falling into the water and the ripple that this produces, with other more technical elements such as the thick arrows or vectors, signifying the outward spread of the wave and the mathematical symbol for wavelength λ.

Figure 7.5. Image representing the concept of a periodic wave showing naturalistic elements combined with mathematical symbolism (Young & Freedman, 2004, p. 551).

In this image, the 'reality' of the water is enhanced through computer imaging to produce the intense hue of the blue and the reflection on the waves in the water, thereby foregrounding the interpersonal metafunction. It could be seen both as a transitional image, bridging the gap between material reality and scientific reality (Kress & van Leeuwen, 1996, p. 103), and as an image designed to engage the reader's interest.

Other images are highly technical, such as the graph in Figure 7.6 from the physics textbook, and interact with mathematical symbolism, visual display and language, depending on each of these systems for their interpretation.

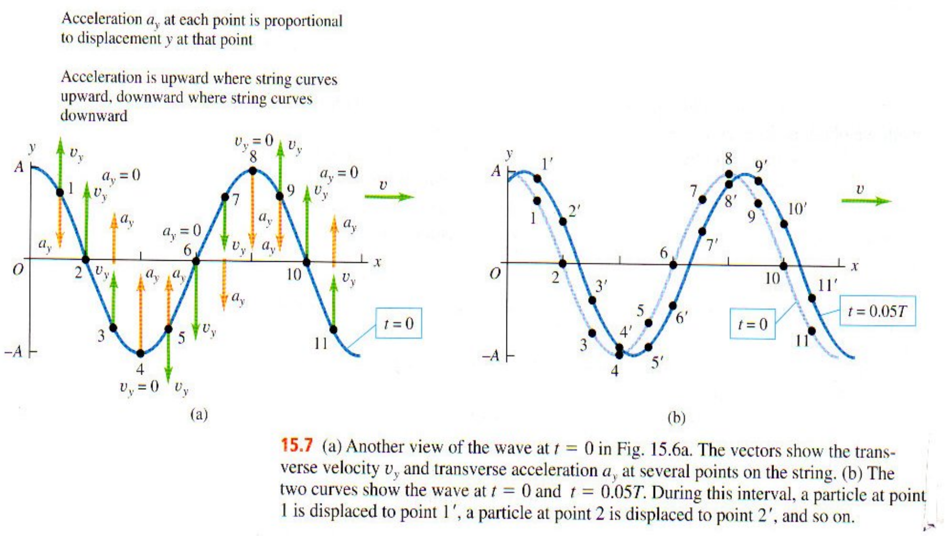


Figure 7.6. Image of a graph showing a high degree of visual technicality (Young & Freedman, 2004, p. 558).

Thus from a reader/user perspective, some images clearly need higher levels of expertise to 'read' them, such as the electron micrographs in biology or the graphs of wave phenomena in physics. This is akin to a reader with insider or outsider status in understanding technicality in the verbal text. The higher up the ladder of field expertise a reader is, the more he/she 'belongs' inside the discipline. Technical terms no longer need to be defined and explained. Just so with images. Some images, such as those found in the science research literature or those created by scientists using highly sophisticated imaging technology can be understood by the insider without needing to defined, explained or even labelled. The expert reader of images in a certain field may need recourse to the verbal text for a very different purpose, such as communicating his/her interpretation of the image to another expert in that field (see also Myers, 1992). However, the continuum of technicality in scientific images is only one dimension of their status as products of science. The other dimension is to what extent images in science are depicted as abstract representations of the material world. If an image is technical it may, at the same time, be depicted as abstract but it does not have to be. A micrograph is technical but not abstract – it depicts what is 'there' in the world under the microscope or viewed from a scanning electron microscope but a graph is both technical and abstract.

7.2.2 Visual and verbal abstraction

As discussed in Chapters 2 and 3 and, following Kress and van Leeuwen (1996, pp. 162-164) and Unsworth (2001, pp. 89-90), abstract images were taken to be those which involved a shift from concrete reality, removing them from familiar representations of events, participants and places in the concrete world. Aspects of form, function, setting and other detail are removed to render the whole image or elements of the image, abstract. Topologically, the level of abstraction of images can be conceptualised as a continuum, similar to the one above suggested for technicality, with photographs at one end and graphs at the other. As images move along a cline of abstraction from most representative of the perceived world to more schematic, they can be seen to be removed from commonsense understandings of the perceived world or from congruence.

However, this broad conceptualisation of abstraction does not take into account the affordances and conventions of each type of image and their context of use. Each type may be ranged along its own continuum of abstraction based on the conventions of representation for that type. For example, some drawings may be close to photographic depictions with surface or background details, while others may be closer to diagrammatic depictions. Graphs may include detail from visual display as well as mathematical symbolism. In terms of their context of use images in science are selected for a purpose and may be used as evidence to support argument, or as examples extending verbal explanation as in textbooks or as proof of experimental results as in research articles.

Although visual abstraction is not completely analogous to verbal abstraction there are some points of contact. One is the shift from concrete to abstract, which occurs in both systems of semiosis, resulting in a reconstrual of the experiential meaning in the perceived world. Another is the shift from specific to generic which takes place through grammatical metaphor in language and through the depiction of elements of the image as generic or typical rather than specific. For example, although the image in Figure 7.5 of the wave and the subsequent wave action produced by drops falling into water is a single image, it is simultaneously a generic representation of all wave action of this kind.

A measure of the four categories of images considered to be abstract - drawings, tables, equations and graphs - was obtained by calculating the proportion of these categories of the total number of images for each text. This measure was then compared with the grammatical metaphor measure for that text. Table 7.6 presents the results of the two measures. It also shows the relative level of each measure, described as high, medium or low, to indicate how the measures co-varied.

Table 7.6

Measures for Grammatical Metaphor and Abstract Visuals

Text	Proportion of abstract visuals	Grammatical metaphor	Visual measure	Verbal measure
Txtbk Bio	0.29	1.4	low	high
Txtbk Phy	0.8	1.48	high	high
CD Bio	0.33	1.43	low	high
CD Phy	0.44	0.81	med	low
Web Bio	0.19	1.34	low	med
Web Chem	0.14	1.26	low	med

There was some co-variation in the two measures, as shown in Figure 7.7.

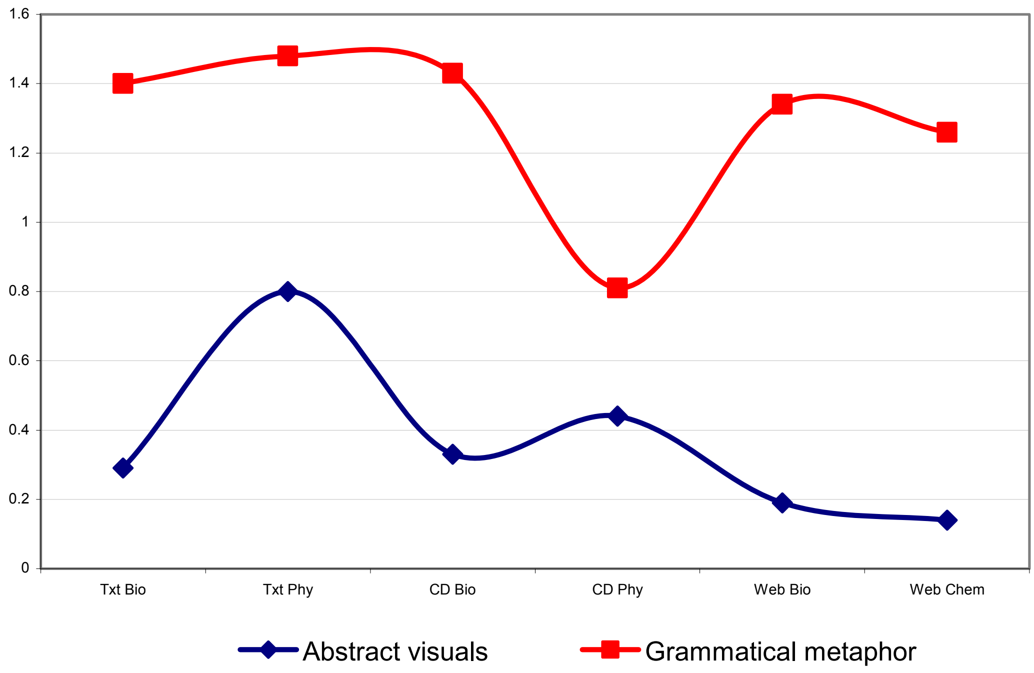


Figure 7.7. The measures for grammatical metaphor and abstract visuals.

In part, similar patterns of co-variation were found to those in visual and verbal technicality. Table 7.6 shows that the highest proportion of abstract visuals corresponded to the highest measure of grammatical metaphor in the physics textbook only, while a low proportion of abstract visuals corresponded to a high measure of grammatical metaphor in the biology textbook and CD-ROM. The websites have a lower proportion of abstract visuals than the CD-ROMs and the textbooks, but a medium high grammatical metaphor measure. This can be explained by disciplinary differences in the choice of abstract visual. In the biology textbook, photographs and micrographs, which are seen at this stage to contribute to the technicality rather than to visual abstraction, were predominant, while drawings occurred less frequently and graphs and equations not at all. The reverse was true in the physics textbook, where drawings, equations and graphs form 92% of the total number of visuals.

7.2.3 The four measures: visual and verbal technicality and abstraction

To determine if there was a relationship among visual and verbal technicality and abstraction, the four measures were compared. They are presented in Table 7.7 with each measure given a value from high to low.

Table 7.7

Values for Visual and Verbal Abstraction and Technicality

Text	Abstract visuals	Grammatical metaphor	Technical visuals	Technicality
Txtbk Bio	low	high	high	high
Txtbk Phy	high	high	high	high
Bio CD	low	high	low	high
Physics CD	med	low	med	low
Web Bio	low	med	low	med
Web Chem	low	med	low	med

Apart from the biology textbook, the values for visual abstraction and visual technicality were similar across the texts. Low or high measures of visual abstraction corresponded to low or high measures of visual technicality. The four measures form a somewhat different pattern in the screen texts. On the websites low visual measures corresponded to medium verbal measures while on the biology CD-ROM low visual measures corresponded to high verbal measures and on the physics CD-ROM medium visual measures to low verbal measures. The only high visual measures were found in the textbooks, with the physics textbook showing strong correspondence in all four measures. The relationships can be seen in Figure 7.8.

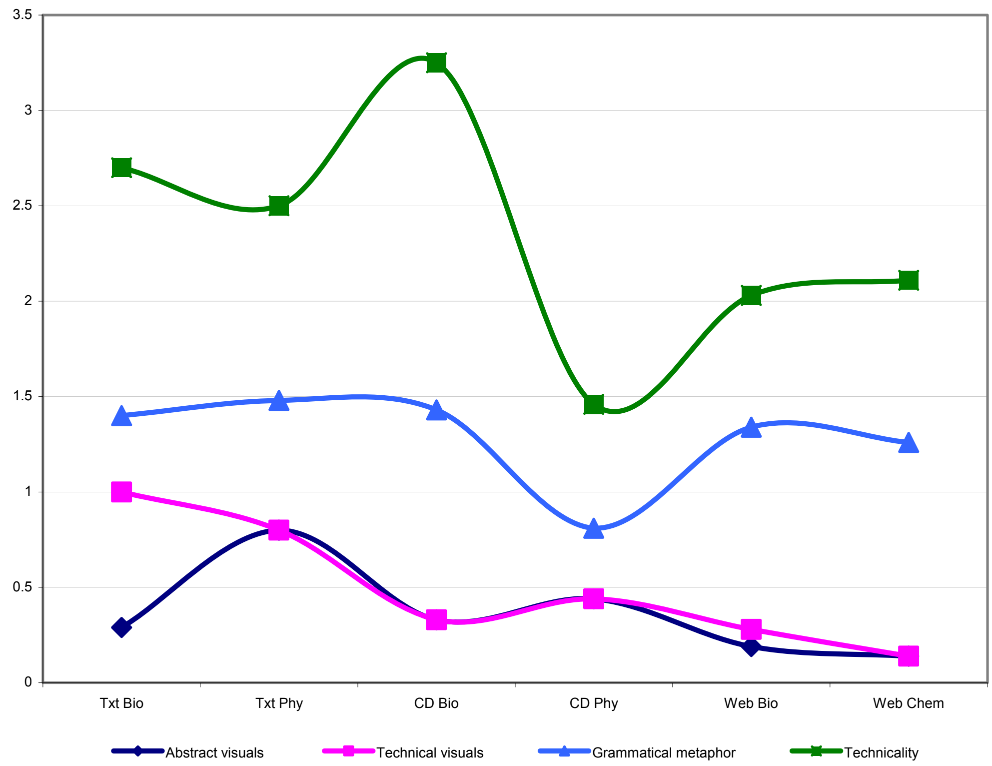


Figure 7.8. Visual and verbal technicality and abstraction.

Seen together, the measures reveal a relatively strong trend of co-variation, although the patterns differ according to format and discipline. This may be expected in such pedagogic genres in science, where visual and verbal semiosis have to work together to create technical and abstract meanings. In pedagogic texts the highly technicalised and abstract images are mediated by the labels, captions and the main text. To an expert eye it may be possible to read such images without verbal explanation or elaboration but for the student, the verbal text plays a vital role in translating the meaning of the image.

Moreover, the principles of selection of images for pedagogic purposes may be quite different from those for expert genres such as research articles, since images, like text, are social constructs and serve different functions in different genres. Myers (1992) claims that images in science textbooks are not there to ‘prove’ a point in a particular piece of research but rather to present generalised ‘evidence’ for accepted knowledge.

In summary, in the verbal text, lexical density, grammatical metaphor and technicality showed a high level of co-variation. Format not discipline was the key factor, whereby screen texts tended to have lower measures than the textbooks. The distribution of technicality and grammatical metaphor categories, however, was similar for all texts regardless of discipline or format. When the measures for grammatical metaphor and technicality were compared with measures for visual technicality and visual abstraction a strong trend of co-variation was again found. The images in the textbooks played a more significant role in constructing the technicality of the field than in the screen texts and different degrees of visual technicality were seen to relate to the level of expertise needed to read them. Disciplinary variation was noted in abstract images, with the physics textbook and CD-ROM displaying higher measures of the abstract categories of visuals than the three biology texts.

The student reader/user of a textbook or of a website designed to teach content is cast in the role of an apprentice in the field not as a fellow research scientist. This does not however, preclude a critical reading of such texts. Now more than ever a critical reading becomes crucial, as pedagogical publications become competitive products in the globalised marketplace of publishing. The relationship between abstraction in text and image in pedagogic texts is seldom made explicit to students at university and would be a very productive area to explore in developing a pedagogy of multiliteracies. The pedagogical implications of the analysis discussed in 7.1 and 7.2 will be taken up in Chapter 8.

7.3 Introduction to intersemiotic and multimodal analyses

The need for research into the mechanisms of intersemiosis was raised in Chapter 3, in particular in relation to the conceptualisation of the semantics of intersemiosis as co-contextualising and re-contextualising relations (Lim, 2006). Related to this and relevant for the analysis of intersemiosis here, is the notion of expansion. Although Halliday (1998) discusses expansion in relation to grammatical metaphor he argues generally that the semiotic power of *expanding* – relating one process to another by a logical-semantic relation such as time' is one of the properties 'specific to a semiotic that is stratified...' (Halliday, 1998, p. 195). The above points will be elaborated through the discussion of the analyses in sections 7.4, 7.5 and 7.6. The discussion follows the order of analyses presented in Table 6.4, p. 139 and will be presented separately for each of the metafunctions.

7.4 Ideational metafunction

This section discusses the results of the multimodal and intersemiotic analyses of ideational meaning (research question 1). The analyses were grouped into those focussing on experiential meaning and those focussing on logical meaning. The discussion will focus first on analyses of experiential meaning at the level of discourse semantics. This comprises discussion of intersemiotic and multimodal activity sequences in 7.4.1 and in 7.4.2 analyses of ideational cohesive relations and taxonomic relations across text and image. Finally, in 7.4.3, logico-semantic relations across text and image at the discourse semantics stratum will be presented. Where relevant, the discussion will also draw on analysis relating to the grammar stratum in transitivity relations across text, image and mathematical symbolism.

7.4.1 Intersemiotic and multimodal activity sequences

Chapter 3, p. 44 discussed the orbital/serial interpretation of ideational meaning as a complementary perspective on constituency and how this could enable a more dynamic representation of discourse and text structure. This possibility was explored through the analyses of activity sequences across modes and forms of semiosis in the textbooks and the biology CD-ROM. The interest here lay in the extent to which nuclear relations in activity sequences could be seen to co-occur and interact across text, still and animated image.

To contextualise the case further for the analysis here, field has been defined as 'sets of activity sequences oriented to some global institutional purpose' realised through logically ordered sequences of nuclear configurations – Process/Medium structures with attendant participants and circumstances (Martin, 1992, p. 292). As discussed in Chapter 6, p. 146, in scientific discourse, expectancy relations (*and/then)* where activity a) is *probably* followed by activity b) are distinguished from implicational ones (*if/then)* where activity a) is *necessarily* followed by activity b) (Martin, 1992, p. 323).

One aspect of field and the ideational metafunction not discussed in Chapter 6 under technicality was the dynamic relationship between technical taxonomies and activity sequences in the verbal text (Martin, 1992; Wignell et al., 1993). In the analysis of technicality in 7.1.2 it was found that technical terms were frequently defined in identifying relational clauses (Category 1B) and that these definitions drew on the grammar of mathematical symbolism at the level of clause, as shown in **[7:4]**, p. 164. It was decided to extend the analysis to examine the interplay between text and image and animation in explaining phenomena beyond the clause, since many of the activity sequences depended for their interpretation on images, verbal text and mathematical symbolism, thereby integrating multiple resources.

Experiential relations in activity sequences spanning text and still image, selected from the biology and physics textbooks and those spanning text, still image and animated image from the biology CD-ROM, were analysed. Analyses can be found in Appendix E. In my data I found that not all verbal activity sequences corresponded to visual sequences and not all visual sequences corresponded to verbal ones. To illustrate this point, the following discussion will first analyse a sequence involving text only, then one involving image only and finally, examples of activity sequences involving more than one semiotic resource.

Text only activity sequence

Figure 7.9, which reproduces Fig. 36.1 in the biology textbook, represents a drawing of different structures of hyphae, which are part of the body of a fungus, called the mycelium.

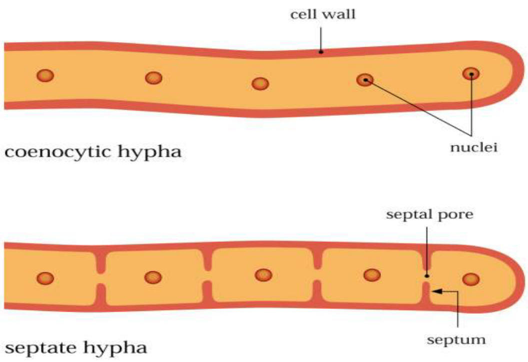


Fig 36.1 Coencytic and septate fungal hyphae

Figure 7.9. Fig 36.1 (Knox et al., 2001, p. 938).

In the main text following the reference to Fig 36.1 found in clause 19 in **[7:12]** there is a short activity sequence about fungal growth in clauses 20-22.

[7:12]

Cl	BIOLOGY TEXTBOOK
18	The body of a fungus, the mycelium, generally grows as filamentous hyphae (sing. hypha),
19	which are microscopic tubes of cytoplasm bounded by tough, waterproof cell walls (Fig. 36.1).
20	**Hyphae extend apically,**
21	**[they] branch**
22	**and, theoretically, have an unlimited life.**

The sequence of the hyphae extending from its tip or apex, then branching and continuing to extend indefintely is, however, not represented in the image. The image is used instead to name parts of the hyphae. The activity sequence in **[7:12]** is reconstrued later in the main text in clauses 59-66 **[7:13]** but it is not represented in any subsequent image.

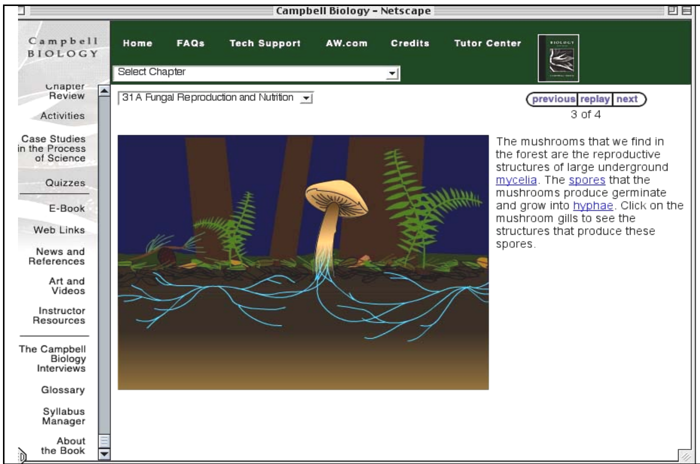
[7:13]

Cl	BIOLOGY TEXTBOOK
59	Fungi grow
60	and explore their substrates by extension from the hyphal tip.
61	As a hypha absorbs nutrients and water,
62	it swells
63	and expands at the tip,
64	where the cell wall is incomplete and elastic.
65	Branches also develop at the growing tip of hyphae.
66	As a consequence of this type of tip growth, fungal colonies grow uniformly outwards by radial extension.

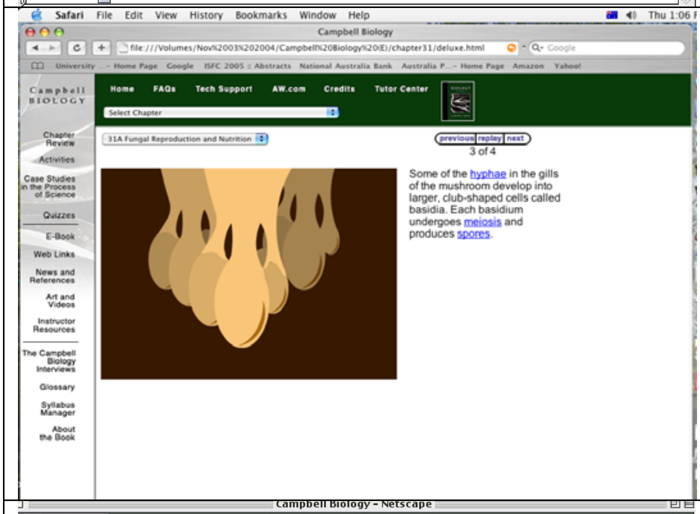
<u>Intersemiotic and multimodal activity sequences</u>

Some activity sequences occurred in the animated images in the biology CD-ROM and were only loosely related to the main text. However, other intersemiotic activity sequences, combining text and image or text, image and mathematical symbolism were found. The verbal elements engaged in the sequence may appear as part of the label, caption or main text. Example **[7:14]**, p. 188 from the biology CD-ROM on the growth of the body of a fungus, involved text, still image and animated image. The student also plays a role in this sequence by activating the image of the fungal gills in Screen 3a, which produces the next image of the growing and enlarging structure in Screen 3b. This structure is then labelled by animated text in Screen 3c as the voice reads the main text. The sequence is shown by the screenshots and glossed in the right column in Figure 7.10.

