UNIVERSITY OF SOUTHAMPTON

The rôle of metaphor in the teaching of computing; towards a taxonomy of pedagogic content knowledge.

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ABSTRACT

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<u>Doctor of Philosophy</u>

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By William John Woollard

The teaching of computing, like all subjects, requires a range of strategies to take the curriculum content (skills, knowledge, understanding and attitudes) and put it in a form that is more easily digested by learners. Metaphor has a particular rôle in the world of computing in that: it is embedded in the design of computer hardware and software; it is part of human computer interface and it underpins important facilities such as icons, pointer actions and window displays. It is proposed that metaphor plays an important rôle in the pedagogic content knowledge (PCK) of computing teachers.

The research adopts a grounded theory approach using text analysis software to record and process a range of documents, statements, interview transcripts and text book analyses. The study is underpinned by consideration of pedagogic content knowledge. The major data source are reflections and reports of experienced and successful computer teachers working at post-16 level (grades 12-13) in 20 south-of-England schools and colleges.

It is proposed that metaphor usage can be divided into many distinct forms. The most easily recognised metaphor is the narrative theme where an object, function or system is described in the clothes of another, more familiar object, function or system. The other approaches with a metaphoric nature identified are algorithm, model, rôle play and diagram. In contrast to metaphoric, it has been identified that approaches are also based upon literal teaching.

The outcomes of the research reveal a new perspective upon the pedagogic content knowledge with respect to the teaching of computing in post-compulsory education. A model of approaches that identifies the key areas and emphasises the rôle metaphor plays in both the teaching strategies and the subject knowledge of computing, is presented. Different practices are described, compared and presented in a form that will help practising and pre-service teachers identify their own preferred approach or approaches.

Future research is proposed to determine the effectiveness and efficiency of particular metaphoric strategies. In particular, the rôle non-literal teaching approaches can make in enabling younger pupils to understand the principles of computing and how non-literal approaches can be used to ensure students are more motivated in their studies will be made.

Keywords:
pedagogy, metaphor, pedagogic content knowledge, literal teaching, pedagogic metaphor, algorithm.

Acknowledgements

I wish to express my thanks to Professor Mary Ratcliffe for her support and guidance for the past five years during which my efforts have waxed and waned. My thanks also go to colleagues for their support.

I am also very grateful to the teachers and tutors in schools who have given their time and conviction to my studies - thank you.

And, of course, to my family and all those jobs not done.

John Woollard
May 2004

The rôle of metaphor in the teaching of computing; towards a taxonomy of pedagogic content knowledge.

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Chapter 1 Introduction

> PHILOSOPHERS AGAINST METAPHOR
>
> With the decline of metaphysics, philosophers have grown less and less concerned about Godliness and more and more obsessed with cleanliness, aspiring to ever higher levels of linguistic hygiene. In consequence, there has been a tendency for metaphors to fall into disfavour, the common opinion being that they are a frequent source of infection.

(Horsburgh, 1958: 231)

My research focuses upon an area of study close to my heart and my experience. Since 1978 I have been involved directly and indirectly with the teaching of the use of computers. That has ranged from working with children under the age of five years (the identification of prerequisite skills and determining the understanding by pupils) through to training non-English speaking adults in asylum prisons. It has included observing and teaching rudimentary word processing through to the concepts and procedures of object orientated programming at post-16, undergraduate and Masters levels. I have been a teacher trainer of ICT since 1989 and have worked in higher education in computing, IT and ICT since 1998. I am now a teacher trainer with a responsibility to ensure that trainee teachers can teach computing efficiently and effectively in the 11-18 years age range and in particular in the post-16 phase.

This study identifies and then focuses upon the teaching of the concepts of computing in post-16 education (grades 12-14) and is concerned with the means by which teachers enable their students to learn those concepts. The processes associated with pedagogic content knowledge (PCK) are paramount in this study. The evidence base is the statements of the teachers themselves and their own reflections upon practice. Those teachers are associated with initial teacher training and the teaching of computing and ICT at post-16 level. The teaching of computing is in its infancy; compared with the 4000 years of the teaching of mathematics, the mere 40 years of computer education means that there is still much to be learned about the teaching and learning processes.

For some time I have been interested in the ideas relating to metaphor. In the world of computing we are frequently devising new products, indeed new ideas, which need explaining to the client or learner. For instance, in 1979 I devised a program that recorded and reported the progress and attainment of pupils for my MA(Ed) dissertation (Woollard, 1981). To help the pupils understand the system parallels were drawn with the class record book (one page per pupil) and that pressing the space bar (page turning) enabled the computer to use the right record (page). Page turning has appeared as a widespread description of a certain type of multimedia software. A classic example is the description given to a filtering system that prevents damaging data crossing between two computers. It was called a “firewall” to enable other computer technicians to imagine its functionality. The language of computing is rich with metaphor: gateway; walled garden; portal; desktop; window; dialogue box... Also, the language of computer related conversation is rich with metaphor and an investigation based upon discourse analysis is very revealing. My earlier work (Cooke and Woollard, 2004) considered the icon as a metaphor. The area of visual literacy and, in particular, computer visual literacy is also one rich with metaphoric implications. Metaphor occurs at the level of concept, system, object and speech within computing.

Tim Rohrer of University of Oregon Philosophy department observed “I like to think of myself as someone who sits on the curb of the info-highway, bemusedly watching all the traffic whiz by - and also as someone who occasionally darts out into the traffic to pick up interesting litter” (Rohrer, 1997). My own position is somewhat different. I'm travelling down that highway at a goodly pace, knowing something of the technology and something of the procedures. Using Tom Rohrer’s metaphorical image, I know about lane discipline and when to signal. My job is to get more people using the highway, obeying the rules of the road and getting effectively from A to B; I am a teacher and a teacher trainer. It is hard, once you are on the highway, comfortable with travelling, relaxed and confident, to place oneself in the position of someone tentatively edging their way down the slip road for the first time. How do I persuade fellow drivers that it is worth using the highway and not the same familiar side streets? Importantly, for the depth and quality of study and curriculum enhancement, how do I teach the mores of the highway and the range and length of the many highways available? How do I change my subject knowledge of travelling the information highway into pedagogic curriculum knowledge?

The internet owns the metaphor “information highway”. This metaphor implies the artefacts, systems and relationships of the highways we drive along. By using a metaphor in the passages above, Tim Rohrer articulated his position and I have also articulated the motivations for my work on metaphor. My study relates to the role of metaphor in teaching computing.