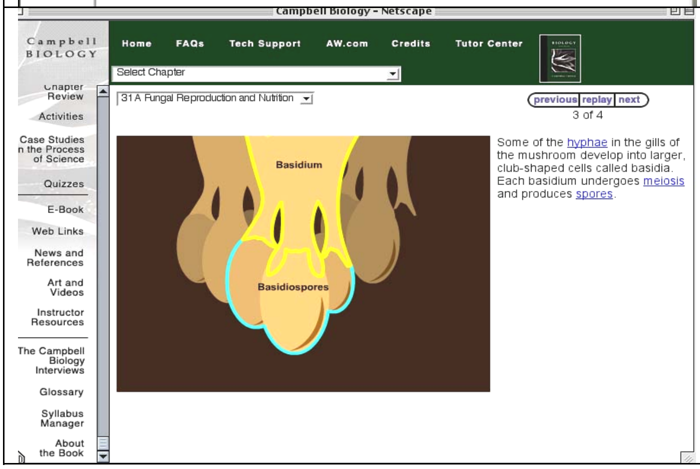
[7:14]

<table>
<tr>
<td>
</td>
<td>Screen 3a
Gloss of activity sequence

<u>Image</u>: Fungal gills activated

<u>Main text</u>:
Click on the mushroom gills to see the structures that produce these spores</td>
</tr>
<tr>
<td>
</td>
<td>Screen 3b

<u>Image</u>:
Fungal gills enlarge into club shaped cells

<u>Main text</u>:
Some of the hyphae in the gills of the mushroom develop into larger club-shaped cells called basidia.</td>
</tr>
<tr>
<td>
</td>
<td>Screen 3c

<u>Image</u>:
Basidia labelled by animated text and cell shapes become delineated

<u>Main text</u>:
Some of the hyphae in the gills of the mushroom develop into larger club-shaped cells called basidia</td>
</tr>
</table>

Figure 7.10. Activity sequence across main text, animated and still image and label in biology CD-ROM (Campbell, 2002).

Other examples of intersemiotic activity sequences in the biology textbook and CD-ROM were found in the drawings, as in the drawing of the life cycle of a fungus from the textbook in Figure 7.11 **[7:15]**. Here, arrows combine with labels and images to indicate a sequence of activities in the stages of the life cycle of a typical Basidiomycota. It is also an example of a conversion process (Kress & van Leeuwen, 1996, p. 68; Unsworth, 2001, p. 76), in which text and image work together to explain the cycle of activities. Stages such as those I have indicated with dotted lines are realised visually, but named verbally.

[7:15]

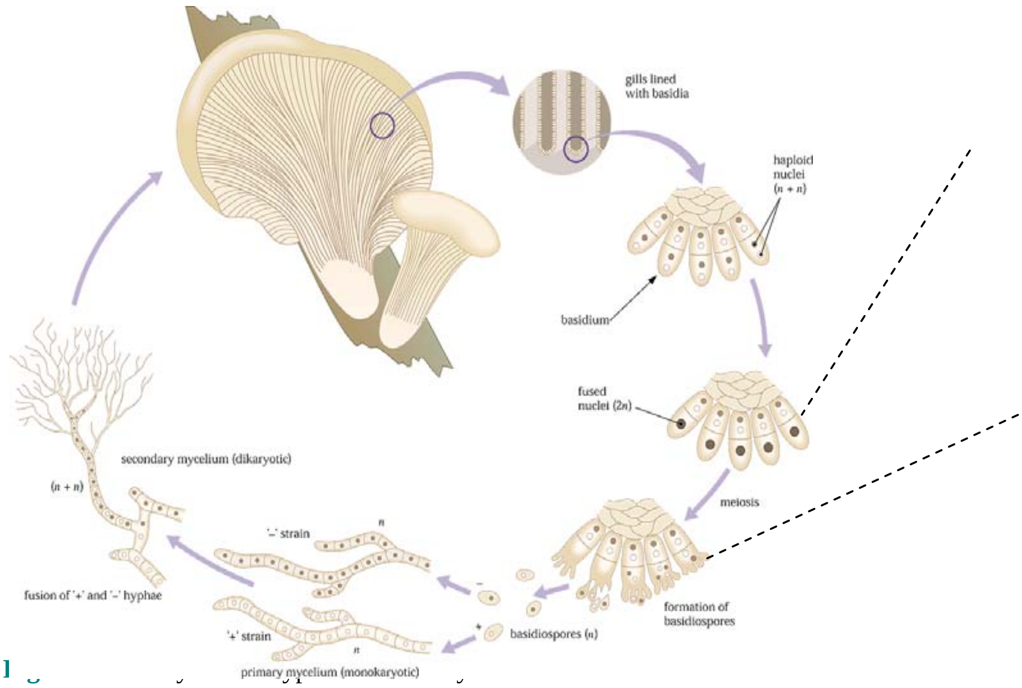
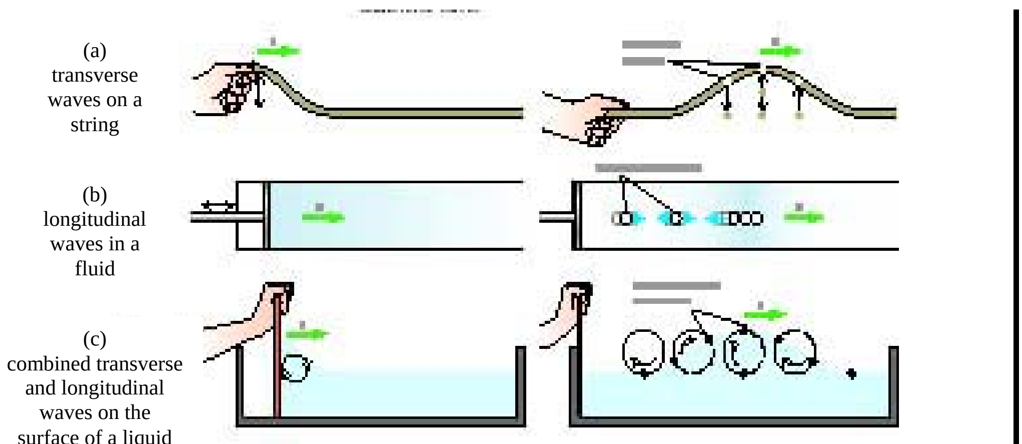


Figure 7.11. Activity sequence in a drawing of the life cycle of a fungus (Knox et al., 2001, p. 951).

This example also shows how expansion of meaning can take place through semiotic metaphor (O'Halloran, 2005; Guo, 2006), which involves a functional shift between image and text. The stages in the cycle are named in the verbiage in image labels such as meiosis and formation of basiospheres and fusion of '+' and '-' hyphae, realised as nominal groups or participants, two of which involve grammatical metaphor, while the visual elements to which the labels refer are depicted as processes. Thus in the distribution of experiential relations across semiotic resources visual and verbal meanings are shared and become co-contextualised.

This complex mechanism of intersemiosis also occurs in the activity sequences in the physics textbook in Figure 7.12 **[7:16]**, which combine text, visual display and mathematical symbolism.

[7:16]



15.1 Three ways to make a wave that moves to the right. (a) The hand moves the string up and then returns, producing a transverse wave. (b) The piston moves to the right, compressing the gas or liquid, then returns, producing a longitudinal wave. (c) The board moves to the right then returns, producing a combination a combination of longitudinal and transverse waves.

Figure 7.12. Figure 15.1 from the physics textbook showing intersemiotic activity sequence, with the caption and part of label re-typed (Young & Freedman, 2004, p. 548).

The image in **[7:16]** is a composite of three pairs of images making up the whole figure, which is a Conceptual Classificational process depicting a taxonomy of three different types of mechanical waves: transverse, longitudinal and combined transverse and longitudinal waves. At the same time, each pair of images is an implicational sequence (*if/then*) of two successive images arranged horizontally. For example, in the top left image the hand shakes the string upwards, producing the wave in the right hand image. This implication sequence is also realised verbally in the main text and in the caption. The image sequence corresponds to clauses 47 and 48 in the main text,

[7:16] (cont.)

46	In Fig 15.1a the medium is a string or rope under tension.
47	If we give the left end a small upward shake or wiggle,
48	the wiggle travels along the length of the string.

and to the following text in the caption:

[7:16] (cont.)

a)	The hand moves the string up and then returns, producing a transverse wave.

This pattern of implication sequence is repeated across semiotic resources for the other two pairs of small images and their related caption and main text clauses. The three specific implication sequences of extending nuclear relations are introduced by the generalised implication sequence in clauses 42-44 of the main text, particularly by the phrase 'of various kinds'.

[7:16] (cont.)

42	As the wave travels through the medium,
43	the particles that make up the medium undergo displacements of various kinds,
44	depending on the nature of the wave.

Each of the three sequences of images is made up of two transactional images: in both images in a) the hand is the Actor and the string is the Goal; in b) the piston is the Actor and the liquid in the cylinder is the Goal and in c) the hand on the board is the Actor and the Goal is the liquid. Within each of the right hand images there is an embedded Analytical process (Kress & van Leeuwen, 1996, p. 49), with the medium as the Carrier (i.e. the rope, the liquid in the cylinder, and the water in the channel) and the particles as the Attributes.

Thus the experiential relations in the implication sequences of the three different types of waves being produced are realised by both text and image, but the sequences can also be said to be related intersemiotically through experiential cohesive relations and through logico-semantic relations of expansion (see discussion in 7.4.2 and 7.4.3). Just as there are visual activity sequences which correspond to verbal ones there are visual elements and processes within those sequences which correspond to verbal elements and processes, resulting in a degree of redundancy or overlap between visual and verbal activity sequences. What is also happening in the shifts back and forth from main text to image to caption, are transitions in technicality and semiotic and grammatical metaphor. This means that the technicality of the images or image elements may be transferred into technicality in the verbiage and that congruent elements in one semiotic resource may be transferred into metaphorical variants in another.

A question which might be raised at this point is, does the visual simply elaborate or reinforce the verbal or vice versa or is the combination of the two multiplicative in its effect? It is difficult to make a case for the latter, although the visual and verbal nuclear configurations can be seen to fuse as they overlap, thereby expanding the meaning potential. Barthes (1977, p. 103) writes of narrative sequences being 'imbricated in one another', or overlapping so that they 'move in counterpoint'. This seems to be what is happening in the physics textbook example of the waves. The counterpoint has arisen from the combination of the visual and verbal sequence, which has made meaning in its own way but the two sequences also make meaning together, creating a new semantic layer. The overlapping meanings in the image and the verbiage are bound closely together in a relationship of intersemiotic complementarity.

Finally, on the display stratum, colour and juxtaposition also play a role in realising experiential meaning in the activity sequence. Colours are repeated in each of the pair of images in the sequence in Figure 7.12, p. 190 to depict the same elements, such as the green of the arrows representing wave speed, the skin colour in the hands, the blue for the liquid in the piston and the trough and red for the particles. The juxtaposition of the six images in their relative positions simultaneously realise sequence and classification. The two images in each pair are arranged side by side, realising the sequence. Each pair is also arranged in three separate rows with the label on the left acting as a heading, realising co-classification. The considerable complexity to be found in the interaction among the intersemiotic ideational meanings in these activity sequences is likely to pose challenges for the novice reader, unless the transitions between verbiage and image are made explicit. The analysis shows that the physics textbook exemplified explicit transitions while the biology textbook did not.

Multimodal researchers (e.g. Royce, 1998; Thibault, 2000, pp325-326) argue for mechanisms or principles of intersemiosis which can capture the nature of complementarity between interacting semiotic systems. The analysis discussed in this section demonstrates one way in which intersemiotic complementarity may take place through the experiential relations in visual and verbal activity sequences.

7.4.2 Intersemiotic experiential cohesive relations

As discussed above in 7.1.2 under technicality and in 7.4.1 under activity sequences, the description of ideational meaning at the level of discourse in scientific texts is complemented by analysis of composition and classification taxonomies. Intersemiotic experiential cohesive relations of hyponymy (classification), meronymy (composition), repetition (verbal text only) and correspondence (image) were analysed across the image or image element, label, caption and main text in the two textbooks and in the biology CD-ROM. The analysis can be found in Appendix E. As explained in 6.6.3 p. 145, correspondence was preferred as a term to synonymy or repetition to describe the relationship between a visual and verbal element, as the meaning constructed in the visual semiotic does not 'repeat' meaning in language, although there is a correspondence. The interest lies in the co-deployment of visual and verbal meanings to achieve correspondence and the resulting expansion of meaning. The examples of experiential cohesion across semiotic resources discussed below, will explore one of the mechanisms of intersemiosis, that of semiotic cohesion (O'Halloran, 2005, p. 169).

Multiple ties were found among all visual and verbal components. For example, the image or image element could be related to the main text, or the caption, or the label or to all three; the caption could be related to the label and to the image or image element; or the main text could be related directly to the image or image element or vice versa. Thibault (2001, p. 305) argues that 'such relations are quite typical of multimodal scientific texts' and that meanings are not restricted to any one of these components. 'Rather, the caption or label is co-contextualised with the visual elements of the figure or some specific aspect of this' (Thibault, 2001, p. 306). Of interest then, is how these components work together, which the following discussion of examples **[7:17]** to **[7:22]** from the two textbooks and the biology CD-ROM will attempt to elucidate.

Intersemiotic experiential cohesion in the biology textbook

The discussion in this section is of cohesive relations among the seven images, captions, labels and main text from the first two-page spread of the biology textbook. For reference, the images have been numbered and the pages reproduced in Figure 7.12.

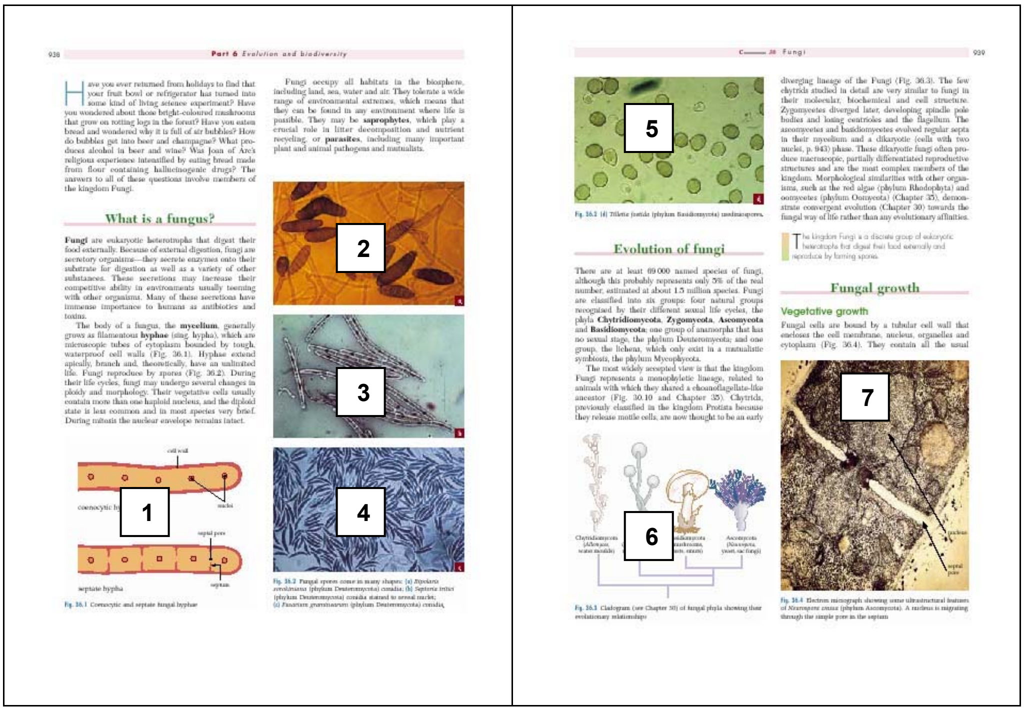


Figure 7.12. Two-page spread from the biology textbook (Knox et al., 2001, pp. 938-939).

Intersemiotic cohesive relations which relate to Image 1 in Figure 7.12 are discussed in example **[7:17]**. The image is enlarged in Figure 7.13, with the caption re-typed.

[7:17] Image and caption

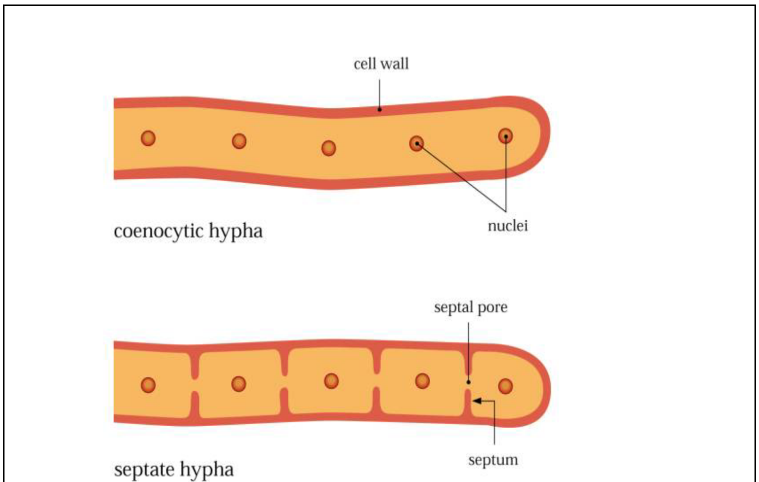


Fig. 36.1 Coencytic and septate fungal hyphae

Figure 7.13. Image 1 enlarged from Figure 7.12. (Knox et al., 2001, p. 938).

The image in Figure 7.13 is a Conceptual Analytical process, relating the

Carrier (the whole drawing) to its Attributes (the parts), which are labelled. At the grammar level, intersemiotic identifying relations are realised through the arrows (vectors) pointing to the parts of the drawing, establishing a relation of identity between the verbal and visual realisation of the same Possessive Attributes. This relationship of identity is reinforced through the caption text, the sub-caption text, the labels and clauses 18 and 19 of the main text.

[7:17] Main text

18	The body of a fungus, the mycelium, generally grows as filamentous hyphae (sing. hypha),
19	which are microscopic tubes of cytoplasm bounded by tough, waterproof cell walls (Fig. 36.1).

Intersemiotic experiential cohesion is also set up at the discourse level through the interaction between the image, labels, caption and main text. This occurs in **[7:17]** through intersemiotic correspondence, marked (**corr**) and meronymy (**mer**) where the image part, the labels and caption set up two part/whole taxonomies:

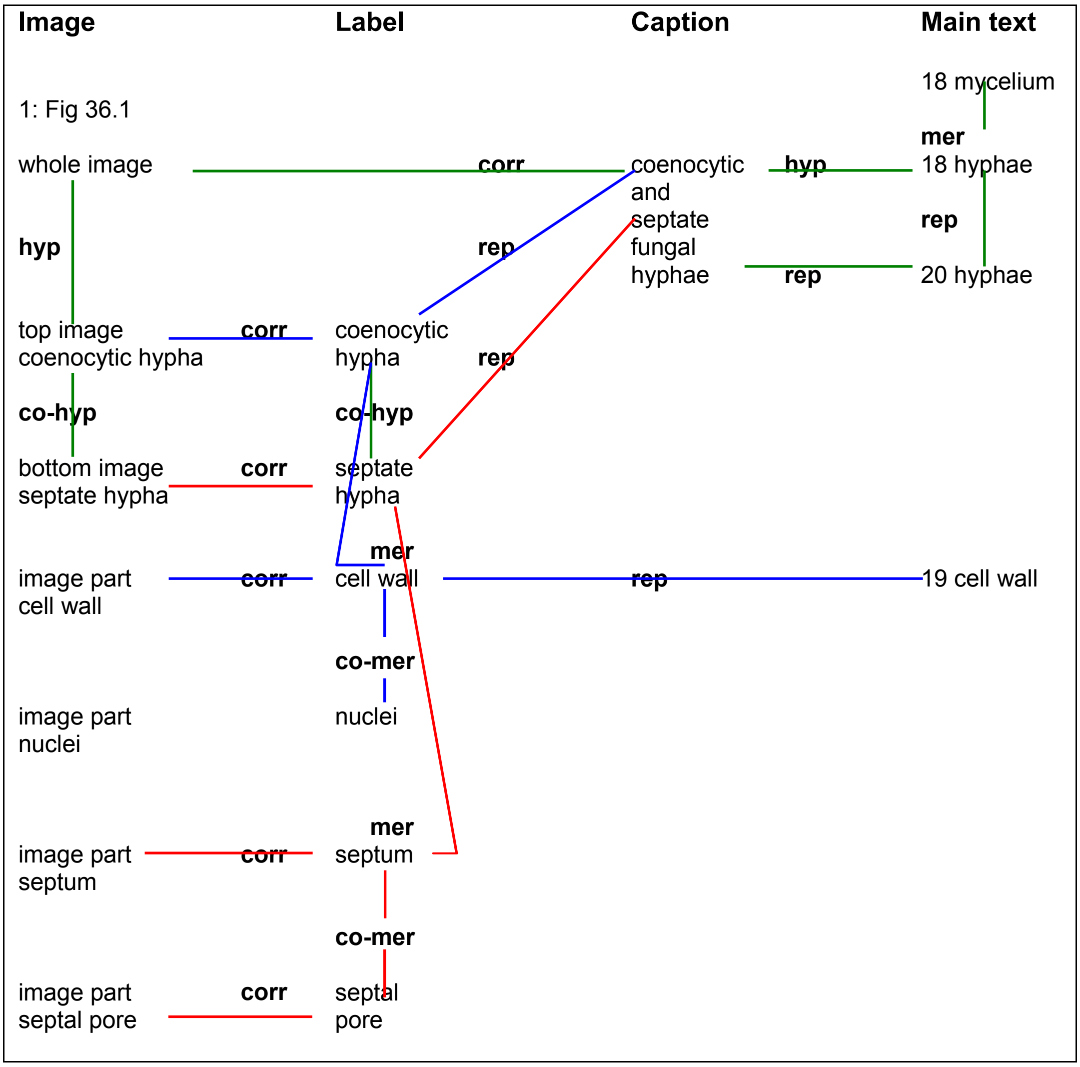
i) *the blue string*

Image part/caption: [coenocytic hypha] (whole): Image part/label: [cell wall/nuclei] (parts)

ii) *the red string*

Image part/caption: [septate hypha] (whole): Image part/label: [septal pore/septum] (parts).

[7:17]



At the same time, in the green string, relations of hyponomy (**hyp)** are set up among the *whole image* representing two types of hyphae and the *two separate images* representing these types, the *label* naming these types, the *caption*, again naming the types and the *main text*, setting up the superordinate 'hyphae' in clause 18. Co-hyponymic relations also occur between the two separate images and the labels on each image. Thus each semiotic resource realises these cohesive relations in its own right but for an apprentice reader, the captions and labels help to mediate between the image and the main text, making explicit the relationships between the image, its parts and the text.