The research questions begin with “what is the rôle of metaphor in the construction of computer pedagogic content knowledge?” (see Figure1.)

Metaphor began as a primary focus of the work but the more general discussion of content pedagogic knowledge in the teaching of computing and ICT is one of importance. Indeed, it has yet to be fully explored in contemporary literature and, when compared to the teaching of mathematics, language and other subjects has a very short history. From the starting point of the role of metaphor in the construction of computer pedagogic content knowledge, the question is operationalised and becomes “what do teachers do to turn content knowledge into pedagogic content knowledge with special emphasis upon the use of metaphor and analogy within computing and the use of computers?”

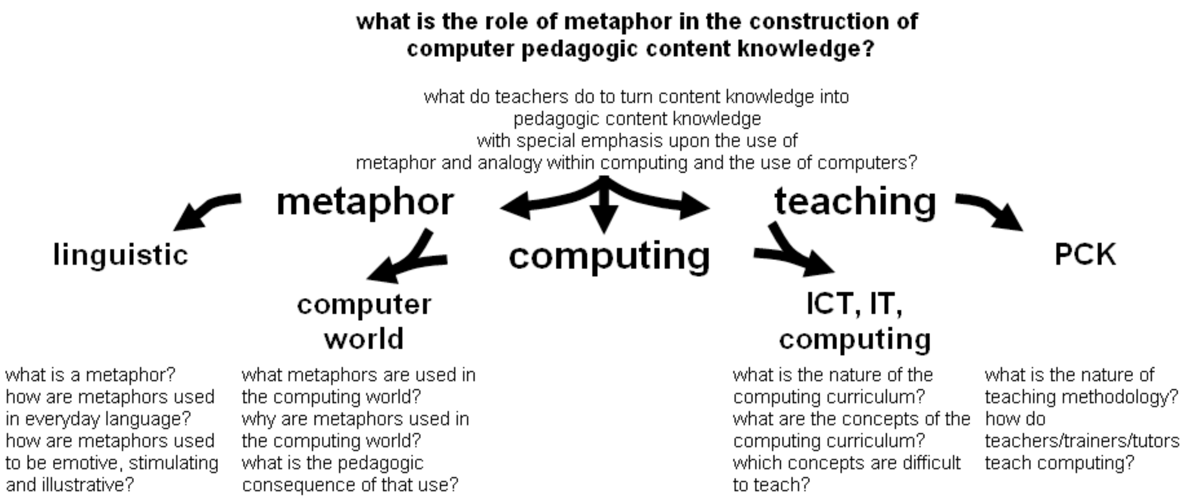
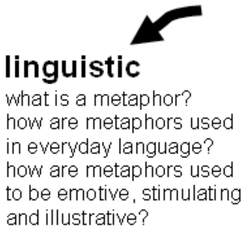


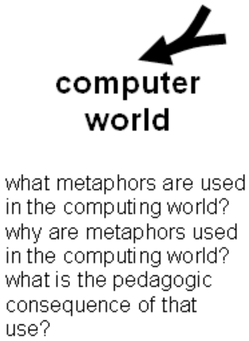
Figure 1 research questions and sub-questions

The development of the research questions then arose from aspects of “metaphor” and “teaching”. The three aspects of metaphor are those relating to: linguistics; the computer world and the computing curriculum. The aspects of teaching are those related to: the curriculum of computing; IT and ICT; difficult concepts within the curriculum and pedagogic content knowledge.



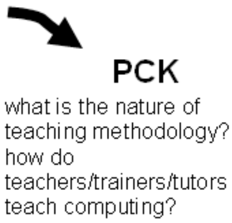
Chapter 2 Metaphor from rhetoric to physiology

This part of the literature review considers both the cognitivists’ and linguists’ approach to metaphor. The questions first ask what metaphors are and how are they used in everyday language. The review also considers how they are used to be emotive, stimulating and illustrative. The literature review reveals the connections being established by physiologists at the level of neuron, synapse and dendrites, through the ideas related to embodiment, semantics, artificial intelligence, cognition and language. The review begins with an analysis of the meaning of the word metaphor, the technical description and its role in conversational language. The contrasting works of Lakoff, Ratzan and Lawler characterise three different approaches to the study of metaphor in language and life. Their models are further explored and the implications of their work related to the use of metaphor and computing. The chapter concludes with a declaration of metaphor description based upon metaphor theme and image schema.



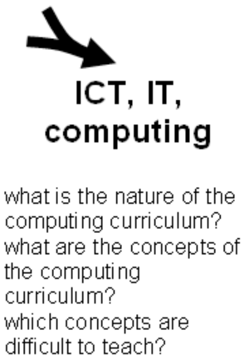
Chapter 3 Metaphor in the world of computing

The second aspect of the research questions is reflected in the next section of the literature review which is concerned with the use of metaphor within the world of computing, how metaphor arises, the value in particular areas of technological development and the pedagogic implications for error and misconception. This section addresses the research questions: what metaphors are used in the computing world; why are metaphors used in the computing world and what is the pedagogic consequence of that use? The chapter considers the image schema of: being or located; virtual physical activity; container and surface metaphor. It then considers the rôle of the more complex integrated metaphor including the ubiquitous desktop and the superhighway metaphor. It concludes by considering the “metaphor too far” when the use of metaphor causes misunderstanding or anxiety for the user.



Chapter 4 Pedagogic content knowledge

This chapter reviews the literature regarding the strategies employed by teachers to teach and reviews the theories associated with those strategies. It creates the pedagogic context for the research and a foundation for the grounded theory approach. This literature review underpins the major focus of this work: what do teachers do to turn content knowledge into pedagogic content knowledge with special emphasis upon the use of metaphor and analogy within computing and the use of computers? It directly addresses the subsidiary research questions: what is the nature of teaching methodology and how do teachers/trainers/tutors teach computing? The major focus is the study of pedagogic content knowledge (PCK) as described originally by Lee Shulman in 1986.



Chapter 5 Developing the research design

This chapter discusses the research methodologies that were considered and adopted to enable the collection of empirical data. It contains a brief overview of the cycles of enquiry undertaken and the rationale for the initial organic nature of the research The qualitative versus quantitative division is identified and a justification for qualitative practice is stated. The interpretative nature of enquiry is described and the use of grounded theory method justified. The rationale for the appropriateness of interviews and the interview process is outlined and the challenges that the approach presents are described. The writing of the interview schedule and the cautions are clearly described and the ethical issues are presented as part of the full description and rationale of the methodology.

Chapter 6 Implementing the research design

This chapter describes the implementation of that methodology, the prerequisite activities and the subsequent coding process. There are four distinct phases to the research implementation that take place before carrying out the interviewing of teachers. They are: identifying and describing the stakeholders of the research; gathering and describing metaphor (teacher inset groups); identifying and describing the sample group (teachers of computing) and identifying and describing the difficult concepts of computing (focus group). The interview schedule is informed by: the ethical statement; A-Z of metaphors; difficult topics of computing and the literature review. The major data sources are the transcripts and documents of the interviews informed by the experienced and successful teachers of computing. These are processed and encoded in QSR-NVivo software.

Chapter 7 Towards a taxonomy of pedagogic approaches

This chapter describes the results of the empirical data collected, the characteristics of the respondents, the conceptualisation of the situation and the move towards establishing theory (grounded theory method). The data collection is underpinned and contextualised by a range of activities including: scrutiny of examination reports and text books; teaching sessions and focussed discussion of the role of metaphor in computer design and computing curriculum and research seminars with interested professionals. The results of this study are primarily based upon the outcomes of interviews with experienced and successful teachers and tutors. The final aspect of the analysis is an exercise of intellectual engagement with the transcriptions, reflections upon the literature and a growing sense of a justified theorem relating to the teaching of computing. The research is underpinned by the principles of grounded theory method and the use of computer software to facilitate the coding, memoing and analysis of the data.

As a result of the analysis there is described a model of pedagogic content knowledge which includes metaphoric and literal approaches. This research has had a profound impact upon me as a teacher trainer of computing and ICT teachers. As a result of these studies, I have identified significant teaching points and areas of the training process that require change.

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03 September 2009

Chapter 2 From rhetoric to physiology - a literature review

This first chapter of the literature review directly addresses the research questions:

what is a metaphor?

how are metaphors used in everyday language? and

how are they used to be emotive, stimulating and illustrative?

From the early works of Aristotle to the most recent contributions of Lakoff, the rôle of metaphor in rhetoric and literature is considered. The research question asks “how are metaphors used in everyday language?” The tropes of the English language (metonymy, synecdoche, simile, analogy) are explained and exemplified. A model of metaphor categories is described using the constructs of colour, position, space and time and the relationship between metaphor and physiology is considered. Finally, a discussion of the “wrongness” of using metaphor is presented - this is later returned to in the analysis of teacher responses.

The literature review reveals the connections being established between the physiologists’ work at the level of neuron, synapse and dendrites and the ideas related to embodiment, semantics, artificial intelligence, cognition and language. The review establishes the importance of metaphor across a range of disciplines within physiology, linguistics, cognition and psychology.

From different perspectives, metaphor can be seen to be a variety of things.

Metaphor is related to our cognition, our understanding and our thinking. It is with metaphor that cognitive scientists explain how thinking is structured through categorisation of conceptual structure and image schema.

Metaphor is a powerful trope of language and communication. Language is an expression of our understanding or, arguably, our understanding is established through language. The metaphor is an important tool for explaining the relationship between language and learning.

Metaphor is related to literature and rhetoric. It is an artistic device to enable more colourful and stimulating writing and speech. It is a means of conveying meaning at a level not possible by the literal use of words.

Metaphor is related to everyday life and language. It is a natural trope engaged in without conscious effort and interpreted without angst or difficulty. Metaphor is the vehicle for our conversational wanderings whether that is plodding through a description, stumbling through an interview or stepping through an argument. As the previous sentence show, we use terms that are not literally true but bring colour to our speech and writing. The world of computers is full of everyday metaphor, much of it flavoured by the technology. However, in addition, metaphor plays a different and important rôle.

Metaphor is related to the design of computer software and the human computer interface. The metaphor is exploited in a conscious and even artificial way to support the computer user when dealing with new facilities and new presentations of computer functionality. Metaphor is seen to be an important tool of the computer scientist and the design of the human computer interface (HCI).

Chapter contents:

2.1 Overview and introduction

The storyline of this review begins in the beginning with Aristotle's thoughts and a consideration of the traditional view of rhetoric and literature. The rhetoric application of metaphor does have cognitive implications and the discussion moves towards understanding. The "model, product, theme" terminology is adopted and described in terms of the other nomenclature found in the literature. Other tropes of the English language are discussed, and an initial identification of metaphor categories is made. Finally, in this chapter the physiological aspects of metaphor are considered and the wrongness of metaphor use is discussed.

The metaphor extends our ability to describe new and unknown situations. It has a particular place in the world of computers including the metaphoric "being or located", virtual physical activity, the image schema containers and the naming of objects and functions. The integrated metaphor is described through the example of the internet called the "information highway". It, the metaphor, implies the constructs, systems and relationships of highways we drive along. We can describe other aspects of our use of the internet in terms of the highway with its policing systems, checkpoints and tolls. This is described later as the model-product relationship (Figure 3) within a metaphor theme and is illustrated in Figure2.

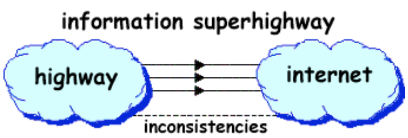


Figure 2 the information superhighway metaphor theme

The other important aspect of metaphor is the assertion that it is part of the structure of knowledge and understanding. The following premises were first articulated by George Lakoff in 1980 and later in his book Women, Fire and Dangerous Things:

- thought is embodied - conceptual systems are directly grounded in perception, body movement and experience;
- thought is embodied - it is represented by physical connexions between cells of the brain;
- thought is imaginative - it goes beyond the physical experience and employs metaphor, metonymy and mental imagery;
- imaginative thought is embodied - categories are embodied in the same way as experiences;
- thought has *gestalt properties* - a structure can have more than one meaning;
- conceptual structures can be described using cognitive models.

These principles are adapted directly from George Lakoff (Lakoff, 1987: xiv). This work, as described later, underpins category and image schemata.

It is at this point that our consideration of metaphoric language and thought, our understanding of computer systems and processes and our ability to ensure that learners have a better understanding of those processes come together. There is a deeper and more profound reason why this study may have implications for human knowledge. The author and the science are at a very early stage of development in these ideas. Perhaps this is the start of the “brave new world” where human understanding is fully complemented by computer understanding. Perhaps our understanding of the cognitive, linguistic, gestalt and physiological properties of metaphor will direct advances in artificial intelligence. The metaphor may be the key to the development of computers that think like humans.