On the display stratum, experiential meaning is further enhanced by juxtaposition, in the relative positioning of the figure and the accompanying labels and caption; colour in the use of the same two colours for each drawing of hypha to show they are related experientially; and the use of the same font size for labels and the caption. In the main text, the technical term, 'hyphae' is highlighted in bold, providing another tie typographically to the labels and caption, and hence to the image.

A further intersemiotic experiential link is set up between the image, caption and labels of Image 1, the image, caption, labels of Image 7 on the facing page and the relevant clauses from the main text on the following page (see Figure 7.12, p.195 again for reference). This example is discussed in **[7:18]** below. There is already a relationship between the two images, in that they both depict the same experiential content (a nucleus in a septal pore), but this is expanded intersemiotically through the labels, caption and main text. Interestingly, the technology used to produce each image is different - the simple, but abstract drawing in Image 1 is 'scientifically' reinforced with the highly technological electron micrograph in Image 7, providing important supporting visual evidence for the drawing and related text. Image 7 is enlarged and reproduced below in Figure 7.14 with the caption re-typed.

[7:18]

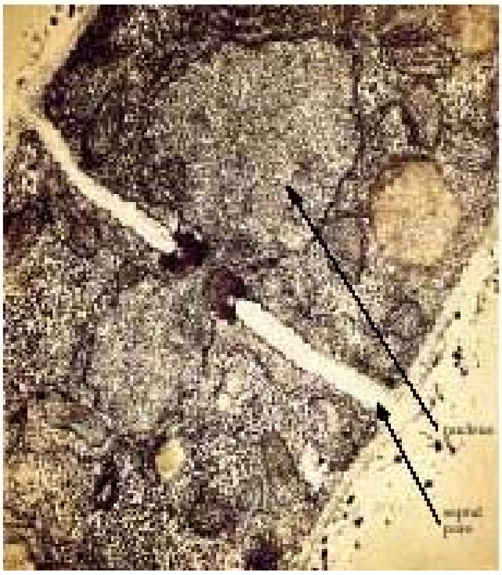


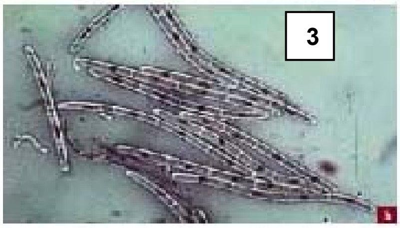
Fig. 36.4 Electron micrograph showing some ultrastructural features of *Neurospora crassa* (phylum Ascomycota). A nucleus is migrating through the simple pore in the septum.

Figure 7.14. Image 7 enlarged from Figure 7.12. (Knox et al., 2001, p. 939).

The image in **[7:18]** is again a Conceptual Analytical process, with a visual Carrier (the whole image) related to its labelled parts (the Attributes), which are also identified in the caption and the main text. The arrows (vectors) pointing to the labelled parts of the image also establish an intersemiotic relationship between the verbal and visual elements intrastratally, at the level of grammar. For example, the label [nucleus] (the participant/nominal group) is instantiated by a visual element through the arrow. As in **[7:17]** intersemiotic experiential cohesion is established through correspondence and meronymy.

Images 2-5 from Figure 7.12, however, establish experiential intersemiosis in different ways. They are enlarged from Figure 7.12 and are reproduced below in Figure 7.15, and will be discussed as example **[7:19]**. The caption has been re-typed. The full analysis of this example can be found in Appendix E, Table E2.1.

[7:19]



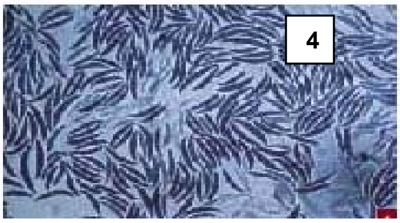


Fig. 36.2 Fungal spores come in many shapes: **(a)** *Bipolaris sorokiniana* (phylum Deuteromycota) conidia; **(b)** Septoria tritici (phylum Deuteromycota) conidia stained to reveal nuclei; **(c)** *Fusarium graminearum* (phylum Deuteromycota) conidia

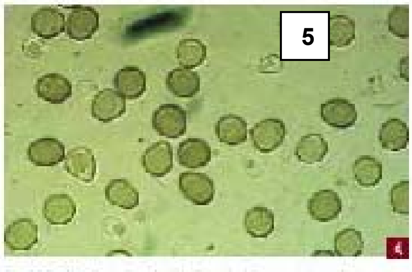


Fig. 36.2 (d) *Tilletia foetida* (phylum Basidiomycota)

Figure 7.15. Images 2-5: Fig. 36.2 (Knox et al., 2001, p. 938).

Firstly, and intrasemiotically, although they are spread over a double page, the images are related as a series of Conceptual Classificational processes depicting a taxonomy of four micrographs of types and shapes of fungal spores from different phyla. There are no labels on these images but intersemiotic relations occurred through the caption and the images. The caption, rather than the main text, establishes the superordinate of the taxonomy in the Classifier^Thing structure ‘fungal spores’. The subordinates of the taxonomy are depicted in the four images showing contrasting shapes of fungal spores, which realise co-hyponymic relations. Each image is also identified in the caption text as an example of a type of spore from a specific phylum. The main text is not cohesive experientially with the images or the caption, except through repetition of the word ‘spores’. On the other hand, the superordinate ‘hyphae’ for the taxonomy in **[7:17]** (Figure 36.1), is found in the main text, not in the caption. The discussion of examples **[7:17]** to **[7:19]** suggests that taxonomies may be set up *intersemiotically,* with the superordinate occurring in the verbal text and the subordinates in the image (or vice versa) or *intrasemiotically*, with the superordinate and subordinates occurring in both systems simultaneously, thereby reinforcing each other intersemiotically in a relation of correspondence. Can the same patterns be found in the physics textbook and how are the patterns mediated by hyperlinks which may set up relations across screens in the biology CD-ROM? It is to these questions that the discussion will now turn.

Intersemiotic experiential cohesion in the physics textbook

Compared with the biology textbook example discussed in **[7:19]**, the intersemiotic experiential cohesive relations of Figure 15.1 and related main text in the physics textbook were more intricate and the domain of these relations was more extensive. Unlike the biology example, the ties between the main text and the image extended further than the main text which immediately surrounded the image. The full analysis relating to this figure spanned main text clauses 41-76 and can be found in Appendix E, Table E2.2. The image is reproduced below in Figure 7.16, first as it occurs on the page with its related main text and then as an enlarged image in Figure 7.17, with the caption and label rewritten for clarity.

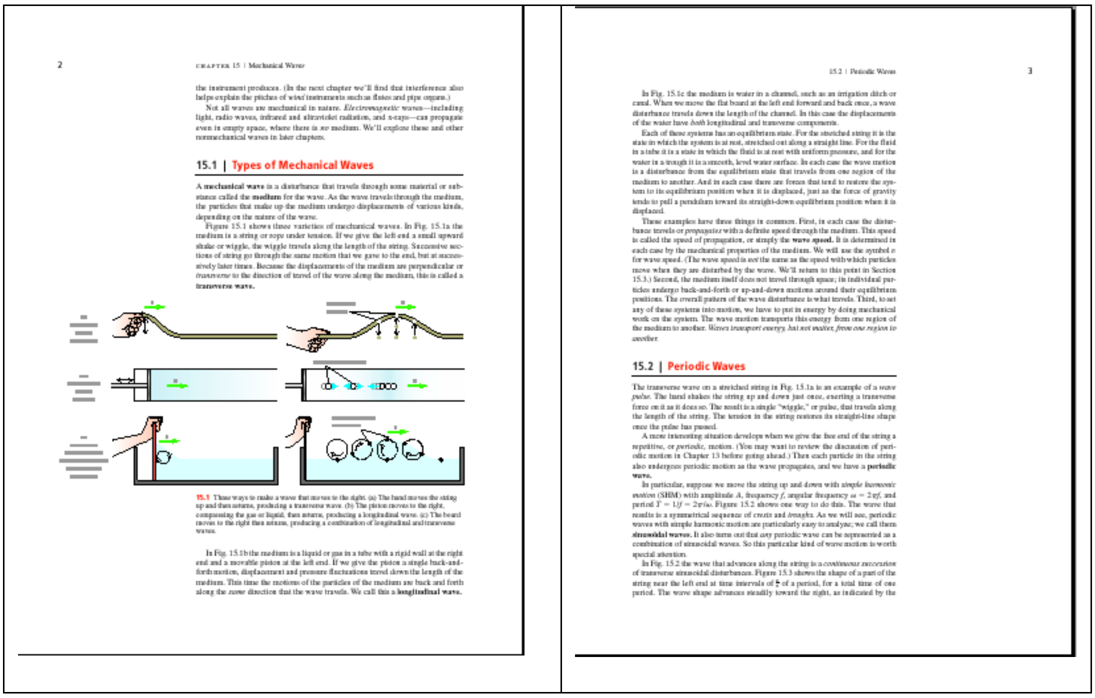


Figure 7.16. Physics textbook pages showing Figure 15.1 and related main text, caption and labels (Young & Freedman, 2004, pp. 548-549).

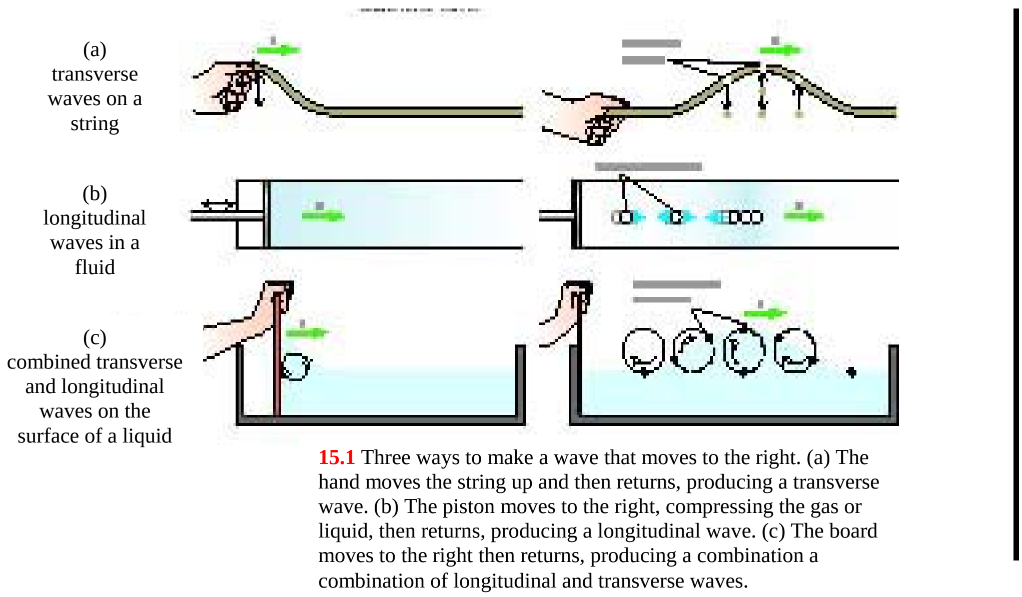


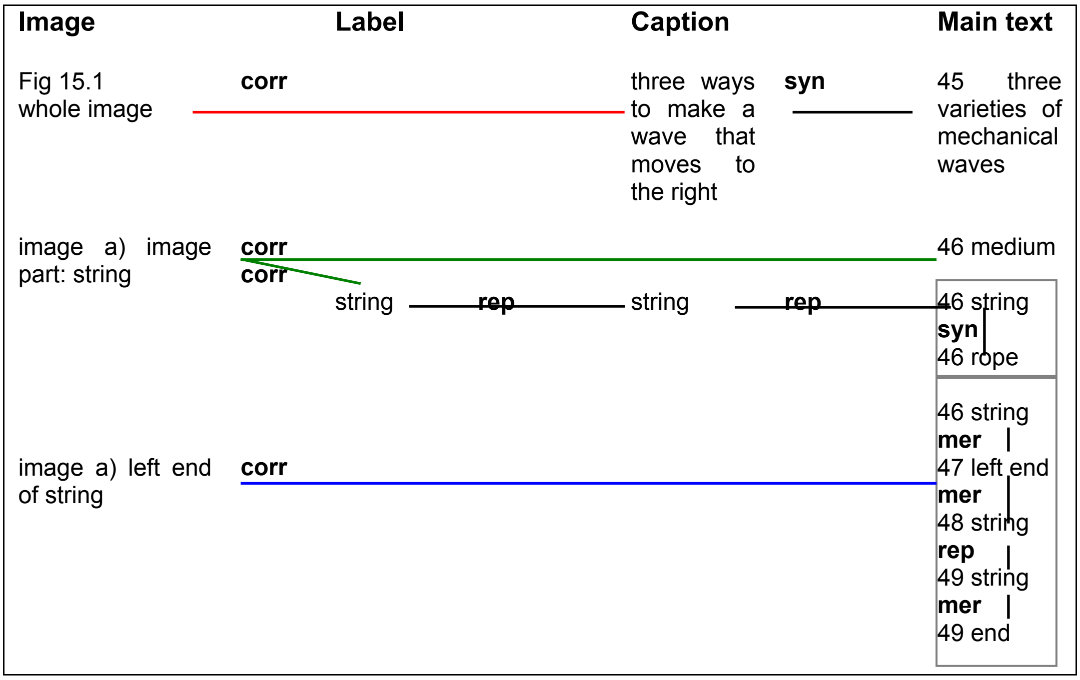
Figure 7.17. Enlarged image, caption and labels of 15.1 (Young & Freedman, 2004, p. 548).

As discussed under activity sequences in 7.4.1, the image in Fig 15.1 is a composite of three pairs of images making up the whole figure, which is a Conceptual Classificational process depicting a taxonomy of three different types of mechanical waves: transverse, longitudinal and combined transverse and longitudinal waves. The superordinate is set up in the heading for section 15.1 **Types of Mechanical Waves**, which is repeated in the main text clause 45:

> Figure 15.1 shows three varieties of mechanical waves.

Following is an extract from the analysis of Figure 15.1(a), of Clauses 45-49 in the main text and the related image, label and caption. This will form the basis for the discussion of **[7:20].**

[7:20]



In the verbal component, the black strings in the extract show relations of *synonymy* (e.g. between string and rope in Clause 46 of the main text); *repetition* of text elements across main text, caption and label (e.g. string in Clause 46 and string in the caption and label); and *meronymy* (e.g. between string and left end in Clauses 46-47). The whole image/text segment analysed in Appendix E, Table E2.2 also found many instances of intersemiotic correspondence linking text and image, some of which are shown in **[7:20]** by the green string and marked (**corr**). Some occurred at the level of clause and whole image, as in the correspondence between the caption and the whole image of Fig 15.1, shown by the red line in **[7:20]**. Others were at the level of nominal or verbal group and image part, such as that marked by the blue line in **[7:20]**.

In the same extract, relations of hyponymy were also set up across semiotic resources. The whole segment is about types of mechanical waves and how they are produced in different media. The taxonomy, introduced in a generalised way in clause 41: [a mechanical wave is a disturbance that travels through some material or substance called the medium for the wave] is first set up across verbiage and image.

[7:21]

Image	**Label**	**Caption**	**Main text**
image a)	**hyp** **hyp**	three ways to make a wave that moves to the right	45 three varieties of mechanical waves
co-hyp		**hyp**	**hyp**
	hyp transverse wave	transverse wave	51 transverse wave
	hyp	**co-hyp**	**co-hyp**
image b)	longitudinal wave	longitudinal wave	56 longitudinal wave
co-hyp		**co-hyp**	**co-hyp**
image c)	combined transverse and longitudinal wave	a combination of longitudinal and transverse waves	60 both longitudinal and transverse

As shown by the green string in **[7:21]**, the superordinate of the taxonomy is found in the nominal group in clause 45 [three varieties of mechanical waves] and again in the caption [three ways to make a wave that moves to the right]. The subordinates occur in the main text in clauses 51, 56 and 60, are repeated in the caption, in the label and in the image as co-hyponyms (the black string). The pink string shows how hyponymy was realised across resources, although the cohesive ties may be read multidirectionally (e.g. from image to label to caption to main text or from main text to image to label to caption), depending on how the student chooses to read the text. The cohesive use of symbols such as arrows on the image (see Figure 7.17, p. 202 for reference) also function intersemiotically. Arrows signify different types and directions of movement of both the medium and the particles of the medium (up and down; back and forth, up; down, circular). For example, in image b), the longitudinal waves in a fluid, the superordinate for movement of the particles occurs in the main text [this time the motions of the particles of the medium are back and forth along the same direction that the wave travels] and for movement of the medium the superordinate occurs in the caption [the piston moves to the right and then returns] while the subordinates are realised symbolically by the arrows. The consistent use of colour and size in these arrows adds another dimension of cohesion.

On the Display plane, ideational cohesion in image and verbiage is also reinforced by juxtaposition, in the relative positioning of the whole figure and sub-images to the labels and caption. Colour is also cohesive ideationally across the three smaller images, with the choice of the same colour to represent the hands (light brown), the string (brown), the fluid medium (blue), and the arrow for wave speed (green). Font is cohesive in the consistent choice of font style (serif) and font size for main text, captions and labels.

The image/verbiage/visual display correspondences serve to create tightly integrated meanings across image, label, caption and main text, reinforcing the experiential content for the student reader. The cohesion analysis revealed intersemiotic complementarity in the relations of correspondence, hyponomy and meronymy as well as redundancy in the relations of repetition. In pedagogic texts of this nature, rarely would the image be expected to be interpreted on its own without the text. In other words, some degree of redundancy should exist between text and image to facilitate student understanding. The extent to which this can be said to apply to a screen format will be explored further in the next example.

Intersemiotic experiential cohesion in the biology CD-ROM

As a contrasting example to the textbook format intersemiotic experiential relations were analysed for Activity 31A in the biology CD-ROM. Interestingly, the same degree of intricacy of cohesive relations across text and image as in the physics textbook example or even in the biology textbook was not found in the screen text. The full analysis can be found in Appendix E, Table E2.3. The analysis tracked a) the intersemiotic experiential cohesive relations between the text, still image and animated image in all screens; and b) the relations in the verbiage set up across screens through hyperlinks between the main text and the glossary, which appears as a separate smaller screen on the main screen. Students can choose to activate any (or none) of the hyperlink glossary terms on the active screen at any time during the unfolding text, which is viewed on screen and read aloud by a woman's voice. After one hyperlink has been activated the glossary screen appears as a pop-up with the definition of the term. Students can then either close that glossary screen or click on another hyperlink in the on-screen text and the glossary screen for the new term appears. They can also move the glossary screen elsewhere on the main screen. Figure 7.18, which will be discussed as example **[7:22]** shows Screen 2 with the glossary screen activated after clicking on the first hyperlink 'spores' in the main text on the top right, indicated here by the red line.

[7:22]

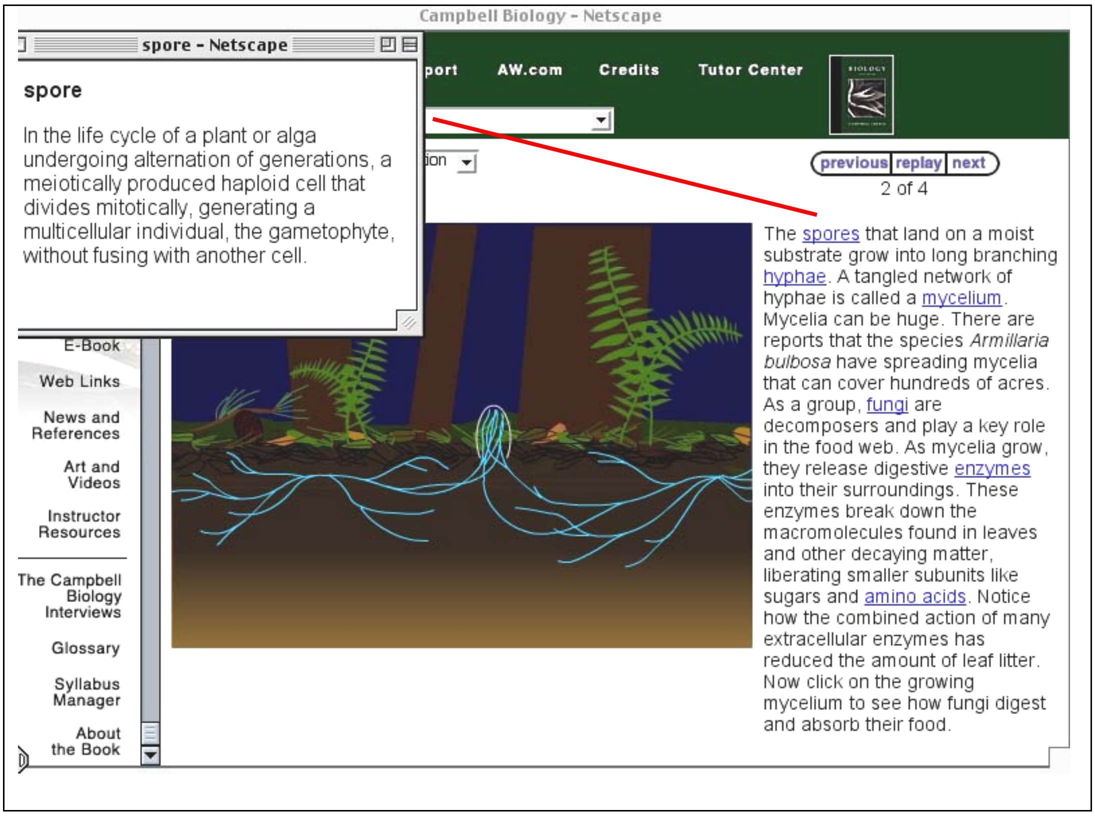


Figure 7.18. Biology CD-ROM Activity 31A with main screen and glossary screen activated for the technical term hyperlink ‘spores’ (Campbell, 2002).

Analysis of the cohesive ties showed complex patterns were set up in the verbiage through the interaction of the two screens. Relations of repetition occurred between the main text screen hyperlink, the glossary term on the glossary screen and its definition. The hyperlink terms appear on the subsequent main screens of the activity and can be activated again. Repetition of the hyperlinked term occurs in the main text but was not always realised as a hyperlink. Cohesive relations could also occur between items on the glossary screen with no link to the main screen text.

The hyperlink ‘spore’ is also intersemiotically cohesive. It is a key term for the activity in which the text, image and animation are all about the reproduction and nutrition of fungi through the production of spores. The animation shows the spores leaving the mushroom gills, growing into hyphae and then into a network of hyphae called a mycelium. Later in the activity the animation shows how the hyphae develop into cells which undergo meiosis and produce spores. The main text supports the animation in guiding the student through the activity and in explaining what is going on in the animation.

As was observed in the discussion of technicality in 7.2.1, p. 174, this text had the highest level of verbal technicality of the six texts but a low level of visual technicality. Most of the verbal technicality however, occurred in the glossary, which expands the key terms with definitions. Only a small proportion of the verbal technicality from the glossary is fed back into the main text. Moreover, the drawings are not the highly technologised images such as the micrographs found in the biology textbook and have no captions and few labels. In both textbooks technical terms were defined in the main text and could re-appear in the labels and captions. In the biology CD-ROM, because of the constraints of space on the screen, the hyperlinked technical terms and their definitions in the glossary screen function to flesh out the technicality of the main text but are not as well integrated into either the main text verbiage or the image as in the textbooks.

Thus both image and text are deployed to create discipline specific taxonomies in biology and physics and hence the technicality of the field. The examples discussed above of experiential cohesion across semiotic resources, can be seen to illustrate the intersemiotic mechanism of semiotic cohesion (O'Halloran, 2005, p. 169). Such intersemiotic mechanisms, as we have seen, 'generally involve a two-way directional investment of meaning' (O'Halloran, 2005, p. 170). From a pedagogical point of view, I would argue that the experiential cohesive relations across the main text, image, image parts, labels and caption in the physics textbook exemplify the 'best' bi-directional investment of meaning, one which would facilitate student reading and understanding, while the biology textbook and is less effective and the screen text is a much poorer example. In other words, the level of redundancy and explicitness across semiotic resources contributes to the pedagogical effectiveness of the physics textbook.

7.4.3 Logico-semantic relations across text and image

Complementing the experiential analyses, analysis was carried out of logical meaning in activity sequences involving text and image in the biology CD-ROM and of logico-semantic relations found in image/text complexes in the textbooks. Each of these analyses will be discussed in the following sections. Analyses can be found in Appendix E, Tables E1.1, E3.1, E3.2.

<u>Logical relations in activity sequences in the biology CD-ROM</u>

Activity sequences across text and image have already been discussed from the perspective of experiential meanings in activities. However, at the discourse level, semantic expansions occur through the logical structure of the sequence, realising expectancy (*and/then*) or implication (*if/then*) relations.

In discussing activity sequences, Martin (1992, p. 537) draws on Barthes' (1977, p. 101) notion of sequence in narrative structure as 'a logical succession of nuclei bound together by a relation of solidarity (in the Hjelmslevian sense of double implication: two terms presuppose one another)'. But Barthes (1977, p. 102) also describes a sequence as 'a threatened logical unit', involving 'moments of risk' which can introduce an alternative at any point in the sequence. Although this may be typical of the narrative genre, such relations of counterexpectancy, or 'threatened' logical relations, were not a feature of text and image activity sequences in these science texts. In example **[7:15]** of the fungal life cycle drawing discussed on p. 189, the logico-semantic relations between successive images in the cycle show an interplay of temporality (succession), indicated by the direction of arrows, and spatiality in the location of the visual activities in the sequence. The eye follows the direction of the arrows to link the labelled images in the sequence, while the colour, size and shape of the images further indicate the cohesion of the sequence. There is no question, however, that at any point the sequence could be interrupted or threatened. The logical order is fixed – the images must follow each other in the order depicted and one image/text unit necessarily implies the other.

The image sequences in the animations on the biology CD-ROM follow a similar fixed order, predetermined also by the technology used to construct the animation. The student cannot interrupt the sequences or the voice over text which accompanies them. For example, the animated image sequence on Screen 1 of Activity 31A, which unfolds in this order,

spores leaving fungus gills
spores floating to right
spores landing on ground
one spore moving off to right

involves spatio-temporal logical relations of succession. Each activity or movement in the sequence is dependent on the one before, thereby successively expanding its meaning. The whole sequence lasts no more than four seconds and unfolds within just one shot as a continuous succession of movements, interrelated logically and experientially. At the same time, the voice-over text on the audio/written track accompanying the animation is logically related to the image sequence, adding another layer of meaning. The analysis is shown in **[7:23]**. The brackets indicate the activity sequences in the animated image on the left and the text on the right.

[7:23]

Animated image activity sequence in visual track		**Clauses in audio/written track which relate to image sequence**
		4. as we'll see later in this **activity**
1.spores leaving fungus gills 2. spores floating to right 3. spores landing on ground 4. one spore moving off to right	=	5. Fungi reproduce sexually or asexually 6. by producing spores, 7. which are dispersed by the wind

The animation begins in Clause 4, synchronous with the word activity, shown in red. The analysis shows an elaborating relation across the text and image activity sequences. The image sequence, however, only partially elaborates clauses 5-7 on the audio/written track. The words reproduce sexually or asexually in Clause 5 are not fully elaborated or unpacked by the image until Activity 31B, a new module which depicts asexual and sexual reproduction in fungi. Van Leeuwen (1991, p. 77) argues that logical relations can exist between the audio and visual tracks in film as well as within each of these tracks.

<u>Logical relations across image/text complexes in the textbooks</u>

The reasoning behind the analysis of logical relations across image and text complexes was described in 6.6.4 (p. 145 ff.). The type of logico-semantic relation of expansion in image/text complexes and inter-image complexes was analysed for each textbook. The full analyses can be found in Appendix E. The following discussion of **[7:24]** is of the logico-semantic relations between text and image and inter-image for the biology textbook extract shown in Figure 7.19. For reference, the images are numbered on the figure. The intersemiotic experiential cohesive relations of this extract have been discussed in examples **[7:17]** to **[7:19]**.

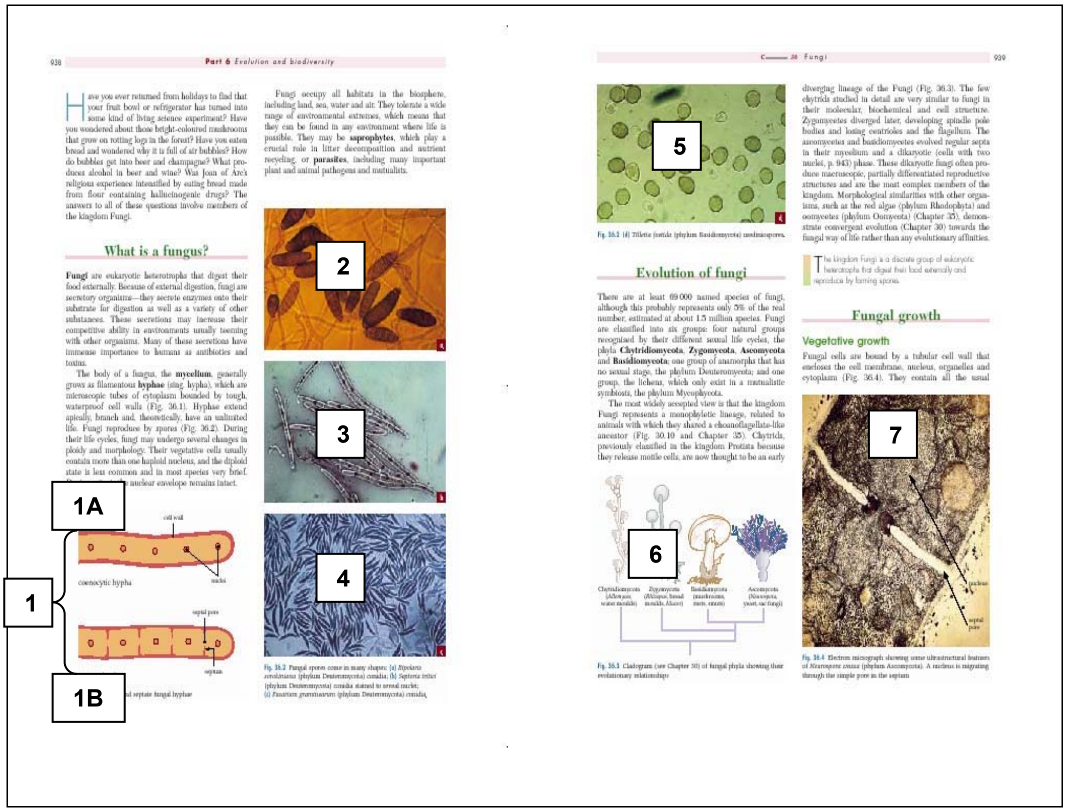


Figure 7.19. Two-page spread from the biology textbook showing numbered images (Knox et al., 2001, p. 938-939).

First, the key to the analysis and the types of relationship are shown in Table 7.8:

Table 7.8

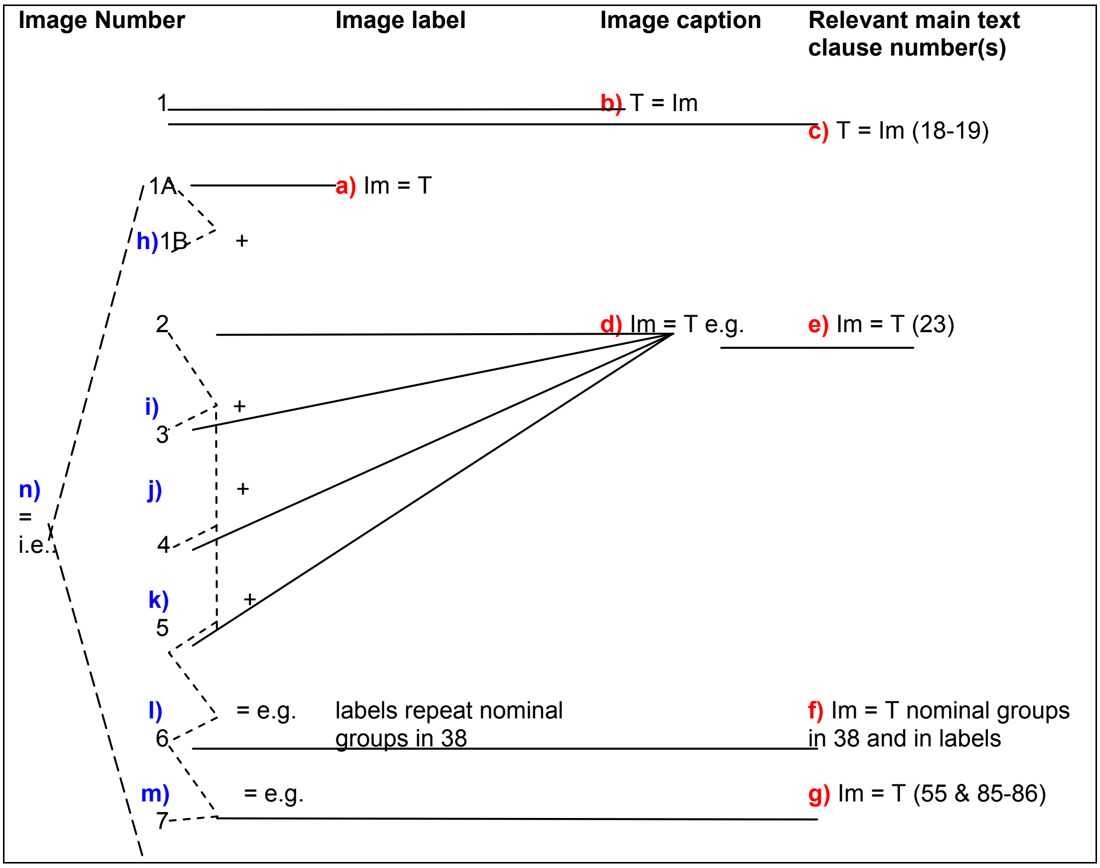
Key to Analysis of Logical Relations

Types of logical relation: Expansion		Types of bi-directional complex across text and image
=	elaboration with sub-types:	Intersemiotic T = Im Im = T
i.e.	exposition; 'in other words'	
e.g.	exemplification: more specific	
viz	clarification 'to be precise' 'explanation'	Intrasemiotic Im = Im
+	extension	Intersemiotic T + Im Im + T Intrasemiotic Im + Im

As explained in 6.6.4 interdependence in image/text complexes was analysed as bi-directional, where neither element can be seen to be dominant or dependent. In intersemiotic elaborating relations, text and image work closely together, 're-stating' or exemplifying elements in a different semiotic resource or specifying an aspect of the text or image in greater detail. In intrasemiotic elaborating relations one image or image element elaborates or exemplifies another image or image element. In extending relations the verbal element extends the visual element (or vice versa) by adding a new element or intrasemiotically, one image or image element extends another.

Example **[7:24]** is an extract from the biology textbook analysis. It shows both *image/text* complexes, numbered a) –g) in red and marked by solid horizontal or oblique lines and *inter-image* complexes marked by oblique dashed lines and numbered h) –n) – in blue. The full analysis can be found in Appendix E, Table E3.1.

[7:24]



Logico-semantic relations were found between image and image label, image and caption, and image and main text and between images. Relations were between the whole image and a nominal group in the verbiage, between the whole image and clause or clause complex, between image elements and a nominal group or between an image element and clause or clause complex. The verbal elements often served to 'reflect' or reinforce the meaning of the image or vice versa. Where this occurred the two were seen to be in a relationship of co-contextualisation (Lim, 2006; O'Halloran, 2005).

All of the image/text relations across main text, label caption and image in **[7:24]** were elaborating, while the inter-image relations were elaborating or extending. The image/text complex **a)** is an elaborating relation between the image part depicting a cell wall in 1A (see Figure 7.19, p. 212) and the nominal group [cell wall] in the label. Similar relations exist between the image parts and labels in image 1A and 1B (see Figure 7.19) but, for space reasons are not shown in the analysis extract in **[7:24]**. The text/image complex **b)** is an elaborating relation between the nominal group complex [Coenocytic and septate fungal hyphae] in the caption and the whole image. Text/image complex **c)** is an elaborating relation between the main text clauses 18-19:

CI BIOLOGY TEXTBOOK

18 The body of a fungus, the mycelium, generally grows as filamentous hyphae (sing. hypha), 19 which are microscopic tubes of cytoplasm bounded by tough, waterproof cell walls (Fig. 36.1).

and the whole image. The image/text complex in **d)** is initiated by the caption [fungal spores come in many shapes] and continued by images 2, 3, 4, and 5 (see Figure 7.19) in an elaborating image/text complex, which exemplify different spore shapes. There is also an elaborating text/image complex in **e)** between the main text clause 23 [Fungi reproduce by spores (Fig 36.2)] and the four images exemplifying spores. It is interesting that the caption elaborates the topological aspect of *shape* of the spores of specific fungi from different phyla, while the main text simply identifies that spores are depicted in the images. Without the caption, the images would be unidentifiable to a student reader. The complexes in **f)** and **g)** are between nominal groups in the main text clauses, the labels and image elements. In **f)** the four sub-images in Image 6 elaborate, by specifying visual detail, the main text clause 38 which contains the nominal groups [the phyla Chytridiomycota, Zygomycota, Ascomycota and Basidiomycota] and the labels [Chytridiomycota, Zygomycota, Ascomycota and Basidiomycota]. In **g)** Image 7 in Figure 7.19 is elaborated firstly by the caption clauses [Electron micrograph showing some ultrastructural features of *Neurospora crassa* (phylum Ascomycota)] and [a nucleus is migrating through the simple pore in the septum], and secondly, by the main text clause,

CI	BIOLOGY TEXTBOOK
55	Fungal cells are bound by a tubular cell wall that encloses the cell membrane, nucleus, organelles and cytoplasm (Fig. 36.4).

and then again much later in the main text by clauses 85-87.

CI	BIOLOGY TEXTBOOK
85	Septa grow centripetally inwards from the cell wall,
86	leaving a pore at the centre.
87	These pores allow for nuclear migration and cytoplasmic continuity (Fig. 36.4).

The same image can also be seen to form an elaborating inter-image complex with image 1A in **n)** as it 're-depicts' the drawing of a septal pore in the septum (or septal wall) in Image 1A as an electron micrograph of a septal pore in the septum. Thus the technology of electron microscopy plays a role in establishing visual technicality, translating the simpler drawing in Image 1 into a more expert representation. The remaining inter-image relations **h)** –**m)** are either elaborating or extending. Images 1A and 1B, of two types of fungal hyphae, are related through extension, as Image 1B adds new elements to Image 1A, i.e. septal pores and septal walls, thereby differentiating the two drawings. The image is reproduced below in Figure 7.20, where I have shown the added elements using the blue arrows. The new elements also occur in the original as labels.

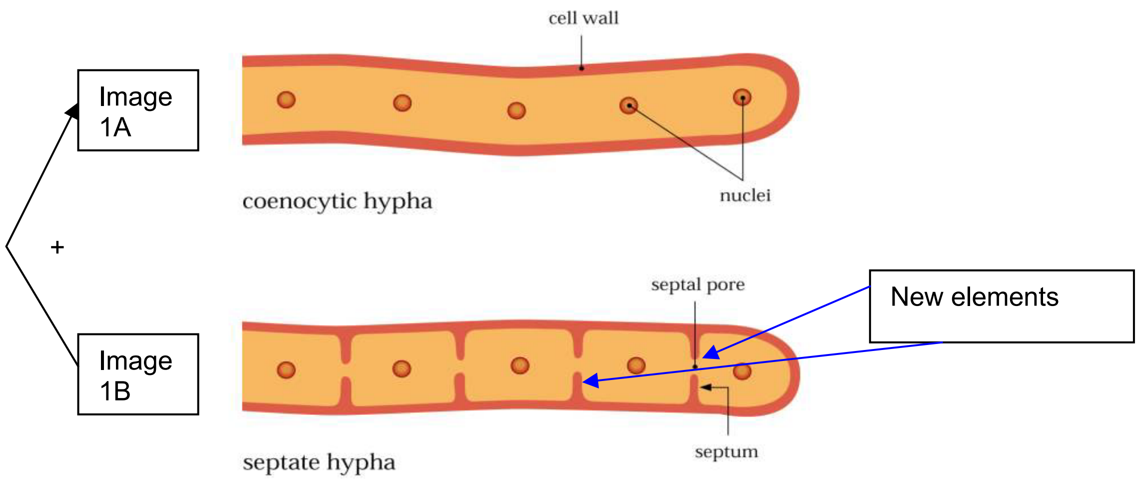


Fig 36.1 Coencytic and septate fungal hyphae

Figure 7.20. Extending relations between image 1A and image 1B showing new elements (Knox et al., 2001, p. 938).

Similarly, there are extending relations in the inter-image complex between Images 2, 3, 4 and 5 on Figure 7.19, shown by the dotted lines at **i)**, **j)** and **k)** in **[7:24]**. Each subsequent image to Image 2 adds a new element in the different shape of the fungal spores. The remaining inter-image complexes at **l)** and **m)** are examples of elaborating relations but function differently from the previous elaborating complex at **i)**, **j)** and **k).** In **l)**, one of the four smaller images in Image 6 is a drawing of a typical fungus from the phylum Basidiomycota, while the spores of a real example of a fungus from this phylum are shown in Image 5. A similar relationship exists in **m)**. Image 7 is an electron micrograph of some ultrastructural features of a member of the Ascomycota group, thereby elaborating the macroscopic drawing of a typical example of this phylum in Image 6. The relationship between the macroscopic generalised drawing in Image 6 and the specific microscopic image in Image 7 is not only interesting from the perspective of logical relations. There are also changes in interpersonal meaning in the shifts from the more naturalistic drawing to the highly specialised micrograph, and changes in textual meaning, in the degree of specificity of each image. These points will be taken up in 7.5 and 7.6.

In the physics textbook, similar inter-image and image-text logical relations of expansion were found across the image, caption, label and main text which related to Figure 15.1, discussed in **[7:20]** and **[7:21]** under cohesion. The image and caption are reproduced in Figure 7.21, with the images numbered for reference purposes.

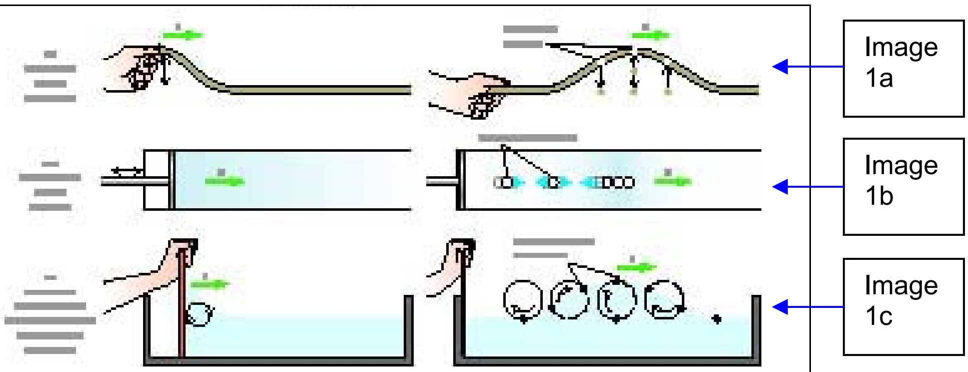
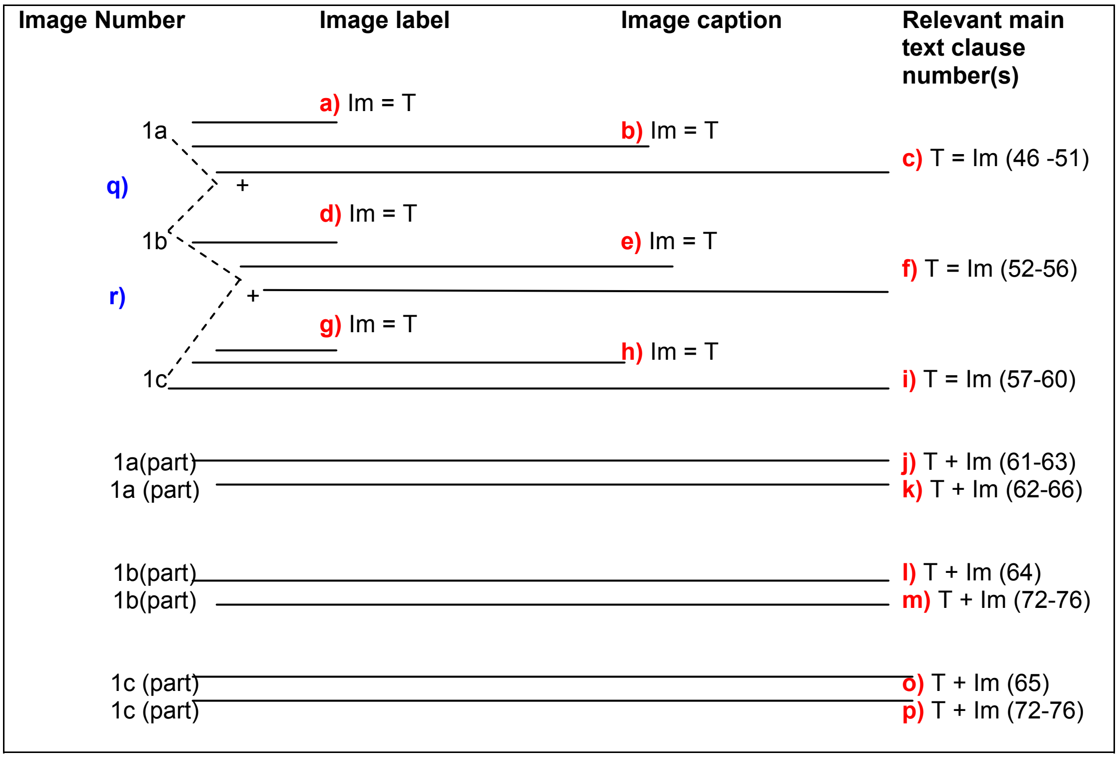


Fig 15.1 Three ways to make a wave that moves to the right. (a) The hand moves the string up and then returns, producing a transverse wave. (b) The piston moves to the right, compressing the gas or liquid, then returns, producing a longitudinal wave. (c) The board moves to the right and then returns, producing a combination of longitudinal and transverse waves.