2.2 In the beginning…

Aristotle’s Rhetoric, translated by WR Roberts (1952) in The works of Aristotle: Rhetorica, De rhetorica ad Alexandrum, Poetica relates that Aristotle believed metaphors to be implicit comparisons based upon analogy and that they equate to the comparison theory of metaphors. This is pertinent to computer based metaphor. In Poetica, Aristotle defined metaphor as giving “a thing a name that belongs to something else” thus emphasising the “lie” associated with metaphor. In paraphrasing Plato’s definition of a myth, Carolyn Pinkard describes metaphor as “lies that tell the truth” (Pinkard, 2000). Aristotle’s definition draws upon the analogy aspect when two things are alike in such a way that one can take the name of another. The computer device for disposing of unwanted files has the given name of another object, the recycle bin. The familiarity of the ideas associated with “recycling” gives a perceived familiarity and understanding of the functions of the computer device. A consideration of the way the computer feature properly emulates that of a recycling bin, what other more distinct functions it possesses and the implications of the iconic representation will be made in the next chapter.

Plato’s “Myth of the Cave” recounts that men were fastened to the walls of a cave in such a way that they could not see out of it. Their heads were fixed in a position that permitted them to see only straight ahead at the walls of the cave. There they could see only shadows created by fires built behind them. In this way the men who tended the fires could govern what the prisoners saw. Over time the men became convinced that the shadow figures made up all the content of the world. They became sure that the shadows they saw were the only reality (Pinkard, 2000: 10). Plato acknowledges that myths are stories purportedly true but actually false, but tell a truth. The cave myth warns us to take care that we are seeing the reality and not just shadows of the reality and what we can see is the whole truth and not just a small part of the truth.

The early works of Aristotle and Plato reflect and underpin much of the 20th century use of metaphor. More recent analyses of language emphasise the naming of one object to describe another. John Sowa (1983) in his Conceptual structures: Information Processing in Mind and Machine describes a metaphor as a normal means of adapting existing words to new situations. An example is the use of firewall; the name and its meaning existed in general use well before its usage to describe a hardware/software resource that protects a system from external damage. However, Gilbert Ryle in The Concept of Mind (Ryle, 1949: 14) describes it differently as the presentation of the facts of one category in the idioms appropriate to another, for example, describing prose instructions in the form of a list or the diagrammatic representation of a concept. His ideas are underpinned by the concept of categories which lead to the classification of metaphor; this is considered later in this chapter. Another definition of metaphor made by Nelson Goodman in The Structure of Appearance suggests it to be “a whole set of alternative labels, a whole apparatus of organisation that takes over new territory” (Goodman, 1976: 72-74), the alternative labels being textual, diagrammatic or pictorial. Gareth Morgan, in his treaty on organisational metaphors, describes them as “a primal force through which humans create meaning by using one element of experience to understand another” (Morgan, 1998: 4). These ideas, which describe the source of metaphor as being one of linguistic manipulation, are later questioned when the physiological basis (the embodied mind) is considered. However, these ideas form an understanding of metaphor and its occurrence in everyday language and teaching methodologies. Further ideas are developed by John Carroll who relates metaphor to the cognitive representation of computing (Carroll, 1982).Those considerations include the desktop interface and the common software such as spreadsheets, painting programs, database management systems and the word processor.

Word processing has the underlying concept of a scroll (Carroll, 1984). Early word processors (of the graphic user interface) had icons to reflect this metaphor including the word processors Impression and Ovation (Computer Concepts, 1994). All word processors until recent times (c1995) were based upon the facility of a single sheet of writing material extending downwards in an apparently limitless way with clear start and end points. Pagination only takes place at the point of printing when the computer automatically chops-up the text into pages based upon the specifications of the printer. The earliest word processors, for example Wordwise, introduced some limited control over the output (for example, force a new page) but essentially what you saw was a flowing screen of text and not what you got when printing. More recent WYSIWYG (what you see is what you get) word processors enable the user to see the page layout before printing (print preview). Some users even prefer to work in WYSIWYG format although the software designer’s default remains a presentation based upon an ancient scroll.

In contrast to word processing, desktop publishing software is based upon a different metaphor. Desktop publishing, like several other genres of programs, is based upon a page-turning metaphor. The software can be imagined to be an exercise book where each page of the book is accessible and information is placed on a particular page, in a particular position. There is not a continuity of text flowing from one page to the next (although this can be made to appear to happen). The emphasis is upon single page design and the user turning the page to get to the next display. This metaphor is extended in multimedia authoring programs such as Illuminatus and Toolbook (Helander, 1997; Madsen, 1994).

2.3 Rhetoric and literature…

In this section the metaphor is analysed in terms of "manipulation of the use of words" through the spoken "utterance" or the written text. This emphasis upon words is described by IA Richards in his Philosophy of Rhetoric. He provides the definition "the traditional theory ...made metaphor seem to be a verbal matter, a shifting and displacement of words, whereas fundamentally it is a borrowing between and intercourse of thoughts, a transaction between contexts. Thought is metaphoric, and proceeds by comparison, and the metaphors of language derive" (Richards, 1936: 96). Importantly, this reflects the all-embracing role of metaphor in everyday language and conceptual understanding. This is the connection between metaphor used as "common parlance" and the metaphor as a model for our perception of the understanding process. For example, many computer users will comfortably use the phrase "burning a CD" – simply because they have heard someone else using the phrase – it is common parlance. Our exposure to the science fictions of James Bond and others gives the impression that the laser light is intense, powerful and associated with heat. The metaphoric phrase "burning a CD" is accepted by computer users because it fits with the literal image of the laser. The burning process is perceived to be irreversible – a one-way journey. This example shows two aspects of metaphor. The first is one is "of enabling understanding". The association of combustion (a well known phenomenon) with placing information on a CD implies a one-way event and a sense of permanence. Incidentally, the term "saving" to a CD was not used as this had connotations of less permanence because traditionally saving implied that it could be resaved and, importantly, deleted. The metaphoric use of "burning a CD" carried with it a good deal of meaning.

Another aspect of metaphor that "burning a CD" exemplifies is that of the potential for error and misconception. Technology has moved on and CD writing has changed. The activity undertaken is not one of combustion or even intense heat. The reality is that the light from the recording device changes the nature of crystals that are suspended in the plastic of the compact disc (Knott and Waites, 2000: 131). "The melted crystals along the track flow into the amorphous phase which is then "frozen-in" by cooling the layer quickly. The reflectivity of the amorphous areas is much lower than that of the crystalline areas which gives rise to the peak-and-trough pattern along the recording track (just as the lands and pits produce the pattern on a regular CD). During rewrite, some amorphous areas along the track are returned to the crystalline phase by an annealing process (heating at a temperature below the layer's melting point for a somewhat longer period). Others are converted to the amorphous phase by heating above the melting point. This process can be repeated more than a thousand times and some media manufacturers claim the number is even higher" (M&M Productions, 2003). The innocent phrase "burning a CD" now can prevent new users or learners from immediately comprehending the truth. They may have the misconception that it is a permanent and a one-way process.