Figure 7.21. Figure 15.1 in the physics textbook showing numbered images (Young & Freedman, 2004, p. 548).

Example **[7:25]** of the image, label, caption and main text of Figure 15.1 shows the analysis of the inter-image complexes - **q) –r)** – and image-text complexes - – **a) –p)**. The full analysis can be found in Appendix E, Table E3.2.

[7:25]

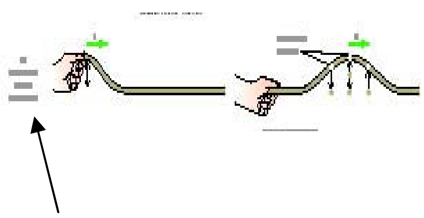


In **q)** and **r)** Images 1a, 1b and 1c form an extending image complex, each adding new elements to the next. The three images depict a taxonomy of different types of waves and build up the visual taxonomy by successively adding image elements such as the piston (Image 1b) or the trough (Image 1c), the depiction of the different movement of particles in 1a and 1b and in the different media through which the waves travel – the string (1a) and water (1b and 1c).

The remaining complexes between image and text were either elaborating or extending and were similar to the complexes discussed in the biology textbook. The closer the main text was to the image and its caption and labels, the more likely it was to be elaborating the image or being elaborated by the image. The further away the text was, the more likely it was to add a new element to a part of the image, such as the explanation of the symbol *v* for wave speed, or the explanation of the equilibrium state, which, to a non expert reader, are not immediately retrievable from the image.

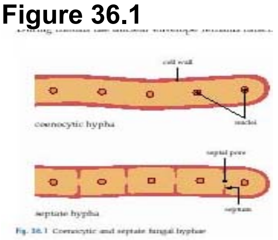
However, compared to the biology textbook example, the domain and intricacy of the text image relations in the physics textbook example were quite different. The whole figure and its constituent images were tightly integrated with the caption, label and running text, spanning 1.5 pages over a range of 36 consecutive clauses, whereas the first figure in the biology textbook spanned only five clauses (clauses 18-19, and then 84-86), which were spread over three pages. The text-image relations in the physics figure were also more intricate, with the running text elaborating the caption and the image. All parts of the image are explained in the text and a reduced version of the text is found in the caption, as the next example, **[7:26]** will elucidate.

[7:26]

Figure 15.1a and main label	**Caption**	**Main text clauses**
 (a) Transverse waves on a string.	(a) The hand moves the string up and then returns, producing a transverse wave.	46 In Fig 15.1a the medium is a string or rope under tension. 47 If we give the left end a small upward shake or wiggle 48 the wiggle travels along the length of the string. 49 Successive sections of string go through the same motion that we gave to the end, but at successively later times. 50 Because the displacements of the medium are perpendicular or transverse to the direction of travel of the wave along the medium, 51 this is called a transverse wave.

In Figure 15.1a shown above, the main text elaborates the image, label and caption over six consecutive clauses (clauses 46-51). Each of the other two smaller images of different types of waves (image 1b and 1c in Figure 7.21, p. 218) showed a similar degree of intricacy with the label, caption and main text all serving to reinforce each other. The same degree of intricacy cannot be said for the biology drawing in Figure 36.1, discussed as example **[7:27]**.

[7:27]

Figure 36.1	**Caption**	**Main text clauses**
	Fig 36.1 Coencytic and septate fungal hyphae	18 The body of a fungus, the mycelium, generally grows as filamentous **hyphae (sing. hypha),** 19 which are **microscopic tubes of cytoplasm** bounded by tough, waterproof **cell walls** (Fig. 36.1). 84 Septa (sing. septum) are cross-walls that form after mitosis. 85 Septa grow centripetally inwards from the cell wall, 86 leaving a pore at the centre.

Here, the drawing is loosely related, experientially but not logically, to the caption and main text near the drawing in clauses 18 and 19, in the words I have marked in bold. In these clauses the main text introduces new technical terms [mycelium] [cytoplasm] which are not not fully explained or marked on the drawing. The drawing also refers to technical terms [septum] [septal pore] which are not fully explained in the main text until clause 84, two pages further on. The student is therefore left to do a lot of work in unpacking the technicality of the text. Overall, this is borne out by the other intersemiotic ideational analyses. The verbal component of the activity sequences, the experiential cohesion and the logical relations of both the biology textbook and biology CD-ROM were not reinforced by the images to the same degree of intricacy as in the physics textbook.

In conclusion, if the need for explicitness in ideational meanings across semiotic resources for the student reader/user of these texts is acknowledged, analyses such as those undertaken in 7.4 could have important implications for learning. Understanding the mechanisms of intersemiosis through analysis of transitions across different modes and forms of semiosis and of the degree redundancy between text and image could be a useful step towards a more explicit and effective educational design of learning resources.

7.5 Interpersonal metafunction

As argued in Chapter 1, because of the need to limit the scope of the analysis, the main focus of this thesis is on multimodality and intersemiosis in ideational meaning. The interpersonally-oriented analysis, although less comprehensive, was related to the areas of negotiation and scientific realism, which will form the basis of the discussion in this section. The analysis set out firstly to explore how pedagogical roles such as reader/viewer/learner and writer/teacher/designer/knower were being constructed as the discourse unfolded in the pedagogical activities on the page and screen. This was done to compare the notion of interactivity in page and screen formats (research questions 3 and 4). Secondly, to examine the role of disciplinary variation, the notion of scientific realism was explored briefly through an analysis of mood and modality across text and image (research question 5).

7.5.1 Negotiation and interactivity in the textbooks

Interpersonally, both textbook chapters are introduced in similar ways. In each there is a photograph which is interpersonally oriented, designed to engage the student reader in the topic – a dramatic picture of a scene after an earthquake in the physics textbook and an enlarged digitally faded image of a fungus in a woodland setting in the biology textbook. These images serve a different function from most of the other images in the chapters, which are more experientially oriented. The opening paragraphs of each chapter also reflect the interactive purpose of this introductory segment, which is to engage the reader's interest in the topic through the use of questions and personal subjects 'you' and 'we'.

In the opening paragraph of the Biology textbook, 7 of the 12 clauses in **[7:28]** are questions, which culminate in 'the answer', the Hyper New in clause 12. This effectively sets up the topic for the whole chapter.

[7:28]

Cl	BIOLOGY TEXTBOOK
1	Have **you** ever returned from holidays
2	to find
3	that **your** fruit bowl or refrigerator has turned into some kind of living science experiment?
4	Have **you** wondered about those bright-coloured mushrooms that grow on rotting logs in the forest?
5	Have **you** eaten bread
6	and wondered
7	why it is full of air bubbles?
8	How do bubbles get into beer and champagne?
9	What produces alcohol in beer and wine?
10	Was Joan of Arc's religious experience intensified
11	by eating bread made from flour containing hallucinogenic drugs?
12	The answers to all of these questions involve members of the kingdom Fungi.

The reader is directly addressed as 'you' and invited to embark on a voyage through the chapter to discover the answers to the questions. However, nowhere else in the main body of the chapter is the reader directly addressed. The interactive relationship between writer/teacher and reader/student is thus backgrounded after clause 12.

Similarly, in the opening segment of the physics chapter, the following question is asked in the text appearing alongside of the image of the earthquake.

> Which aspects of a seismic wave determine how much power is carried by the wave?

The question is introduced by a small image of a question mark inside a thought bubble, as shown in Figure 7.22, inviting the reader to think about the answer, which serves the purpose of orienting the reader to the topic of the chapter.

Figure 7.22. Opening page of physics textbook chapter showing interpersonal orientation to the topic (Young & Freedman, 2004, p. 547).

The invitation to readers to be joint ‘discoverers’ of the topic is extended in the opening paragraphs, where several clauses use the subject ‘we’ and the complement ‘us’, as shown in **[7:29]**.

[7:29]

Cl	PHYSICS TEXTBOOK
20	**We**’ll begin this chapter
23	To help **us** understand waves in general,
24	**we**’ll look at the simple case of waves that travel on a stretched string or rope.
29	**We**’ll discover
34	(In the next chapter **we**’ll find

However, unlike the biology textbook, the relationship between the writer and reader in the physics textbook continues to be interactive. The use of personal subjects ‘you’ and ‘we’ and the use of the imperative is sustained throughout the main text of the chapter, resulting in a much more personal and conversational style, akin to classroom talk, as the following sentences in **[7:30]** show.

[7:30]

PHYSICS TEXTBOOK

Let’s see how to determine the form of the wave function for a sinusoidal wave (p. 552).

You may want to review the discussion of periodic motion in Chapter 13 before going ahead (p. 549).

To understand the mechanics of a periodic longitudinal wave, we consider a long tube filled with a fluid, with a piston at the left end as in Fig 15.1 (p. 551).

Be very careful to distinguish between the motion of the transverse wave along the string and the motion of a particle of the string (p. 550).

As always, make sure that you identify the target variable(s) for the problem (p. 555).

If you double the wavelength of a wave, what happens to the speed of the wave? (p. 552)

Moreover, the preliminary *Systemics 1.0* (O'Halloran & Judd, 2002) analysis showed speech functions were often commands, with imperative mood used for problem-solving steps or working through equations in the main text or questions, with interrogative mood used for checking students understanding. Interestingly, this personal style does not occur in the image captions, which are all in declarative mood.

Thus in the physics textbook, the reader is positioned as a student in an interactive relationship with the writer/teacher, engaged in a series of problem solving activities (which could occur in a classroom), whereas in the biology textbook, apart from the opening paragraph, the reader is not directly addressed and is positioned as a dutifully passive and comprehending student, as in a lecture. This bears out Thibault's claim that 'school science textbooks negotiate between notions of expertise and authority on the one hand, and notions of apprenticeship and accessibility' (Thibault, 2001, p. 318). The above discussion has shown that the textbooks of this corpus approached the student reader in different ways in the negotiating between expertise and apprenticeship.

7.5.2 Negotiation and interactivity in the CD-ROMS

As discussed in Chapter 5, both CD-ROMs involved interactive activities for the student user such as problem-solving tasks, labelling images from pull-down menus or multiple choice questions with built-in feedback. In the biology and physics CD-ROM, the dynamics of exchange structures across text and image was analysed from a discourse semantics perspective: a) to establish how pedagogic roles were being played out throughout the sequence of interactive moves on the screen during an on-screen activity; and b) to test the publishers' claims of interactivity of such activities. Exchanges were analysed following Martin (1992 pp. 31-91), and following the Speech Function network presented in 6.7.1 p. 151. Moves in the exchange were analysed for speech function and sequence in the exchange. The full analysis can be found in Appendix E, Tables E4.1 and E4.2.

<u>Biology CD-ROM</u>

Both Activity 31A and Activity 31B were analysed in the biology CD-ROM. Each has different patterns of negotiation. On the five screens in Activity 31A there are only three exchanges, all action or goods and services exchanges, in which the student/user is given a command to carry out some action relating to the image. For example, on Screen 3 the student, marked S on the analysis extract in

[7:31], is instructed by the voice-over text, marked T= teacher, to click on the image of the mushroom to see the spore-producing microscopic structure of the mushroom gills. As a result of the student's response to this command, the image moves and changes into an enlarged section of the gills.

[7:31]

Activity 31A: Clause	**Image/ action**	**Exchange across text and image**	**Speech function**	**Role**
37 Click on the mushroom gills		A2	Command	T
38 to see the structures that produce these spores	S does this	A1:nv	Resp to comm:comply	S

This is a simple A1^A2 exchange consisting of two moves, but one which involves the student's non-verbal response of clicking the image. If the student does not comply with the command, the choices he/she has are to replay the screen, to go back, to go forward to the next screen or to quit the activity. These moves can be seen as dynamic rather than synoptic as they have the potential to interrupt or abort the exchange. Deviating from the default exchange is one way in which the dynamic potential of the medium can be exploited. Also in this activity, the 'teacher' has the lion's share of the discourse, with the student passively listening to the voice-over text. The long sequence of declarative statements by the teacher as the primary knower is interrupted only three times by exchanges with the student, all of which are commands like those in **[7:31]**.

Similarly, in Activity 31B on fungal life cycles, there are exchanges consisting of commands from the teacher in which the student has to complete the steps in the life cycle drawing by choosing the correct word from a pull-down menu as shown in the sequence of screenshots in Figure 7.23.

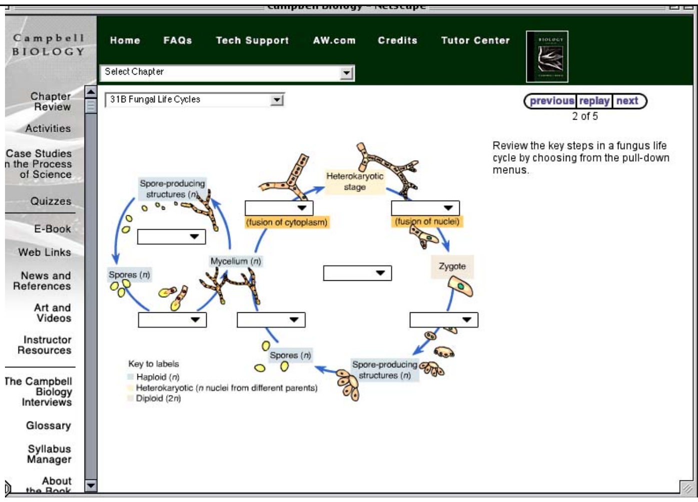
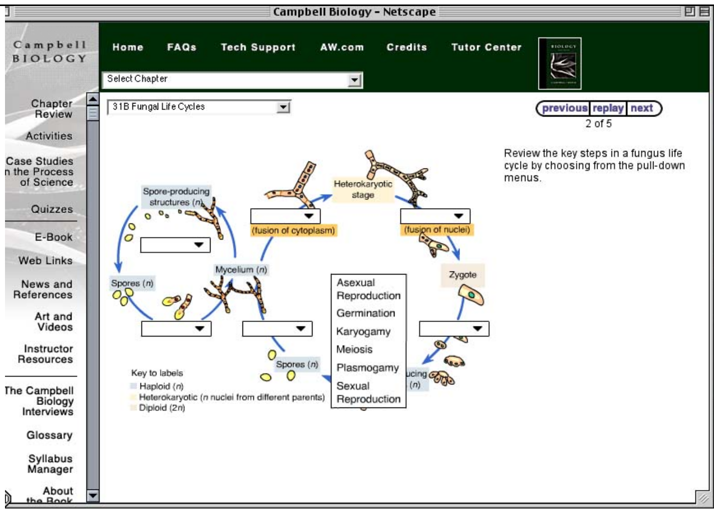
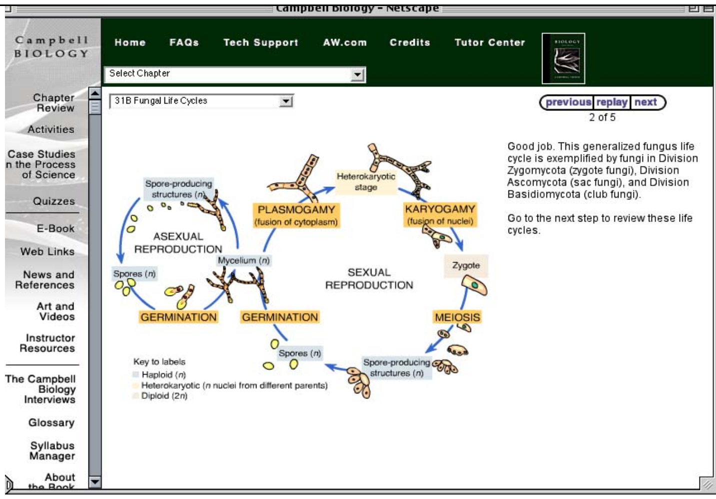
<table>
<tr><th>Screen No</th><th></th></tr>
<tr><td>31B:2</td><td>
</td></tr>
<tr><td>31B:2a
View of 31B:2 with one pull-down menu activated</td><td>
</td></tr>
<tr><td>31B:2b
View of 31B:2 with all pull down menus completed</td><td>
</td></tr>
</table>

Figure 7.23. Screenshots of Activity 31B showing changes after student activates one pull-down menu and all pull-down menus (Campbell, 2002).

Interestingly, the exchanges in this activity are more like classroom discourse in that they have feedback moves following the completed action by the student, as in the next example.

[7:32]

Activity 31B: Clause	**Image/action**	**Exchange across text and image**	**Speech function**	**Role**
21 Review the key steps in a fungus life cycle **α**		A2	Command	T
22 by choosing from the pull-down menus. **xβ**				
	S does this and completes all menus	A1	Resp to comm:comply	S
Good job		A2f	Follow-up	T

This follow-up move giving positive feedback [Good job] only happens after the student has finished the task of completing all menus. If the student makes a mistake and chooses the wrong word from the menu, 'negative' feedback is given by a horn sound and the student must try again until the correct option is chosen.

<u>Physics CD-ROM</u>

The activities on the physics CD-ROM, on the other hand, are more complex in their exchange structure. Although some of the exchanges in the *Interactive Exploration* activities involve the student interacting with the images as in the biology CD-ROM, others involve interaction with text and mathematical symbolism rather than images. I will take one example of the latter type from the *Warm-up* activity, which is structured as series of multiple-choice questions and answers to test student's knowledge on the topic of waves and sound. If the student selects a correct answer, positive feedback [yes] is given in the written text but the student is also encouraged by a written command to check the correct solution to the problem. If the student chooses an incorrect answer, negative feedback [no] is given but the student is then given a hint before trying again. Each time an incorrect solution is selected, a different hint is given. The sequence in **[7:33]** shows how the interaction unfolds if the student chooses incorrect answers.

[7:33]

Warm-up Waves and Sound: Physics: Clause	**Image/action**	**Exchange across text and image**	**Speech function**	**Role**
What is the frequency of a wave if a single cycle lasts 0.50 min? a) 2.0 Hz b) 30 Hz c) 3.3 Hz d) 0.033 Hz e) none of these		Dk1	Question	T
	S clicks a)	K2	Resp to question	S
No		ch	Challenge	T
You've got to use T in seconds.		cl	Clarification	T
Remember that f=1/T		cl	Clarification	T
and rework the problem		cl	Clarification	T
	S clicks b)	rcl	Resp to clarification	S
No		ch	Challenge	T
This period is rather long (T=0.5 min)		cl	Clarification	T
Remember that f=1/T		cl	Clarification	T
	S clicks c)	rcl	Resp to clarification	S
No		ch	Challenge	T
This answer corresponds to a period of 0.3s not f=1/T		cl	Clarification	T
	S clicks e)	rcl	Resp to clarification	S
No		ch	Challenge	T
Keep in mind that f=1/T		cl	Clarification	T
and try it again		cl	Clarification	T
	S clicks d)	rcl	Resp to clarification	S
Yes		K1f	Follow-up	T
	S clicks 'Complete Solution' button			

The first move is analysed as a Dk1 move (a ‘teacher question’) (Martin 1992, p. 65), as the teacher already knows the answer and is the primary knower. The exchange is prolonged by a series of dynamic moves, in which the teacher challenges and then clarifies each of the student’s incorrect responses. The student’s response to clarification is to select another response which is challenged until the correct response, d), is selected. The exchange ends when this happens and the teacher gives feedback – [yes] – in the final follow-up move. Of course, if the correct answer had been chosen sooner, the exchange would have been shorter.

One of the points of the exchange structure analysis was to explore the claim made by the publishers (Campbell, 2002; Hecht, 2000), that these CD-ROM activities are highly interactive. The analysis showed that the power roles remain mainly with the teacher/designer who initiates most of the exchanges and is cast in the authoritative role of primary knower (K1). The student user has limited power and has the role of primary actor (A1) – the one who carries out the commands. He/she cannot challenge the responses of the teacher or negotiate the direction of the exchange. The only option the student has to assert control is in aborting the exchange through quitting the activity. The dynamic challenge moves are from the teacher and are only there to steer the student into choosing the correct answer.

Thus, interactivity does exist in such activities in that there is an exchange between the teacher and the student but the student’s role is passive and mainly concerned with carrying out the action as directed by the teacher. This confirms the results of the content analysis discussed in Chapter 5, which found that the majority of the work being done by the interactivity was related to the navigational function than to the pedagogical activity or the subject content.

7.5.3 Scientific realism: verbal and visual modality

As outlined in Chapter 6, one dimension of interpersonal intersemiosis is the relationship between the modality of the image and the mood and modality of the text. Visual representations can be 'true' in different ways and have different coding orientations or culturally determined views of reality (Kress & van Leeuwen, 1996; van Leeuwen, 2000). The text can also have different values of modality (high, medium, low) and different types of modality – probability and usuality (modalisation); obligation and inclination (modulation) (Halliday 1985, p. 336). The other dimension of modality is its subjective or objective and explicit or implicit orientation to the proposition or proposal.

The preliminary *Systemics* 1.0 analysis of mood showed that in all texts the majority of the clauses which dealt with defining and explaining content rather than the interactive activities or problem-solving exercises discussed above, were declarative mood with little gradation within probability and usuality. The analysis showed propositions were typically unmodalised, indicating that the writer's stance towards the content is one which accords it a high truth value or which assures solidarity. The verbs in the text extracts in **[7:34]** are all declarative mood, unmodalised and positive polarity.

[7:34]

Cl	BIOLOGY TEXTBOOK
58	Fungi grow
59	and explore their substrates by extension from the hyphal tip.

Cl	BIOLOGY WEBSITE
30	All fungi are EUKARYOTES.
31	The nuclear region and organelles located in the cytoplasm are found within a membrane.

CI	PHYSICS TEXTBOOK
120	The wave moves with constant speed v along the length of the string,
121	while the motion of the particle is simple harmonic and transverse (perpendicular) to the length of the string.

CI	CHEMISTRY WEBSITE
53	If the reaction is exothermic
54	it gives out heat to its surroundings
55	ΔH is negative,
56	an increase in temperature will reduce the value of K.

There is thus a high degree of certainty about the content – this is the way the world is according to the biologist, the physicist and the chemist. The stance these texts take towards the reader is one of high authority, as the text operates to introduce the student reader/user to the new content, defining and explaining the technicality of the field. There is little projection or attribution of claims to outside sources, thereby opening up propositions to different views, which would occur in a scientific research article. Claims are largely unsourced and hence timeless, and the source of authority remains with the writer.

A discussion of modality in images in science needs to take into account the scientific realism for each discipline. Scientific realism in biology may mean high naturalistic modality but in physics it may mean high abstract modality (Kress & van Leeuwen, 1996). As was shown in the discussion of the multimodal content analysis in 5.2.2, p. 108, disciplinary differences in the images were closely related to the technologies of reproduction. In biology, colour photography and micrography form the basis of scientific realism, while in physics the scientific realism is abstract, involving mathematical symbolism and graphic display. The photograph of a fungus in an open field may be recognisable in our everyday world but it is through the verbal text that it becomes coded as scientific.

Kress and van Leeuwen (1996) outline eight continua of naturalistic modality in images, shown in Table 7.9.

Table 7.9

Eight Continua of Naturalistic Modality in Images based on (Kress & van Leeuwen, 1996, 165-168)

A	*COLOUR SATURATION*	full colour to absence of colour (black and white)
B	*COLOUR DIFFERENTIATION*	maximally diverse range to monochrome
C	*COLOUR MODULATION*	fully modulated (i.e. many shades of one colour) to unmodulated
D	*CONTEXTUALISATION*	from absence of background to most fully articulated and detailed
E	*REPRESENTATION*	maximum abstraction to maximum representation of pictorial detail
F	*DEPTH*	from absence of depth to maximal depth
G	*ILLUMINATION*	from fullest representation of interplay between light and shade to its absence
H	*BRIGHTNESS*	from maximum number of different degrees of brightness to 2 values of the same colour

According to Kress & van Leeuwen (1996), highest modality in a scientific coding orientation corresponds to black and white in the scale of Colour saturation, monochrome in Colour differentiation, unmodulated colour in Colour modulation, absence of background in Contextualisation, minimum pictorial detail in Representation and absence of Depth (Kress and van Leeuwen, 1996, p. 171). However, the scales of modality and what is accorded a high value of scientific truth will vary according to the discipline. This was also borne out by the multimodal content analysis in 5.2.2. If we acknowledge that scientific realism in biology is partly naturalistic and that scientific methods may involve observation using photography as the technology, it is interesting to use this as a benchmark to compare other images in biology which use different technologies such as micrographs and drawings. The biology textbook contains several photographs such as the one in Figure 7.24 of a fungus (*Amanita muscaria*).

Figure 7.24. Photograph of *Amanita muscaria* from biology textbook (Knox et al., 2001, p. 940).

Apart from the scales of Contextualisation and Depth this photo shows maximally high modality on all scales. Using the same naturalistic coding orientation, i.e. photography, when this is compared with a stained micrograph of a fungal spore in Figure 7.25, the modality patterns are quite different.

Figure 7.25. Micrograph of fungal spores from biology textbook (Knox et al., 2001, p. 938).

Only Representation would be coded as high, with maximum representation of pictorial detail. This is because microscopy and its variant Scanning Electron Microscopy (SEM), as key technologies in biology, operate on a different order of reality. What is viewed under a microscope is part of a 'hyperreal' world, 'not available to ordinary human perception' (Thibault, 2001, p. 301). The micrograph images which are selected for the textbook require a high degree of expertise to 'read' them. They show a level of detail beyond that which can be perceived in our everyday world and are oriented towards objective scientific truth. However, if microscopy is used as the benchmark, i.e. a scientific/technological coding orientation, then the modality scales would be rewritten so that high Colour saturation, Colour differentiation and Colour modulation represent low rather than high modality, while the other scales remain as for photography.

The biological drawings in this chapter mostly represent the microscopic world, such as the drawings of fungal hyphae or spores, and hence a scientific coding orientation. However, the modality scales differ again from those for micrographs and photographs and colour plays a different role in drawings. All the drawings use colour but not fully saturated, differentiated or modulated colour. Colour is used minimally to realise experiential meaning but seems to be more oriented towards sensory principles to add appeal, thereby foregrounding interpersonal meaning. The following drawing of a life cycle of an Ascomycota in Figure 7.26 is a typical example, where medium saturated, differentiated and modulated colour has been used to enhance the drawing rather than provide content information.

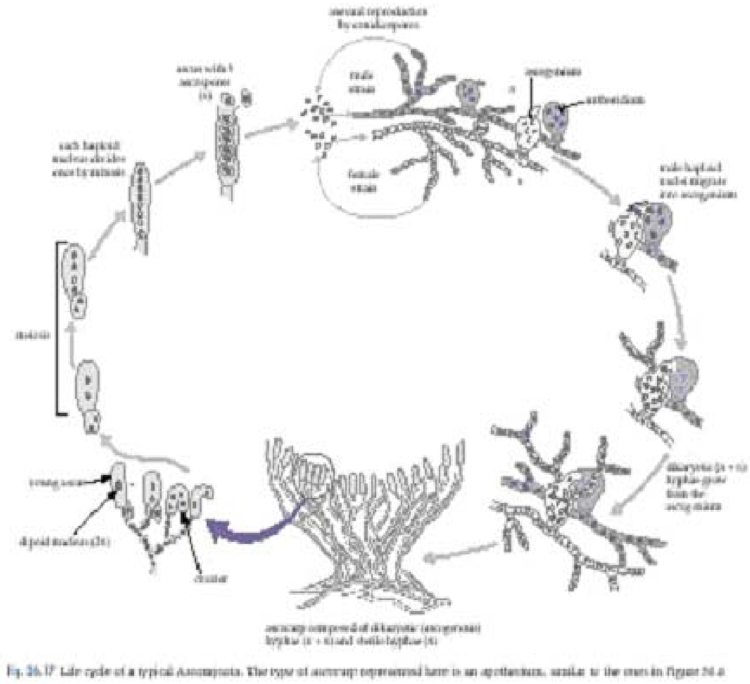


Figure 7.26. Drawing of fungal life cycle in biology textbook showing medium Colour saturation, Colour modulation and Colour differentiation (Knox et al., 2001, p. 950).

Different patterns of modality in images were found in the physics textbook. As discussed in Chapter 5, p. 103, photographs in this text were rarely used to depict experiential content but were oriented towards ‘reader interest’ and hence towards interpersonal meaning. This was in some way aligned to the personal style in the verbal text but, at the same time, it had the effect of disrupting the factual, objective stance towards the content (O'Halloran, 2005, p. 73).

In addition, as was found in the content analysis in Chapter 5, many of the images are either drawings or graphs, which, if mapped against the scales for naturalistic modality and photography, are at the opposite end of most of the scales in the biology textbook. This would however, give a distorted view of visual modality in the physics textbook. If an abstract or scientific coding orientation is used as the standard the patterns would be quite different. For the graph, high modality corresponds to low Colour saturation, low Colour differentiation, absence of Background and Depth, minimal pictorial detail (Representation), low Illumination and Brightness. The highly coloured photographs described above corresponded to low modality and the drawings were somewhere in between.

Thus visual modality and scientific realism will very much depend on the socially determined standards of the discipline and on the context of situation. In these pedagogical texts the resources of mood and modality in the main text, image captions and labels were closely aligned to the visual modality in the images and played a vital role in reinforcing the scientific realism of the images. The continual interplay between notions of apprenticeship and expertise helped to reinforce the pedagogical purpose of the texts. The intersemiotic interpersonal resources shifted between those which foregrounded the interactive relationship between the writer/producer and reader/user in the activities and exercises and those which foregrounded the authority and truth value of the content in the definitions and explanations.

The exchange structure analysis of the interactive learning activities of the two CD-ROMs showed that negotiation often shifted across semiotic resources, as the response to commands involved the student clicking on an image, labelling an image, adjusting values on a graph or completing an equation. However, in these activities the roles were unequal, as the writer/producer assumed a dominant position, was primary knower (K1) and gave the commands (A2). The analysis therefore challenges the claim that the learning activities are highly interactive in terms of the level of engagement by the student.

7.6 Textual metafunction

In 7.1 and 7.2, visual and verbal abstraction was discussed as an indicator of the mode of the texts and of the textual metafunction. This section extends the discussion of the textual metafunction by exploring firstly how visual and verbal participants were tracked on the page in intersemiotic identification and secondly, how the location of text and image on the page related to the underlying design grid and to information flow, salience and framing.

7.6.1 Intersemiotic identification in the textbooks

Following the methods outlined in 6.8.2 p. 154, the textbooks were analysed for intersemiotic identification (O'Halloran, 2005, p. 167, pp. 173-174). The analysis showed which visual and verbal participants were introduced in the image, the label, the caption or the main text and how they were tracked across semiotic resources (Appendix E, Tables E5.1 and E5.2). As is typical of scientific discourse (Martin, 1992, p. 103), reference chains tended to be short but, I would argue, no less complex as they are split and rejoined across text and image (see also O'Halloran, 1999b and 2005). Related to this was the use of generic reference in the text, where the whole of a class of participants is referred to, either definitely (***the*** wave) or indefinitely (***a*** transverse wave) or singular (***the*** wave) or plural (waves). The use of generic reference also has an effect on abstraction as participants are generalised and ordered into taxonomies and activity sequences.

In the verbal component, generic/presenting reference comprised the largest group of reference types, as the text is mainly concerned with presenting new information. The reference chains were mostly short or the generic class nouns were either re-introduced with the repetition of the nominal group or not re-introduced at all and are therefore not phoric. Reference chain **a)** in **[7:35]** from the main text in the physics textbook is the longest chain in the extract analysed (clauses 41-94). It introduces the key technical term for the extract in clause 41, [mechanical wave] defines it and tracks it in clauses 41, 42 and 44. The term is then re-introduced generically in clause 45 [Figure 15.1 shows three varieties of **mechanical waves**], which refers directly to the image of the mechanical waves in Figure 15.1.

[7:35]

Reference type	Clause No	Reference chain	Other clause elements
generic/presenting	41	**a) a mechanical wave** ↑	is a disturbance that travels through the medium for
generic/presuming	41	**the** ↑	wave
generic/presuming	42	**the** ↑	wave travels through the medium
generic/presuming	44	**the**	wave

Reference chain **b)** in **[7:36]** from the main text in the biology textbook is another example of the definition of a key technical term for the chapter, [fungi] which uses a short chain of generic reference. The term is re-introduced in clause 14, which begins a longer chain, extending the definition in clause 13.

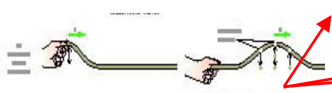
[7:36]

Reference type	Clause No	Reference chain	Other clause elements
generic/presenting	13	**b) fungi**	are eukaryotic heterotrophs
generic/presuming	13	**their**	food externally
generic/presenting	14	**c) fungi**	are secretory organisms
generic/presuming	15	**they**	secrete enzymes onto
generic presuming	15	**their**	substrate for digestion…
generic presuming	16	**their**	competitive ability

When the verbal text was cross-linked with the image or image part, reference patterns became more complex. A participant may be introduced in the main text or caption, presumed in the image, re-introduced in the text and presumed again in the image. When intersemiotic reference is combined with other systems of textual meaning on the Display stratum such as framing, colour, font and juxtaposition, the resulting reconfigurations create a density of texture which is greater than that which exists in the verbal component alone.

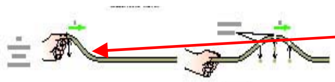
In the realisation of reference across text and image there is also a shift from generic to specific. The generic realisations in the main text Clause 51, caption and label for the participant [transverse wave], shown by the shaded elements in **[7:37]**, are made specific through the image.

[7:37]

Image	Image label	Image caption	Clause No Main text
 *(specific/presuming)*	X transverse waves *(generic/ presenting)*	a transverse wave *(generic/ presenting)*	51 a transverse wave (*generic/ presenting*)

The red arrows show that the links in the main text, caption and label all relate to and converge at the image. Each of these mentions of [transverse wave] in the verbal components is generic/presenting reference but each is cohesive only with the image, which is a specific depiction of a transverse wave. The direction of the arrow indicates the direction of the relationship between presenting and presumed items. In some cases, the image becomes the presenting item and the text becomes the presumed item as in **[7:38]**.

[7:38]

Image	**Clause no/Main text**
 *(generic/presenting)*	62 For the stretched string (*specific/presuming*)

This image has already been introduced by the main text in Clause 46, [In Fig 15.1a the medium is a string or rope under tension]. Here in Clause 62 [the] refers to the image part of the stretched string. Although the image is a specific representation of a hand holding a stretched string, it represents at the same time a generic abstraction several degrees removed from a naturalistic photograph of a 'real' hand holding a 'real' string in a 'real' setting. Thus with certain images such as drawings and micrographs, the verbal text abstracts from the specificity of the visual and construes the visual as generic (Thibault 2001, p. 307). The images in both textbooks, particularly the photographs, drawings and micrographs, operate in the realm of the generic, abstracted from everyday perception. Without labels or captions they could remain as specific, relatively naturalistic and non-abstract.

Many of the drawings in the textbooks have arrows and lines, or vectors, linking the labels to the image. The vectors establish intersemiotic ties and, according to Thibault (2001, p. 309), have a textual or phoric function whereby the image is linked to the text, as in **[7:39]**, from the biology textbook.

[7:39]

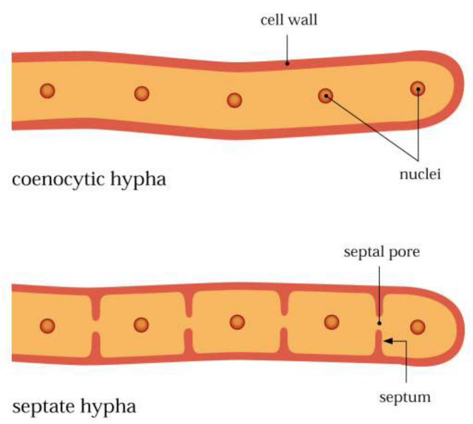


Fig. 36.1 Coencytic and septate fungal hyphae

Figure 7.27. Figure 36.1 showing vectors (Knox et al., 2001, p. 938).

In this image, the label [septum] and the image part are linked by an arrow and other labels by lines with ball points. These vectors establish unidirectional relationships from text labels to image elements which serve an indexical function. Thibault argues that such vectors are unlike visual material processes and do not have experiential meaning (Thibault, 2001, p. 309) but, as was discussed earlier in 7.4.2, they do establish experiential relations of identity. An expert reader would be able to dispense with the arrows and labels and 'read' the visual on its own, but for apprentice readers, labels and arrows are crucial in learning the visual and verbal technicality of the field. Thus, as argued under intersemiotic experiential relations, building understanding of the intersemiotic resources of identification could be important in helping to make the intersemiotic meanings of the text explicit for the student. Again, the level of redundancy between the image and its label and caption and the degree of co-contextualisation of the intersemiotic relations may be related to the effectiveness of the text for learning.

7.6.2 Layout and location of text and image on page and screen

In the content analysis in 5.2.4, pp. 111-112, it was found that the location of visuals on the page was more variable than on the screen. Both the textbook and screen text visuals occupied a large number of locations on the page and screen, ranging from 18 in the physics textbook to 6 on the biology CD-ROM. In 5.5 I also suggested that the location and distribution of text and image on the page and screen was influenced by the designer's grid rather than information value (Kress & van Leeuwen, 1996, pp. 186-211). Kress and van Leeuwen's account of information value relates to the meaning arising from location of visual and textual elements in various zones on the page. This kind of analysis has been critiqued by Bateman et al. (2004) as being overly interpretive and not supported by empirical evidence. Moreover, it does not take into account design and cost constraints and, as Bateman et al. (2004, p. 67) argue, 'is certainly not used as a design criterion in layout'. In a discussion of features of complex layout in book design, Gillieson (2003) points to the use of the vertical axis and a modular grid as a measure of complexity - the more grid fields, the more complex the design. For a designer this grid determines the location of image and text blocks on the page. In order to probe this point, the following discussion concerns the design grids of the textbooks and their relationship to the location of text and image on the page and screen and to information value (research question 6).

The underlying design grid of the biology textbook page is two vertical columns divided into a possible maximum of eight blocks, which can each be occupied by text or image, as shown in Figure 7.28. These eight blocks are arranged on the horizontal axis as four pairs of adjacent blocks.

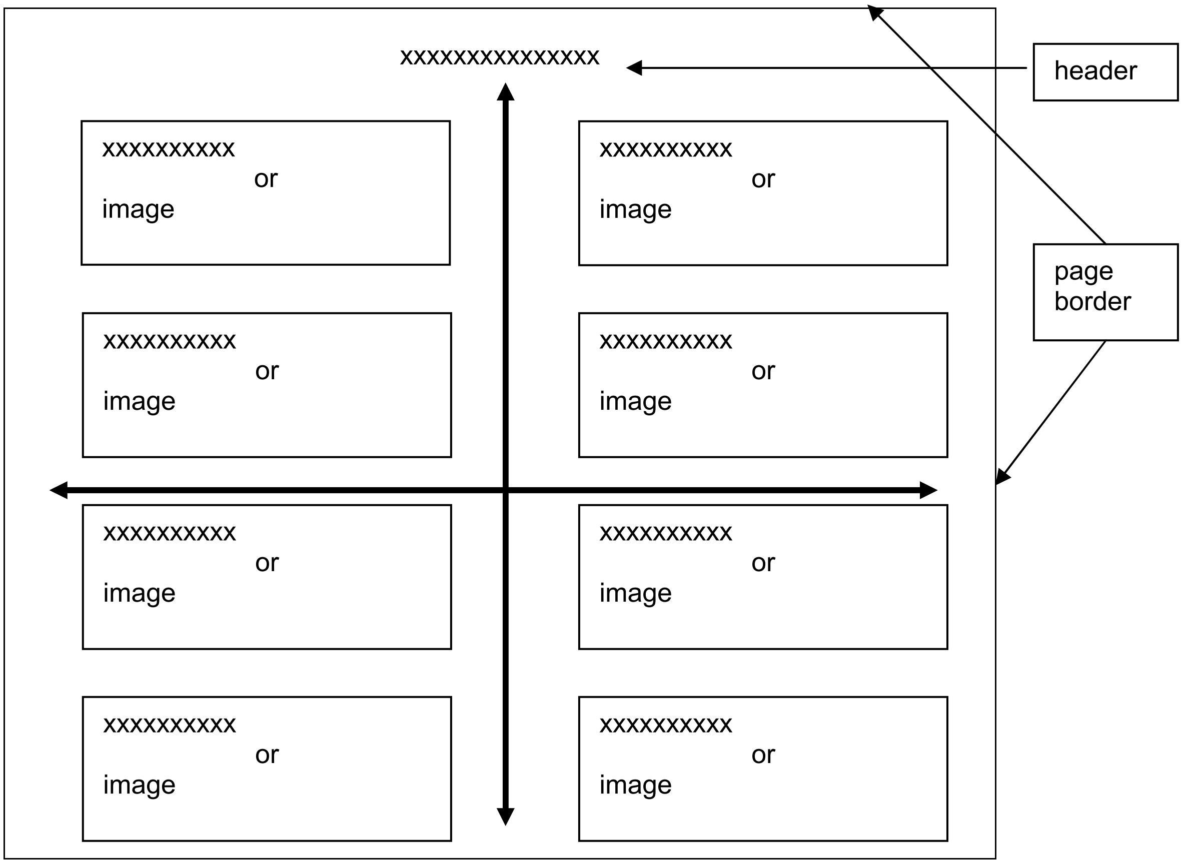


Figure 7.28. Diagram of page layout in biology textbook showing underlying design grid

Figure 7.29 shows an example of this page layout, with the left-hand column taken up by three text blocks and one image block and the right-hand column by one text block and three image blocks.

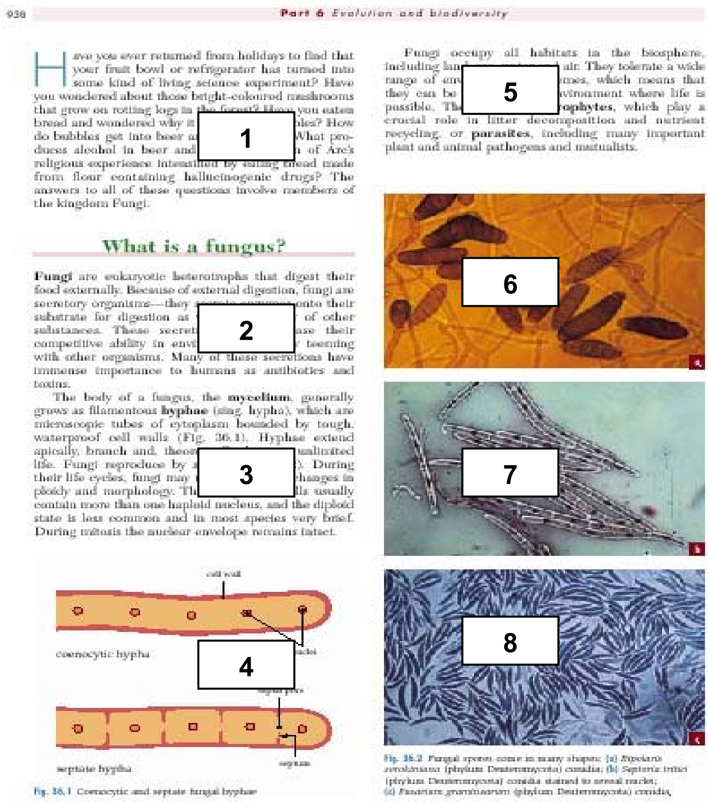


Figure 7.29. Page layout of biology textbook page showing text and image blocks in design grid (Knox et al., 2001, p. 938).

While all pages used the two column vertical axis, not all pages used the full potential of the horizontal axis of the grid. Some images occupied four blocks across the top or bottom half of the page, as shown in Figure 7.30.

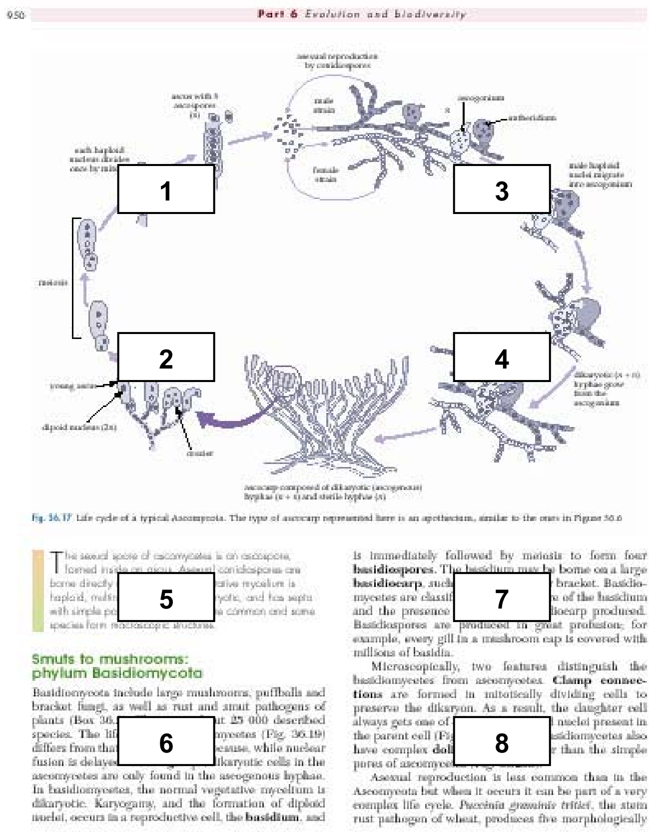


Figure 7.30. Variation in layout of biology textbook page showing image occupying four blocks (Knox et al., 2001, p. 950).

In a two page layout the occupation of the grid space by text and image blocks also varied, although the underlying grid remained constant. The physics textbook, on the other hand, used a totally different underlying grid, or more precisely, two types of grid. Along the vertical axis the first grid divides the page into two columns, in the proportion of two thirds to one third, while the second grid divides the page into two equal columns along the horizontal axis. Each of these patterns could occur on the one page, and each column could be wholly taken up by text or image or white space, as Figures 7.31 and 7.32 show.