IA Richards purports that our communication is limited by misunderstanding. He shows how, through discourse, there is a continual synthesis of meaning, or "principle of metaphor", and through comprehension of the way meaning changes in discourse that we can better control and animate our use of words, and so decrease misunderstanding (Richards, 1936).

Nicholas Burbules (1997) asserts that metaphor is a comparison, an equation, between apparently dissimilar objects, inviting the listener or reader to see points of similarity between them while also inviting a change in the originally related concepts by “changing over” previously unrelated characteristics from one to the other. Ronald Baecker and others (Abrams, 1998) suggest metaphor is an invisible web of terms and associations that underlie the way we speak and think about a concept. For Roland Barthes, the literal and figurative readings and meanings work together to give a text its multilingual nature. Metaphor is a tool for rendering a text more plural (simultaneously having more than one meaning), since with more synonyms and “forms of language”, the text is multiplied in both depth and meaning: “The excess of metaphor... is a game played by the discourse. The game, which is a regulated activity and always subject to return, consists then not in piling up words for mere verbal pleasure (logorrhoea) but in multiplying one form of language... as though in an attempt to exhaust the nonetheless infinite variety and reinventiveness of synonyms, while repeating and varying the signifier, so as to affirm the plural existence of the text” (Barthes, 1993: 17). Annette Lavers writing in the preface to Roland Barthes work (Barthes, 1993: 7) confirms “first and foremost… is linguistics, whose mark is seen not so much in the use of a specialized vocabulary as in the extension to other fields of words normally reserved for speech or writing, such as transcription, retort, reading, univocal… also associated with a rediscovery of ancient rhetoric.” Although this natural or spontaneous use of metaphor is bound to happen in computing lessons as much so as anywhere else in rhetoric and dialogue, it is not the focus of this study. The study is not merely concerned with metaphor arising as a result of classroom dialogue. It is concerned with those metaphors that support student learning arising from the teachers’ planning and pedagogic processes and those metaphors presented in the curriculum specifications and text.

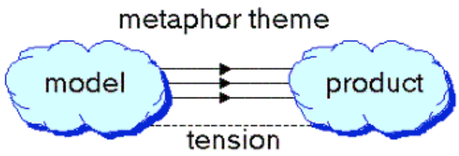
The Oxford English Dictionary (OED, 2003) defines metaphor as that ”figure of speech in which a name or descriptive term is transferred to some object different from, but analogous to, that to which it is properly applicable”. In its simplest form, metaphor is seen to be the borrowing of language that describes one object to be used to describe another object. However, that description denies the complexities of that relation, the nature of the objects and the contexts within which the metaphors exist. A seminal piece of work which draws together the different strands of thinking, redefines their context and acts as a starting point for developments into the current phase of thinking is that edited by Andrew Ortony (Ortony, 1979). It is the rôle metaphor has in the relationship between language and understanding that is important. The initial premise is that there is a dichotomy existing between the “science” of explanation of the physical reality and the “relativism” of the cognitive reality. The objective world is not directly accessible, but is constructed on the basis of the constraining influences of human knowledge and language and the claim that metaphor is the device through which all cognition takes place.

2.4 Model, product, theme…

A metaphor is describing one thing in terms of another. It uses the features of one to explain the features of the other. The linguistic use of the metaphor, in which a word, for example, eat, which is defined with respect to one kind of thing, food, is used in the context of a completely different kind of thing, for example, knowledge, as in “devours knowledge”, “laps up the details” but only returns “tit bits of information”. This is an exemplification of a metaphor. The linguistic approach is to consider that “knowledge” is treated semantically as if it were the same as “food”. The metaphor exists as a model - (usually) a concrete basis or ground - and a product - (usually) a concept or tenor. This is the basis of the metaphor theme. The theoretical, objective or conceptual differences that occur between the tenor and the ground form the tension within the metaphor. Alternative descriptive titles for aspects of metaphor are used. Richards (1936) used tenor and vehicle; Ryle (1949: 16-23) category mistakes; Turner and Fauconnier (1995) used source, target and ground; Andrew Goatly used vehicle, topic and ground (Goatly, 1997: 9) and Lakoff and Johnson (1980, 1999: 47) source target concept. Mary Hesse prefers primary and secondary system and describes the interaction as the “domain of the explanandum” (Hesse, 1965: 250). She supports the idea (also citing the work of Black, 1962: 37) that it is not the metaphor that creates the associations but that the associations created by the mind are the metaphor. This observation has significant bearing upon the use of the words metaphor, metaphoric and literal in the definition of metaphor used in this research. John Lawler uses the idea of theme. “The abstract phenomenon of metaphor and the instantiation of a metaphor are the abstract and concrete poles of the uses of the word metaphor. In between them is one other sense of the word, one that's very important because it represents the cognitive mapping that we use when we use metaphors, and because it controls or licenses the actual instantiations. I call this in-between level the Metaphor Theme and it is this that is frequently meant when people talk about metaphor” (Lawler, 1987: 414).

IA Richards (1936) in the Philosophy of Rhetoric describes a “standard terminology for the components of a metaphor: Tenor: the original concept. Vehicle: the second concept “transported” to modify or transform the tenor. Ground: the set of features common to the tenor and the vehicle. Tension: the effort demanded to span the gap between the tenor and the vehicle”

In the recent work of Turner and Fauconnier (1995), the description of metaphor moves onward from the model/product, domain/target description to one of blending two concepts to portray a single other. Described in a customary view of conceptual metaphor, it carries structure from one conceptual domain directly to another, from the “source” to the “target”. Each approach provides its own elucidation to the form and structure of metaphor. However, this research endeavours to interpret each within the framework of theme, model, product and tension (see Figure3.) This is notwithstanding the implications of the conclusions of George Lakoff in 1999 which dispute the model-product (source-target) similarity (Lakoff and Johnson, 1999: 119) which his earlier works supported. The rejection of the strict source target-model and the functions of relation are clearly articulated by Hoyt Alverson (Fernandez, 1991: 100). There is a justified argument for considering metaphor as simply analogy. However, Hoyt goes on to say “it may well be that the derivation of the meaning of one domain of experience from that of another, more “primitive” pre-conceptual one by a process of functional or relational mapping is the explanation of metaphor”. Support for George Lakoff’s conclusions regarding conflation of the target/concept relationship include Christopher Johnson’s study of MacWhinney’s work with a boy called Shem. That analysis looked for the conflation of the “know” and “see” concepts – that is, knowing is seeing as in “I see what you are saying”. This process of first associating the domains through juxtaposition experience of the words and then use of the words giving them similar meaning is explained physiologically as “the conflations are instances of coactivation of both domains, during which permanent neural connections between the domains develop" (Johnson, 1997: 343).



> A metaphor (theme) exists when the name of a familiar or primitive artefact, system or concept (model) is used in reference to a novel artefact, system or concept (product). Discontinuities between the model and product are tensions.
> http://www.soton.ac.uk/~wjw/metaphortheme.gif

Figure 3 the metaphor theme is the relationship between a model and the product

This model of metaphor has limitations as it does not reflect all aspects of metaphoric instantiation. A telling commentary by Eddy Zemach explains that "most theories of metaphor do not make a distinction between… …concept networks and the realms". He asserts and evidences that when a two part model is proposed there are difficulties in identifying similarities. "As long as the interaction is limited to the source and the target concept networks, only similarity-based metaphors can be accounted for" (Zemach, 1997). However, providing that the "metaphor theme" is appropriately emphasised and that the connections are seen as being only directional in the first instantiation of the metaphoric utterance, then this model (illustrated above) can be the basis of discussion for the research.

2.5 Metonymy, synecdoche, simile, analogy

To help define metaphor it is also necessary to define those aspects of language that appear close to metaphor or are a subset of metaphor including the important tropes of: metonymy, synecdoche, simile and analogy. This section also considers myths and mixed metaphors.

metonymy

Metonymy is the rhetorical or metaphorical substitution of one thing for another based on their association or proximity. Metonymy is an aspect of language where the name of an object or concept is replaced with a word closely related to or suggested by the original, for example, Downing Street for the Prime Minister's advisers – "a Downing Street statement outlined…". "Bill Gates" is used to represent a Microsoft product. We might say that "she's in computers" meaning that she is employed in the computer industry or "new software will solve the problem" meaning the state of using new software. These are examples of metonymy. Metonymy and metaphor are different kinds of linguistic structure (Lakoff and Johnson, 1980: 36). Metaphor is principally a way of conceiving of one thing in terms of another whereas metonymy is letting one thing stand for another in name only. As Roman Jacobson explains, metonyms are based on realistic connections; we say "he is fond of the bottle" (meaning, he likes alcohol) because there is a connection between alcohol and bottles (alcohol is stored in bottles). This is not a literal statement; a literal statement would simply have been: "He is fond of alcohol" (Jakobson, 1988).

synecdoche

Synecdoche is the naming of a part for the whole or a whole for the part (Fass, 1997). I have "a new set of wheels" meaning the whole car. In further exemplification, a part is used for the whole (as hand for sailor), the whole for a part (as the law for police officer), the specific for the general (as cutthroat for assassin), the general for the specific (as thief for pickpocket), or the material for the thing made from it (as steel for sword) (The American Heritage, 2000). Asking a computer teacher how many keyboards do they have is interpreted as asking – how many computer systems. The words “keyboard” or “processor” is used to represent the whole computer system; the word “title” in “how many titles do you use?” represents the whole of a software package. A keyboard is not a computer system but because of their association, one is used to represent the other. There is an important consideration. Metaphor is derived from similarity: metonymy and synecdoche are derived from contiguity (Lodge, 1990) or a physical association. As soon as discourse deviates from strictly literal, denotative reference, it will tend to do so either in the form of metaphor and simile, or in the form of metonymy and synecdoche. The computer “desktop” is metaphoric; there is a similarity between the conventional desktop and the screen of the computer represented by parallels in the function. We can conceive or understand similarities. However, the keyboard being synecdochetically associated with the computer does not signify such parallelisms; there are no parallels in the function between a keyboard and a computer.

simile

Simile identifies through comparison, links or connection that are the same in two separate objects. The categorization theory (Glucksberg and Keysar, 1989) contends that metaphors are stronger than similes giving an example that when a metaphor corrects a simile - as in “Jack isn’t just like a rock, he is a rock!” it is stronger in several respects. The simile makes a statement about a possible number of samenesses between the two objects (Jack and a rock). It does not imply a totality of sameness. The metaphor states an absolute sameness between the two and therefore gives cognitive permission to extend the comprehension of Jack’s characteristics by considering all known characteristics of a rock. For example, protection of children from unsavoury aspects of the internet is a walled garden. It is not like a walled garden – it is totally different but like the conventional walled gardens, there are many identically perceived aspects (Woollard, 1999). Metaphors must be systematic in the sense that they must be communicable from speaker to hearer in virtue of a shared system of principles (Searle, 1979: 113). The principles outlined by John Searle are abbreviated to: (1) single salient similarity; (2) contingent continuity; (3) false association; (4) cultural (natural) association; (5) being the condition of; (6) similar in meaning; (7) of relationship; (8) metonymy and synecdoche (Searle, 1979: 116-118). These principles are described later in relation to the computer metaphors.

analogy

Analogy is a form of logical inference or an instance of it, based on the assumption that if two things are known to be alike in some respects, then they must be alike in other respects. This is the fundamental assumption of metaphor. That is, metaphoric relationships are stated through utterances without qualification or explanation as in “Jack is a rock”, “the children are protected in the walled garden”. Analogy is an explicit relationship; the relationships are “said” to be analogous. For instance, in linguistics there are analogies in constructing grammar. The past of “hide” is “hidden” and the past of “speak” is “spoken”. The past of “hock” would be, if it existed, “hocken”. These are analogous morphological constructions. Words or morphemes are re-formed or created on the model of existing grammatical patterns in a language. In more general terms, analogy is a resemblance of relations; an agreement or likeness between things in some circumstances or effects, when the things are otherwise entirely different. Thus, learning enlightens the mind, because it is to the mind what light is to the eye, enabling it to discover things before hidden (WorldNet, 1997) is a stated analogy between light and eye and knowledge and brain. “This explanation has shed light on the subject” is a metaphoric utterance. It is not literally “shedding light” and there is not a hint of analogy. This can be summarised:

"it is an analogy because someone has said it is an analogy;
it is a metaphor because no one has said that it is an analogy"

This tautology reflects the feature of metaphor that there is no indication that they, the model and the product of the metaphor, are similar. In metaphor they are the same. For example, the written code of a program is the program as much as the presence of electrons in a circuitry is the program or the image on a screen is the program. One is metaphor of the other.