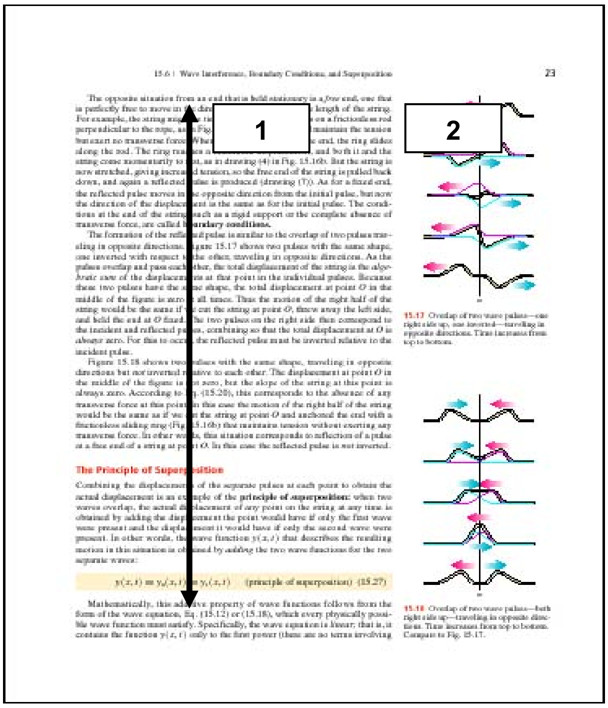


Figure 7.31. Single page of the physics textbook showing vertical design grid (Young & Freedman, 2004, p. 569).

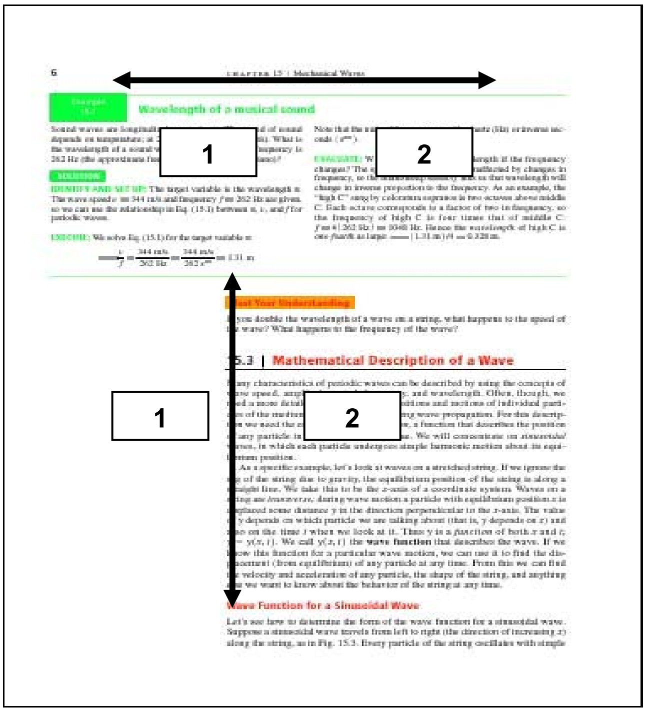


Figure 7.32. Single Page of Physics Textbook Showing Both Horizontal and Vertical Design Grids (Young & Freedman, 2004, p. 552).

In their discussion of left-hand (Given) and right-hand (New) relations in magazine layouts Kress and van Leeuwen (1996, p. 189) claim that the Given space is often occupied by the verbal text while the New is occupied by images. In these textbooks, there was no such pattern, since image or text or both could appear on either the left-hand or right-hand side of the page. Images could also occupy the top or bottom half of the page. Table 7.10 summarises the location of text and image on the textbook pages. It shows the number of instances text and image occurred in each location and the proportion of each location of the total number of pages analysed per textbook chapter.

Table 7.10

Instances of Left, Right, Top and Bottom Location of Image and Text in the Textbooks

	Biology Textbook: 22 pages				**Physics textbook: 33 pages**			
	Left	Right	Top half	Bottom half	Left	Right	Top half	Bottom half
Image	17 0.77	9 0.41	4 0.18	1 0.05	10 0.3	16 0.48	1 0.03	1 0.03
Text	20 0.91	22 1.0	n/a	n/a	23 0.7	24 0.7	n/a	n/a

Table 7.10 shows a varied pattern of left/right top/bottom distribution of text and image for each textbook. Images occurred on the left-hand side of the page in the majority of pages in the biology textbook, while this was not the case in the physics textbook. In both texts, text blocks were to be found in roughly equal proportions on the right or left hand side of the page. Images occurred infrequently in the top or bottom half of the page. From this analysis it would be difficult to support the argument that information value relates to location on the page. The claim that material occurring on the left is already established and

'presented as something the viewer already knows' (Kress & van Leeuwen, 1996, p. 187), while material appearing on the right is presented as something which is not yet known' and therefore 'contestable' or the information 'at issue' (p. 187), does not appear to be supported by this analysis. Since both image and text can be presented on either the left or right and often co-occur in both locations, the left and right space could be used to present either Given or New material or both in the same space. In his analysis of video texts, Thibault (2000) discusses the problematic relationship between information structure and Given-New in images. He argues it is too tied to the concept of constituency in language and the ordering of elements in the clause and does not consider 'the essentially topological-continuous character of visual texts' (Thibault, 2000, p. 330).

It is also difficult to argue that, as the chapters in these textbooks unfold, images and text once presented, become Given for the next New. For example, an image may be introduced by the text, caption and label on a certain page in either location and expanded on a later page with new information, again in either location, as was shown in the discussion of logical relations and expansion in 7.4.3. The location of visual and verbal blocks on the page therefore, may be more often determined by constraints of space, design and cost than by meaning relations. Pedagogically driven reasons for location of text and image may also play a role in placing the image as close as possible to its explanatory text or placing text which introduces the image as close as possible to the image.

Finally, in discussing the degree of intersemiotic complementarity between text and image on the page the relative salience of visual and verbal blocks also needs to be taken into account. According to Kress and van Leeuwen (1996, pp. 212-225) salience may relate to the size, foregrounding, overlapping, definition and colour of elements and hence to the hierarchy of importance. As was found in the content analysis discussion in 5.2.3 pp. 110-111, more space was assigned to text blocks than to visuals in the physics textbook chapter, while the reverse was true for the biology textbook. In any document design there is clearly competition for space between text and image. The salience of text in the size of headings or the salience of an image in its size may relate to the hierarchy of importance but not always. For these texts the larger font size and consistent use of colour in headings was clearly related to their salience and the hierarchy of importance but this did not appear to be the case in the images. Some images in both textbooks occupied more than half of the page space, such as that shown in Figure 7.30 on p. 247, yet, given their size, these images are elaborated by relatively few clauses in the main text. The amount of 'text space' they are given is far less than the visual space and so visually, they are accorded a relatively high salience which does not necessarily correspond to their level of importance in the verbiage. Again, images of such size may be a result of a design constraint, since, in order to convey the level of detail required, an image of that size may be needed. A smaller image would be indecipherable without some form of magnification. In a screen environment this problem would be overcome by clicking on an image to enlarge it or to show some detail.

In summary, the textual resources of identifying relations across text and image, combined with the resources of framing, juxtaposition, colour and font on the display plane were found to contribute to the organisation of intersemiotic meanings in these texts. The resulting density of texture enables the semantic overlays of experiential, logical and interpersonal meanings to be accessed. The relationship between abstraction in the verbal component through the resources of grammatical metaphor and through visual abstraction in images is another way in which intersemiotic textual meanings are realised.

7.7 Concluding comments and research questions

Through discussion of the analyses, this chapter has attempted to provide a descriptive account of the complex meaning relations across semiotic resources and across modes, which can be found in pedagogical texts for university students. To conclude the chapter, the research questions posed in Chapter 1 can now be revisited. These questions concern the ideational, interpersonal and textual metafunctional analyses of multimodality of the thesis corpus. Specifically, these have to do with the construal of content knowledge and technicality across formats, disciplines and modes; the construction of pedagogical roles and interactivity across formats and the notion of scientific realism across text and image; and the role of layout and organisational structure across formats and the construal of abstraction across text and image.

Ideationally, in the page and screen formats of these pedagogical texts in science, language and image are reconstrued as disciplinary knowledge which is characterised by a high level of technicality and taxonomic organisation across semiotic resources and interdependence between visual and verbal activity sequences and among elements in the image, caption, label and main text. Through the mechanisms of intersemiosis this knowledge is distilled as new entities and integrated in a new semantic space. Interpersonally, pedagogical roles of reader/viewer/learner and writer/teacher/designer/knower are enacted differently to some extent across formats through the different types of activities on the page and screen but the source of authority and truth remains with the teacher/designer/knower, regardless of format. Roles are thus minimally negotiable, despite the claims of interactivity in some of the screen texts. Textually, the organisation of meaning across text and image was reflected in the layout determined by the underlying design grid and in the use of graphic design resources of colour, font, salience and juxtaposition. The resources of intersemiotic identification contributed to the organisation of meaning through the tracking of participants across semiotic resources and through the resulting shifts from specific to generic. Finally, through the resources of grammatical metaphor in the verbiage and the reconstrual of images as abstract, both forms of semiosis worked together to shift meanings from congruence to abstraction, into the specialised realm of science.

The final chapter will draw together the key findings of both stages of the study, before discussing its educational implications.

CHAPTER 8

8.0 Introduction

The overall aim of the research in this thesis was to give an account of multimodal and multisemiotic meaning in print and computer-based teaching and learning resources in first year science at university and to consider the implications of this account for students' multiliteracies for academic purposes. The motivation and rationale for the research were seen to derive both from my professional context at the Learning Centre and from current research in the field of multimodality. In a professional doctorate in education, the educational applicability of the research is a strong motivation for building the theoretical account. The significance of this study should therefore be seen not only in terms of its theoretical contributions to the research field of multimodality, but also in terms of its contributions to a professional context.

The purpose of the chapter is twofold. The first section aims to draw together the key findings of both stages of the study in order to discuss their significance and their contributions to SF theory and methods of analysis. This section will conclude with discussion of limitations of the study and suggestions for future research. The second section is divided into two parts. The first part will discuss the general educational implications and the role of this study in advancing the teaching of multiliteracies at university and the chapter will conclude with illustrations of how this can be achieved in my professional context.

8.1 Discussion of key findings

Two underlying themes of the research were to compare the different affordances of textbook and screen formats of the corpus texts and whether disciplinary variation played a role in these environments. The first part of the discussion (8.1.1) will address these themes and integrate findings from the MCA and the MDA. This will be followed by discussion of the general significance of the MDA findings in 8.1.2 and 8.1.3.

8.1.1 Affordances of format and discipline

The metafunctionally-oriented MCA yielded some interesting findings regarding format. Contrary to my expectations and to claims about the page being dominated by the logic of the screen, particularly with reference to school science textbooks (Kress, 2003), the textbooks of this study conformed very much to what Kress calls ‘traditional’ textbooks, divided into chapters with a ‘coherent exposition of a body of knowledge, authoritatively presented’ (p. 7). Visuals were generally allocated less space than text blocks on the screen and there was less variation in the range of visuals than in the range of text blocks. Moreover, in the textbooks, the visual density was higher and a higher proportion of visuals contributed to the subject matter than in the screen texts. The visual content was related more to the experiential metafunction in the textbooks, while the visual content in the screen texts was related more to navigation the organisation of the on-screen activity, and therefore to the textual metafunction. Similarly, in the verbal content analysis, the main function of the text block content in the screen texts was again, to orient the user to the organisation of the content, while the textbooks were more concerned with the presentation of the topic.

This finding was borne out by the MCA of interactivity, where the student was interacting with the on-screen content more for the purposes of navigation than for engaging with the subject matter. The overstated claims of the publishers about the high level of interactivity of the CD-ROM screen texts were not supported by the analysis of exchange structure in the MDA. Here it was found that the student's role was more passive than active and the 'teacher' dominated the exchanges, directing the student through a narrow set of interactive moves, which were mostly in multiple choice format, although they did involve other modes and forms of semiosis such as animation and image. The student had little opportunity to vary the synoptic exchange and enter into more dynamic challenging or clarifying moves, which would be expected in the spoken discourse of face to face group work in a laboratory setting, for example.

Another unexpected finding from the MCA and the MDA related to the location of visuals and text blocks on the page and screen. The location of visual and verbal components was more variable on the page than on the screen and was clearly influenced by the design grid underlying the format of these texts. The MDA of location of visual and verbal components and its relation to information value in the textbooks also challenged the claim by Kress and van Leeuwen (1996) that material located on the left is already established, while material appearing on the right is presented as something which is not yet known. A varied pattern of left/right top/bottom distribution of text and image was found in each textbook. Both image and text occurred on either the left or right of the page and often co-occurred in both locations, often presenting new visual or verbal information. The location of visual and verbal blocks on the page therefore, may be more often determined by constraints of space and design than by the information value associated with location.

In the MCA, clear disciplinary variation in the types of visual was consistent across page and screen texts but variation in text blocks was more related to format than to discipline. This was borne out by the analyses of visual and verbal technicality and abstraction, where the key variable was format not discipline, as the screen texts had lower measures than the textbooks. The measures for visual technicality and visual abstraction, on the other hand, showed that disciplinary variation in the types of images occurred regardless of format, with the physics texts showing a higher proportion of abstract visuals than the biology texts.

Disciplinary variation was also apparent in the choice of image types and the resulting foregrounding of different metafunctions. For example, although four of the texts used photographs, in the biology textbook and website, photographs were used to construct the experiential content of the discipline, while in the physics textbook and on the chemistry website the photographs were more interpersonally oriented, serving more to engage the reader in the otherwise abstract visual world of physics and chemistry.

8.1.2 Visual and verbal technicality and abstraction

Through the interrelationship of the grammatical resources of technicality and grammatical metaphor, experience was reconstrued as discipline-specific and highly abstract knowledge in the corpus texts. The reconstrual of experience in the verbiage, which was evident from the analyses of lexical density, technicality and grammatical metaphor, clearly co-occurred with reconstruals in visual meanings in the choice of technical and abstract images. This was shown by the relatively strong trend of co-variation in the four measures across the texts. In the textbooks, the highly technical and abstract images were mediated by labels, captions and the main text. In the screen texts however, labels and captions were generally not present. To an expert eye it may be possible to read such images without verbal explanation or elaboration, but for the student, whose expertise is developing in the subject, the verbal text plays a vital role in accessing the meaning of the image. The higher measures of visual technicality and visual abstraction in the textbooks support the claim that these images played a more significant role in constructing the technicality and abstraction of the discipline than the images in the screen texts.

8.1.3 Metafunctional analyses of multimodality and intersemiosis

Building on the findings of the MCA and the analyses of visual and verbal technicality and abstraction, the metafunctionally-based analyses of multimodality and intersemiosis set out to unravel some of the complexities and complementarities in meaning arising from the interaction of different modes and forms of semiosis. In each metafunctional area, the motivation underlying the analysis was to explain the nature of semantic expansion during intersemiosis, the principles of co-patterning and the mechanisms by which this expansion takes place.

The experiential analyses of intersemiosis in activity sequences and their cohesive and taxonomic relations, revealed a degree of overlap or redundancy in the visual and verbal meanings across the image, label, caption and main text. Redundancy in this sense was also seen to be an important intersemiotic principle which could help make explicit for the student reader, the complex transitions between visual and verbal meanings. In the shifts back and forth from main text to image to caption, transitions in technicality and in semiotic and grammatical metaphor occur. The technicality of the images or image elements is mediated by the technicality of the verbiage. At the same time, congruent elements occurring in the image may be translated into metaphorical variants in the verbiage.

In addition, the combination of visual and verbal meanings through intersemiotic mechanisms such as semiotic metaphor and semiotic cohesion in these experiential analyses, as discussed in 7.4.1 and 7.4.2, can be said to give rise to a new semantic unit. This unit makes meaning in its own right, in a relationship of intersemiotic complementarity (Royce, 1998, p. 27) or synergy, thereby illustrating the nature of meaning expansion during intersemiosis. This process of expansion is further enhanced in the use of colour, font and juxtaposition on the display stratum in the realisation of experiential meaning.

The intersemiotic mechanism of semiotic cohesion (O'Halloran, 2005, p. 169) was explored through the analysis of experiential cohesive relations of hyponymy, meronymy, repetition and correspondence across the image or image element, label, caption and main text in the two textbooks and in the biology CD-ROM. Through such relations, these elements can be seen to be in a relationship of co-contextualisation, creating tightly integrated meanings across image, label, caption and main text, thereby reinforcing the experiential content for the student reader. Multiple ties were found among all visual and verbal components. Composition and classification taxonomies could be realised intersemiotically or intrasemiotically. For example, in a classification taxonomy, the superordinate could occur in the verbal text and the subordinates in the image (or vice versa) or the superordinate and subordinates could occur in both systems simultaneously. It was observed that the experiential cohesive relations across the main text, image, image parts, labels and caption in the physics textbook, when compared with the biology textbook and the biology CD-ROM, exhibited the ‘best’ bi-directional investment of meaning, and one which would facilitate student reading and understanding. It is therefore suggested that the level of redundancy and explicitness in ideational meanings across semiotic resources contributes to the pedagogical effectiveness of the text.

The logico-semantic relations of expansion in image/text complexes and inter-image complexes in the textbooks also revealed differences in the domain and intricacy of relations. In the physics textbook example, the whole figure and its constituent images were tightly integrated with the caption, label and running text, spanning 1.5 pages over a range of 36 consecutive clauses, whereas in the biology textbook example, the figure spanned only five clauses, which were spread over three pages. Again, intricacy of logico-semantic relations in the physics textbook was evident in the main text explanations of all parts of the image and in the reduced version of the main text found in the caption. The biology examples were far less intricate. When the verbal elements served to contextualise the image or vice versa, the combined intersemiotic unit was seen to be in a relationship of co-contextualisation. Spatial positioning also played a role here in co-contextualising text and image. The closer the main text was to the image and its caption and labels, the more likely it was to be an elaborating relation, while the further away the main text was to the image, the more likely it was to be an extending relation.

The interpersonal analysis of mood in the verbiage and modality in the image reinforced the results of visual and verbal technicality and abstraction. The scientific realism of the images complemented the authoritative stance of the text, enabled by the resources of technicality and grammatical metaphor. The interpersonal resources across text and image shifted between those which foregrounded the interactive relationship between the writer/producer and reader/user in the activities and exercises and those which foregrounded the authority and truth value of the content in the definitions and explanations.

Although the student was cast in the role of learner through such activities, disciplinary expertise and authority was sustained throughout, reflecting the pedagogical purpose of the texts.

Finally, the textual resources of identifying relations across text and image, combined with the resources of juxtaposition, colour and font on the display plane, contributed to the organisation of intersemiotic meanings in the texts. The resulting density of texture enables the semantic overlays of experiential, logical and interpersonal meanings to be accessed.

8.2 Theoretical contributions

The integrating theoretical principle of the analysis of intersemiosis and multimodality conducted in this thesis was the metafunctional organisation of meanings in a stratified model of semiosis. The analysis drew on O'Halloran's (2005) metafunctionally-based framework and discourse semantic systems for intersemiosis in mathematical discourse and Martin's (1992) discourse semantic systems of ideation, negotiation and identification, particularly as they related to scientific discourse.

Extending the boundaries of SF description into the area of multimodality and intersemiosis holds many challenges. A text-based study such as this which is grounded in an educational and professional context needs to weigh up these challenges against what will be useful in those contexts. There will inevitably be trade-offs between the degree of relevance, useability and transferability of the theoretical account and the depth and breadth of description, which should be borne in mind when assessing the theoretical contributions of the thesis. These can be seen in terms of the areas of the theory which were explored through the analysis. In other words, which analytical tools were applied to the corpus and to what extent did the analysis build on these tools? Based on Martin's (2006) table of basic tools of SF analysis, Table 8.1 summarises the thesis analyses and shows where they fit into the theoretical framework.

Table 8.1

Summary of Corpus Analyses in an SF Theoretical Framework

Metafunction / Stratum	Ideational	Interpersonal	Textual
Genre	orbital/serial structure	prosodic structure	periodic structure
Register	Field • Technicality in images • Activity sequences across verbal text & image • Taxonomies across verbal text & image	Tenor • Scientific realism • Power/ solidarity	Mode • Abstraction in images • Action/reflection scale • Monologue/dialogue
Discourse semantics	Ideation • Experiential cohesion across text & image • Logico-semantic relations in image-text complexes & in visual/verbal activity sequences • External conjunction	Negotiation • Exchange structure across verbal text & image • Appraisal	Identification • Tracking participants across verbal text & image • Location of verbal text & image • Information flow • Internal conjunction
Lexicogrammar	• Verbal technicality & interaction with visual technicality • Transitivity	• Mood in verbal text and its relation to modality in image • Person in verbiage	• Grammatical metaphor & interaction with visual abstraction • Theme and information • Tense & deixis; ellipsis & substitution
Graphology	• Colour, typography in realising technicality	• Colour	• Colour, typography, layout
Phonology			

Table 8.1 not only provides a snapshot view of the thesis analyses, shown in blue, and their complementarities but it also points to the gaps in the analysis, as shown by the shaded areas. At the stratum of genre, generic structure was not analysed. The issue here is the concept of a multisemiotic genre and the extent to which the complementarity between types of structure and types of metafunctional meaning in verbal genres, shown in the first row in Table 8.1, can

be seen to operate intersemiotically and multimodally. Table 8.1 also shows that the focus of the analysis has been on ideational meaning at the strata of discourse semantics and lexicogrammar and less so on register. It should be acknowledged that some aspects of the thesis analyses have been explored by others (e.g. Royce, 1998 and Lemke, 1998; 2002 on intersemiotic cohesion). Nevertheless, the results of the MCA and MDA analyses undertaken in this study demonstrate new insights into the nature of multimodality and the mechanisms of intersemiosis, using an under-researched corpus of educational texts in a university context.

There were, however, limitations of the approach to analysis. In the first stage, the manual coding of multimodal content was extremely laborious and time-consuming. Given more time and expertise on my part, the coding table could have been entered into a database to alleviate some of the coding and quantification work. With multimodal corpus-based analysis such as the multimodal concordancer (Baldry, 2000b, 2006), this may be a possibility in the future. In the MDA, the need to confine the scope of the study meant that choices had to be made in the selection of analyses for each metafunction. Accordingly, the primary focus of the analysis was on the ideational metafunction, which resulted in less comprehensive analyses for the other two metafunctions. In my view, however, the results of the study were not too severely compromised by this limitation and it certainly opens up possibilities for future research.

As alluded to in Table 8.1, one area where this research could be extended is genre. Exploring the complex structure of the textbook genre or websites designed for teaching and learning content in a university context could add further dimensions to the existing analysis. Other disciplines and genres could also be added to the corpus. Appraisal resources remain underexplored in this corpus as well as aspects of texture and of the register variables. The study could be broadened to incorporate contextual factors such as students' use of textbooks and computer-based resources, their perceptions of technicality and abstraction in images and verbal text and their reading strategies.