Further, the interest shown by some to differentiate the difference between metaphor and analogy has little benefit o this study. George Scatchard wrote “the compounds of iron… [are] carried in our blood plasma by globulin… which is stored as ferric hydroxide by ferritin much as water is held by a sponge” (Scatchard, 1949: 660) is analogy because one is considered to be like another. He did not say “ferritin is a sponge for storing ferric hydroxide” (illustrated in Figure 4.) But, for the learner, both have equal meaning. The understanding that:

- ferritin is a container;
- ferritin has a capacity that is relatively large;
- ferritin absorbs quantities of ferric hydroxide; and
- ferritin releases the ferric hydroxide easily when required.

Whether the teacher uses analogy or metaphor has little significance in the communication of meaning or understanding.

The gestalt property (see the “When metaphor is wrong” below) is:

Figure 4 gestalt properties of the concept sponge

The image above can be ferritin holding ferric hydroxide or a sponge holding water.

mythology

Myths are those narratives, passed on from person to person with little change, that, like all metaphor, are not literally true. Myth is a system of communication; it is a message. Roland Barthes’ (1915 to 1980) treaties in modern culture apply the term of myth, not to physical and abstract objects, but to forms. His descriptions encompass narratives about such diverse issues as wrestling, holiday cruises, soap powders and detergents, toys and steak and chips. He explores the conceptual meanings that develop behind those terms and how they influence our understanding of the world. Myths are not myths as a property of their content but as a property of the nature of the communication and so anything and everything can become a myth. He explains “A tree is a tree. Yes, of course. But a tree as expressed by Minou Drouet is no longer quite a tree, it is a tree which is decorated, adapted to a certain type of consumption, laden with literary self-indulgence, revolt, images, in short with a type of social usage which is added to pure matter” (Barthes, 1993: 109). And, of course, the world of computing is not without its own myths. Consider Microsoft - immediately there will a reaction from within any group of computing specialists pertaining to the instability of the operating system. That reaction has achieved mythological status. There are cultural acceptances, for example, that it is acceptable to be bad at maths and computing but not at reading or sex. There is the scary myth. A computer can be used to find out your medical records because they are on a computer; the underlying idea here is that computers are powerful, mysterious, and omnipresent and they are, therefore, very threatening. These examples show that myths are a form of metaphor. Myths are culturally based because they widely known by a group of people. They are largely unconscious in nature and, like all metaphors, are literally false, or even ludicrous, when spelled out.

mixed metaphor

Mixed metaphor is both cliché and an important form of communication. There is a perceived wrongness to “mixing one’s metaphors”. The observation that a statement is a mixed metaphor degrades its value – it is an abusage of the English language (Partridge, 1947). However, the mixing of metaphors may indeed bring out a better understanding of a concept or thing. In terms of John Searle’s principle descriptors (Searle, 1979: 116) it can be described as “S is P” but with “P being R-ish” in nature. “There is no chance of pupils getting through the firewall of this particular garden!” S, in this case, is the restricted worldwide web environment. P is the walled garden, R being the firewall. P is the walled garden within which the children’s experiences are protected from the negative influences of the worldwide web as a whole. Alexander Bain states the brevity of the metaphor renders it liable to the vice called mixed metaphors but it could be claimed that it is not the fault of the brevity [of the metaphor] but the inarticulate nature of the user” (Bain, 1887: 165-167). A better defence is that the congregation of two metaphor schemes to underpin one relationship indeed strengthens the understanding.

2.6 Metaphor and cognition

Metaphor is seen in the earlier section, Rhetoric and Literature, as a linguistic device. It is also considered to be a fundamental vehicle of understanding, of cognition. It is the tenet of this work that the metaphor is a means to understanding, that it is important in the cognitive process and it is a tool to be exploited in the teaching process. The next section deals with the terms used in describing metaphor and their use. Alongside that analysis of metaphor is also a description of other tropes that are associated with metaphor and a closer analysis of the cognitive and physiological explanation of the metaphor.

categories of metaphor

George Lakoff's and Mark Johnson's work since the late 1970's is important in identifying metaphor types. They propose that a limited number of analogies can account for most of the metaphors in everyday use. Their assertion is that our ordinary use of language is largely structured by metaphoric and metonymic principles which exhibit directionality. Human beings systematically characterise abstract ideas, thoughts, religious beliefs, political and ethical situations in terms of bodily movements and bodily functions. The primary claim of their position is that these metaphors and the directionality are not arbitrary, but instead are a natural outgrowth of the manner in which our minds are constituted. This physiological approach is discussed below. The placement of metaphors into several theoretical categories arises from the formalised work of Andrew Ortony, Mark Johnson and George Lakoff (Ortony, 1979; Lakoff and Johnston, 1980) and articulated by Lee Ratzan with these examples:

- spatial   I fell into a depression.
- ontological   A mind is a terrible thing to waste.
- personification   Life is cheating me.
- metonymy   She is into dance.
- synecdoche   Cars are choking our roads.
- literal   The Turnpike is very heavy this morning.
- homonymic   I am in the room and I am in love.
- poetic embellishment   "She was my English rose"   (Ratzan, 2000)

Computer related examples include the spatial metaphor "I am moving into computers". "The gatekeeper barred my access through the firewall" is personification of a mechanical device. "Network traffic is heavy at the start of lessons" is literally untrue - it does not possess weight. A homonymic example is "you are in a computer room and you are in a user group". Finally, this is poetic embellishment; it is an example of computer generated poetry that includes metaphoric phrases. "Thrown smoothly over blue he assaults the shore with vaulting glee" (Hinckle, 2003).

against categorisation

There are established arguments for and against categorising metaphors and devaluing the importance of the categories. Victor Kennedy argues that the common features of metaphors are more significant than the category and argues against the categorization theory of metaphors. He uses recent developments in the application of theory to metaphor, including the topics of vagueness (versus explanation), emergent features, the indefiniteness of a grouping, and shifts in the order of terms in the metaphor to test the general and implicit weaknesses of the use of metaphor (Kennedy, 1999).