8.3 Educational implications for multiliteracies for academic purposes

As pointed out in Chapter 1, in my professional context at the Learning Centre at the University of Sydney, much of our work in developing students' academic literacies is underpinned by SFL theory. The theory has helped to facilitate dialogue about student literacies with teachers in the disciplines and has led to the design of print-based and online resources and programs which are either integrated into students' units of study or used by students as standalone resources. Our work is premised on the need for a metalanguage which students can use to reflect on their literacy practices and we as teachers can use to talk to them and to their subject teachers about language. In this process, SF theory is recontextualised to serve as a powerful technology to help build students' and teachers' understanding of how and why language works in the way it does (Jones, 2004). Extending this understanding into a teaching approach which incorporates other modes of meaning and which opens up dialogue with discipline teachers with educational designers about the concept of multiliteracies are essential steps forward.

The final section of this chapter will illustrate how key elements of this research can be operationalised in my professional context. The two examples of educational design to be presented highlight how SF theory and MDA can be recontextualised for our students and for staff in the disciplines and can lead to a genuinely transdisciplinary approach to research and practice. The first example proposes an outline for 9 hour unit of work aimed at developing multiliteracies for academic purposes and is designed for a face to face classroom context. The second is designed for an online learning environment and exemplifies the LC's faculty-based approach to supporting the development of students' academic literacies within their degree courses, whereby their learning of disciplinary content is integrated with their learning how to mean in that discipline. The design of the program has incorporated multimodal resources, such as image, colour, interactivity and animation to explain the genre of a laboratory report.

8.3.1 Example 1: Course on Multiliteracies for Academic Purposes

Table 8.2 outlines details of the proposed course, including the aims, the target group and genres to be used.

Table 8.2

Details of Proposed Course for Developing Multiliteracies for Academic Purposes

Course title:	Visual and Verbal Meaning in Written Academic Genres
Context:	The course would be taught as one of over 20 non credit-bearing courses in the LC's Academic Reading and Writing General Program.
Course aims:	• to introduce students to the resources of technicality, objectivity, abstraction in written text and in images in written academic genres • to explore how these resources combine and interact to make meaning across written text and image.
Length of Course	9 hours : 3 Units x 3 hours each
Target Group:	Senior undergraduate, Honours, Masters coursework students
Mode of delivery:	Group workshop ranging from 8-25 students. Students work on course tasks in small groups and individually.
Target Genres:	A range of genres used for comparative purposes e.g. Student genres: essays, reports, case studies Expert genres: research articles, textbooks
Disciplines:	A range of disciplines used for comparative purposes e.g. Humanities/social sciences/sciences

Further details of the course outline and sample tasks are presented in Tables F1.1 to F1.3 in Appendix F. The course would build on an existing LC workshop, *Writing in an Academic Style*, which covers aspects of academic writing such as formality, technicality, impersonality and abstraction, and targets a range of written academic genres such as essays, reports and research articles. Students rate this course very positively, claiming that it helps them to reflect more critically on their own writing. By making explicit how written text works together with images such as graphs, tables and diagrams, students' understanding of some of the processes of intersemiosis would be increased, which could have benefits for their reading as well as their writing. Such a course would help students to develop a useful metalanguage for reflecting on the multimodal texts they read and have to produce.

8.3.2 Example 2: online learning context

The second example focuses on the design of an online learning program which supports students' development of a particular genre in science writing – the experimental report or 'prac' report in physiology. It builds on the LC's earlier online report writing programs in the sciences, which aim to move genre-based literacy pedagogy to an on-screen environment (Drury, 2004). It is a collaborative project among academic staff from the Department of Physiology, the Learning Centre and technical staff. The project addresses both report writing skills as well as supporting the learning of scientific concepts through the development of a web-based report-writing tool, Flexible Electronic Report-writing Tool (FLERT). A CD-ROM of the program has been included with this thesis as part of Appendix F. The final program will consist of a two linked components, with sub-components with different functionalities. The first is a standardised report-writing template for students to draft their reports online before submission. The template is discipline flexible and thus easily adapted to the teaching and learning of a variety of report types across different disciplines. This first component will also be linked to an ePortfolio, which is a personal web space for each student to collect and showcase their work and to a series of discipline-specific materials to support students' learning of concepts in that discipline. The second component is a series of interactive support materials which focus on the generic stages of the report, on scientific language and on the role of tables and figures in the report. The screenshots in Figures 8.1 to 8.4 illustrate different aspects of the program. The screenshot commentary will discuss how multimodal resources such as animation, colour and typography have been deployed to help students visualise text and genre in a dynamic way.

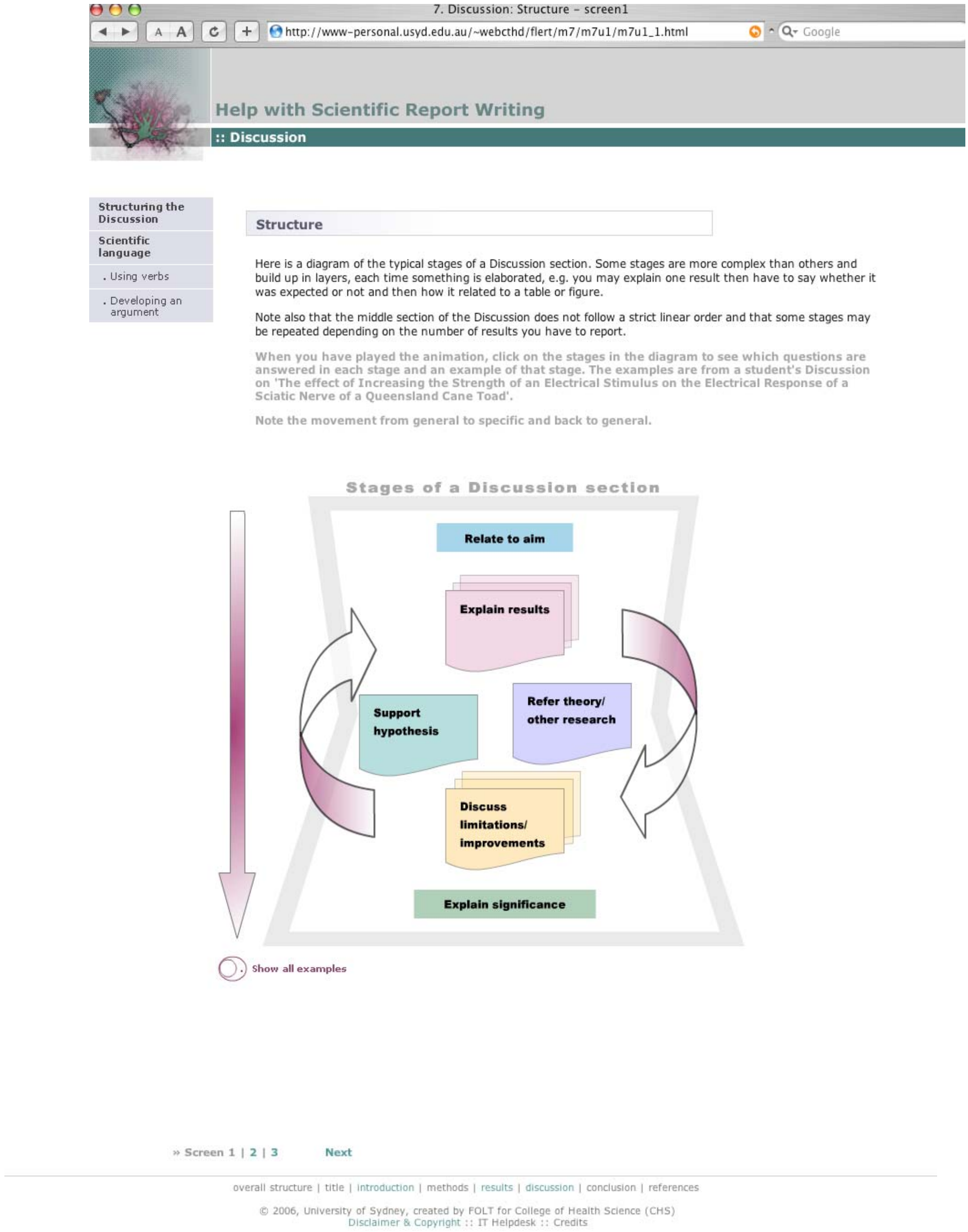
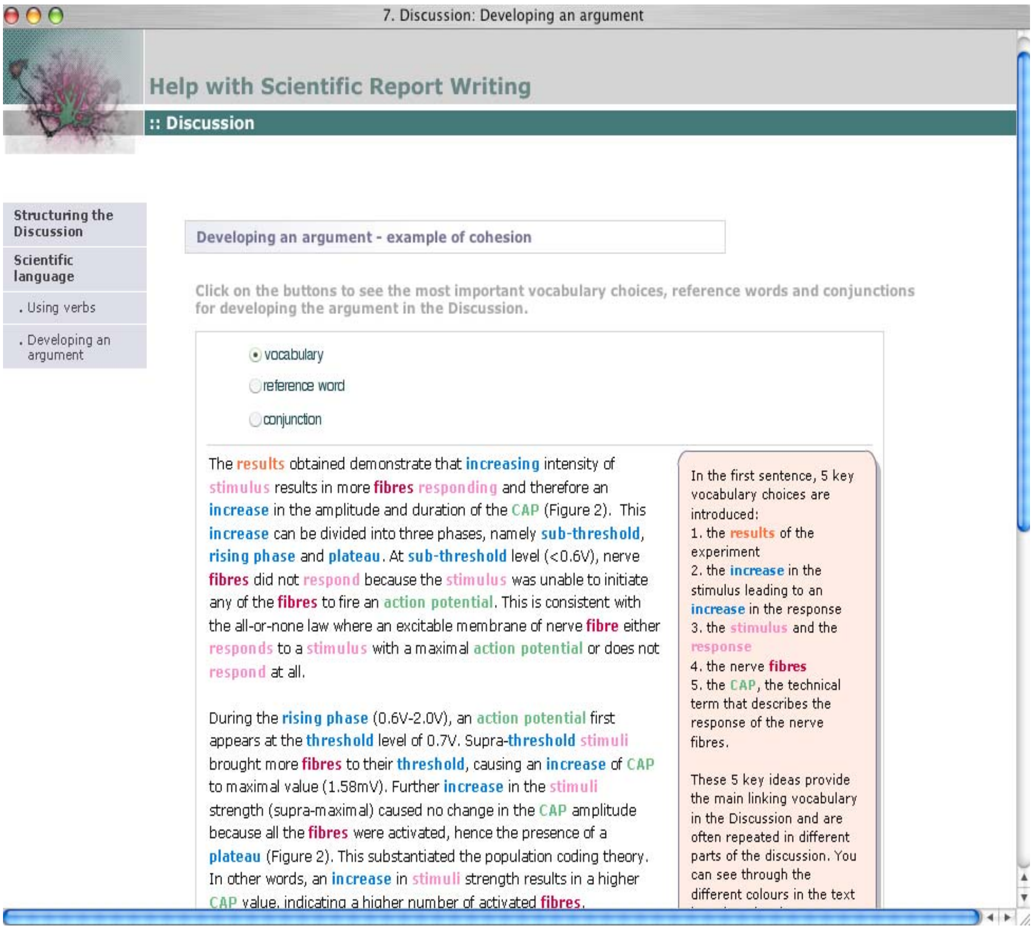


Figure 8.1. Screenshot of stages of Discussion section from FLERT after animation.

The screenshot in Figure 8.1 is from the Discussion section of the Help with Scientific Writing module of the FLERT program. The module is divided into eight parts which reflect the generic stages of the report in physiology – the title, introduction, methods, results, discussion, conclusion, references and appendices and one section on the overall structure of the report. Multimodal resources of colour, to show the different stages of the Discussion section and animation, to show the dynamic unfolding of the stages and the movement from general to specific, have been used in the design. The same use of colour has been used in the exercises to show staging.

In the section on Scientific Language, the resources of colour, animation and typography are used to highlight various aspects such lexical cohesion, conjunction and reference. Figure 8.2 shows screenshots of the use of colour in explaining lexical cohesion in the Discussion section.



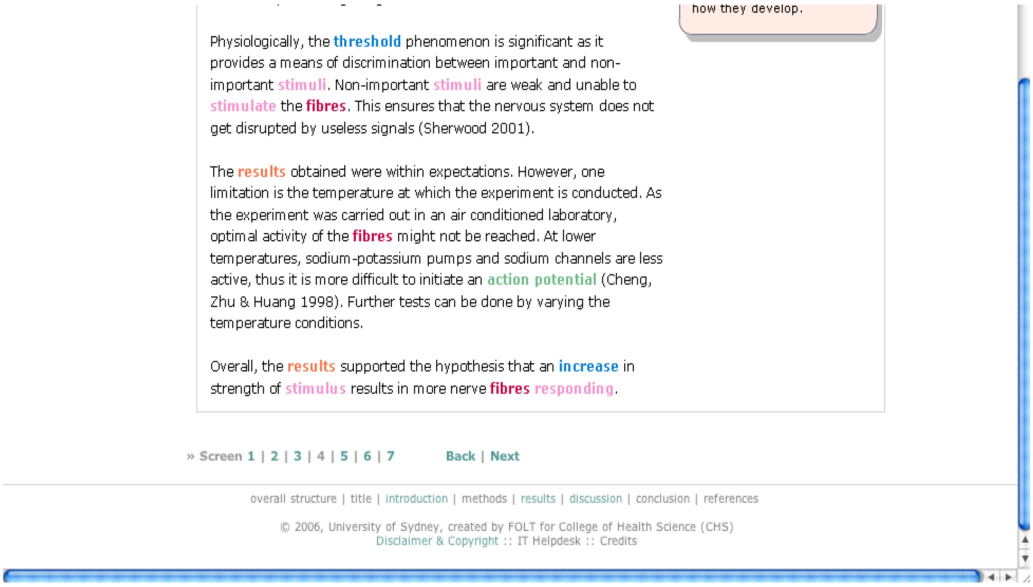


Figure 8.2. Screenshots showing use of colour in lexical cohesion in Discussion section of FLERT.

In Figures 8.3 and 8.4 the resources of colour and animation have been used to demonstrate the patterns of information flow between Theme and New. As the student clicks on the animation button in the right hand corner in Figure 8.3, the animation starts, showing the dynamic unfolding of the text and the links between Theme and New (Figure 8.4).

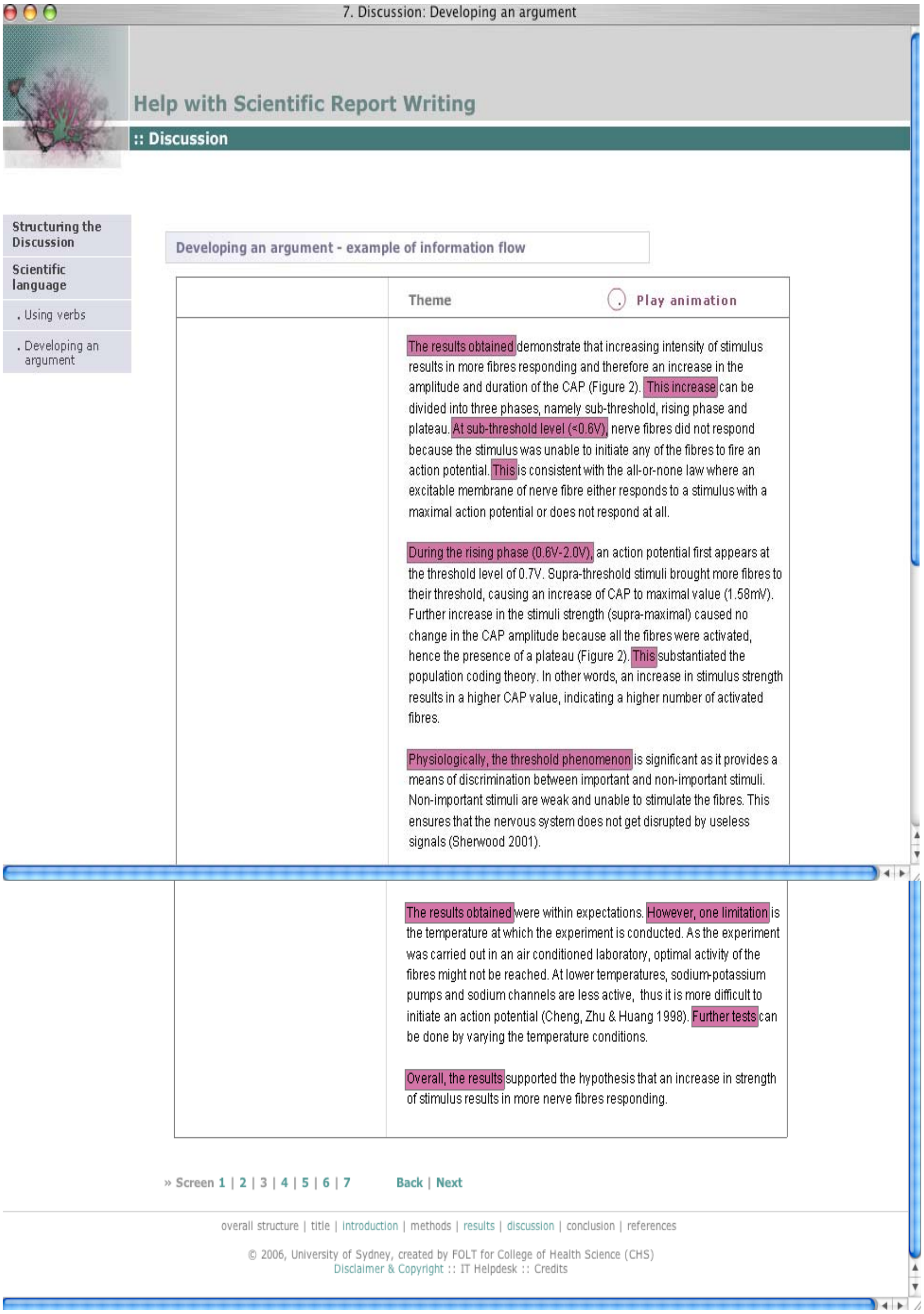


Figure 8.3. Screenshots showing use of colour in Theme, before animation.

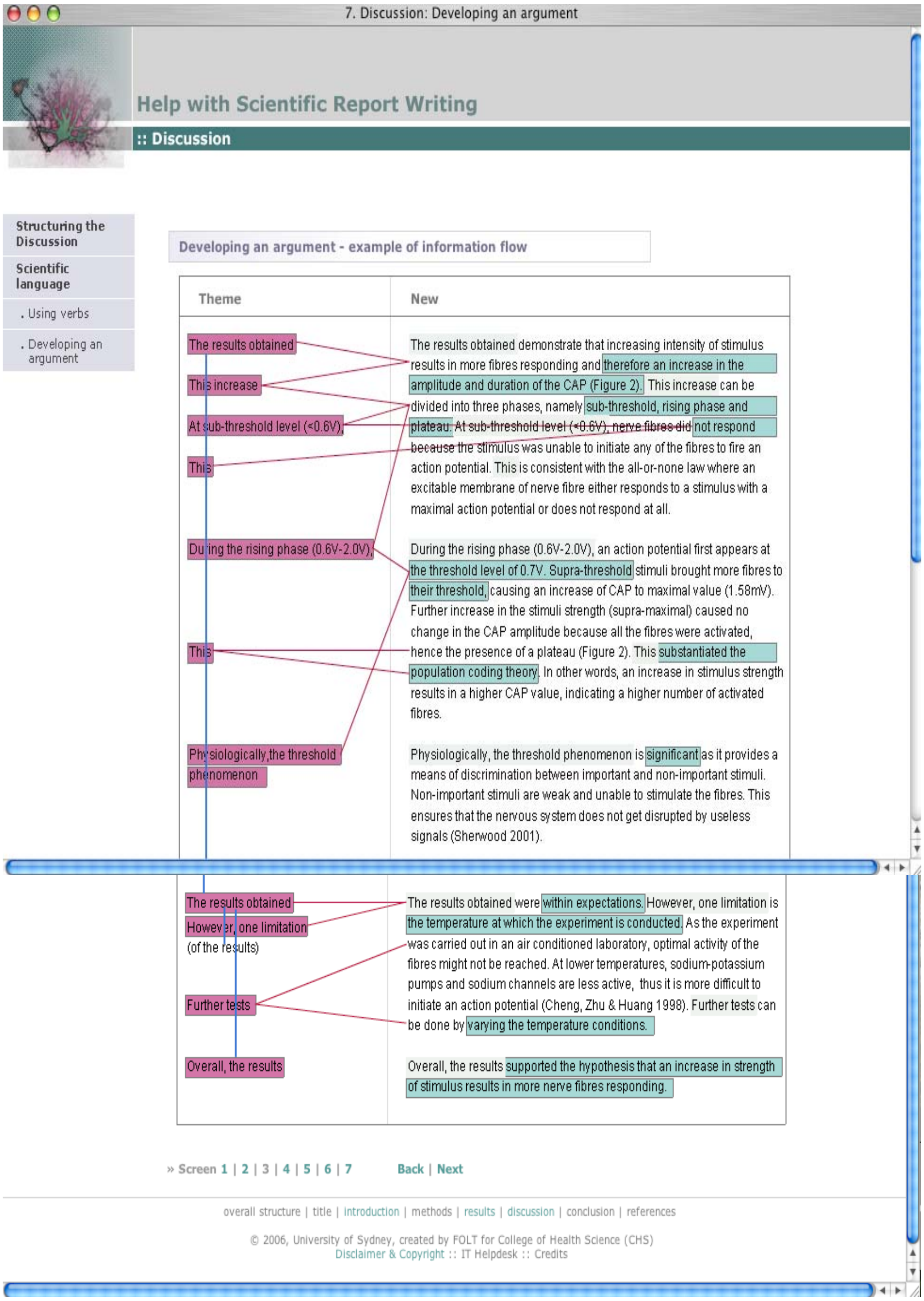


Figure 8.4. Screenshots showing Theme and New after animation.

Chapter 1 suggested a number of possible significant outcomes for the thesis research. Among these were a framework for the analysis of multimodality and intersemiosis which could advance the understanding of literacy practices in science at university and a set of principles which could be used to inform the educational design of teaching and learning resources for university students.

The examples in 8.3.1 and 8.3.2 illustrate the application of the research to a professional context – that of teaching multiliteracies for academic purposes. It is hoped that the study will have applications in other educational contexts to provide insights for teachers and educational designers to assist them in the development of students' multiliteracies, particularly in online learning environments.

8.4 Final comment

This thesis has examined the construction of multimodal meaning in teaching and learning resources for students in science at university and the role of emerging technologies in that process. The study has been firmly located in the professional context of a university Learning Centre, motivated by the need to understand the multimodal texts our students are engaged with as they participate in constantly changing learning environments. For teaching practitioners, the design of online and print-based learning materials poses exciting challenges, necessitating a deeper understanding of the representational resources of the page and screen. Moreover, the value of a study such as this also lies in complementing research from different theoretical paradigms on computer-based learning and multimodality. As a final point, it is hoped that insights from this thesis can lead to more effective educational design of learning resources and a more critical perspective on teaching multiliteracies in the wider educational community.

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