Despite Victor Kennedy's arguments against, the categorisation helps establish a structure into which new metaphors can be placed pro tem as part of the process of observation and reporting. An important area that forms the basis of metaphor usage is the representation of something abstract by something physical. It is natural that we should apply the four physical terms "cold", "warm", "hard", and “soft” to more abstract domains. Since, for example, physically soft surfaces are comfortable and hard ones uncomfortable, we sometimes use “hard” and “cold” and their synonyms to express comfort and discomfort in a moral or psychological sense, as in the expressions “a hard blow” (referring to a misfortune) or “softening the blow” or “hard luck” (Melnick, 1999). Software is manageable, changeable and malleable where hardware is tough, fixed and unchanging.

image schemas

There is growing evidence and assertion from cognitive linguistics and experimental psychology that a substantial portion of language is encoded in the mind in the form of spatial representations that are grounded in perception and action (Richardson et al, 2001: 873). Daniel Richardson goes on to cite recent work which has documented the mapping between spatial linguistic terms and the mental representation of space including Hayward and Tarr, 1995; Carlson-Radvansky, Covey and Lattanzi, 1999; Schober, 1995. There are established consistencies in the ways in which spatial language is produced and comprehended. It is a natural expectation that when language refers directly to spatial properties, locations, and relationships in the world, those linguistic representations will have similar format. The rationale is more problematic when language represents concepts that have no apparent spatial property such as “hatred” or “normalisation”. Much work in cognitive linguistics has in fact argued that many linguistic and conceptual representations (even abstract ones) are based on metaphorical connections to spatially laid out “image schemas”. Daniel Richardson cites support from Raymond Gibbs, George Lakoff, Ronald Langacker and Talmy (Gibbs, 1996; Lakoff, 1987; Langacker, 1987; Talmy, 1983). His work analyses the images produced to represent “argument” and “respect” and shows that “argument” is represented by horizontal opposing arrows and “respect” is consistently represented by an inclined line uni-directional line. It is suggested that this shows clear links between the conceptual and the spatial.

Mark Johnson in The Body in the Mind outlines the rationale for their strong relationship between image and concepts (Johnson, 1987). Evidence for the schemata arises in several areas. The first is that we can manipulate images in ways that require more than simple memory of a detail-rich image such as rotating and then matching shapes. Secondly, by drawing out the established metaphors that “theory is a building” or “argument is a war” the visualisation of those images acts as the carrier for those metaphors. It is also suggested that the existence of polysemy, that is, the multiple related meanings for a single word supports the existence of a schema which could be based upon an image structure. Mark Johnson’s argument rests upon the observation that understanding moves from the concrete and physical to the abstract and non-physical (Johnson, 1987: 107) and the importance of “seeing” in understanding. Mark Johnson proposes a number of schemata which will be described below (Johnson, 1987: 126).

More recently, George Lakoff and Mark Johnson in Philosophy in the Flesh have extended their philosophy that perhaps nearly all speech is underpinned by a system of unconscious metaphor. There has been a development from the original idea that metaphor is the basis of understanding to the consideration that metaphor is also a usually unconscious influence upon attitudes and value judgments. George Lakoff describes these as embodied concepts - metaphor is the reflection of patterns of neurological connections. There are four main aspects: colour, position, space and time.

image schema of colour

Norman Holland describes a psychoanalytical approach to metaphor (Holland, 1999). For example, attitudes towards racial difference are affected by the metaphorical associations of white and black (Lakoff and Johnson, 1999). The use of blacklist, when describing web pages that are prohibited by the filtering software in a walled garden, may be considered to be less than politically correct because of the metaphoric relationship between black (skin colour) and black (bad/wrong/amoral).

George Lakoff's explanation of colour-related metaphors brings together: the consideration of the external features (wavelength of light); the sensory aspects (limitations of cornea, rods and cones); the "neural circuitry" from eye to brain and the physiological representation of that information. Our mental processes associate the sensory data with the blue concept which has manifested itself by the mind. "Thinking of colour as merely the internal representation of the external reality of surface reflectance is not merely inaccurate, it misses most of the function of colour in our lives" (Lakoff and Johnson, 1999: 25). The perception of colour is embodied in a similar way to that of other image schema. Vilayanur Ramachandran describes one of the goals of cognitive neuroscience as developing conceptual links between brain anatomy, neurophysiology, and phenomenal experience. Using the concept of synaesthesia, he illustrates how the study of certain neurological syndromes and brain-damaged patients can illuminate fundamental principles of the organization of the normal human mind (Ramachandran, 2001). One of these features of synaesthesia is that a colour concept is related to another concept. A person might report that Wednesday is orange, edges are red or the squeal of brakes is blue. Terry Regier identifies, in his analysis of the works of Kay, Berlin, Merrifield, McDaniel and others (Regier, 1996: 16-17), that colour has cross-cultural standards and the embodiment of the concepts of colour within neurology are based upon a model similar to that of other metaphoric image schema. This work reinforces the idea that connections between our physical experiences (perceptions), our neurological structures and our "understanding" of concepts are all important.

image schema of position

The source-path-goal schemata has several features: an object that moves, a starting point, a goal (destination), a route from source to goal, a trajectory of motion, the position of the object at a given time and the direction of object at a given time. There are associated adverbs: over, beneath, next to, before, during and nouns: front, back, start, course, programme, schedule, agenda, end, penultimate, order. There are a number of images and iconic representations of the position image schema including: the symbol for a ship's muster station, the road traffic sign for stop, the start and end shapes of a flow chart, chevrons at a sharp bend, function buttons on media player software and so on.

image schema of space

Spatial concepts are described in terms of the container schema (Lakoff and Johnson, 1999: 31) and chronological in terms of a timeline or source-path schema (Lakoff and Johnson, 1999: 32). Both are extremely important in conceptualising the fundamentals of computing. Two primary examples are the concepts of backup and archiving. Container metaphors include aspects of: the internet; web pages/sites; memory and stacks. As described in the next section on everyday language, "memory is a container metaphor" is evidenced through utterances like: "putting it [a file] into memory"; "the size [memory] of a computer"; "poking into memory".

image schema of time

It is the argument of current cognitive philosophers that understanding is embodied. "Reason and conceptual structure are shaped by our bodies, brains, and modes of functioning in the world. Reason and concepts are therefore not transcendent, that is, not utterly independent of the body… our most fundamental concepts - time, events, causation, the mind, the self and morality - are multiply metaphorical" (Lakoff and Johnson, 1999: 128). Time as a concept has many parallels which will have the same underlying embodiment as similar concepts. For example, time is like money. We spend, use, waste and invest both time and money and the embodiment is reflected in natural utterances where one will act as the metaphor for the other. "Don't waste my time by spending too much invested in other things." In a similar way computer memory is like time. We use and have time/memory. We also run out of time and memory.

There is an alternative perception of time. In the example above, time is a resource or a quantity. It is also a passage or a flow. Time is a journey and is metaphorically associated with the path schema. The timing of a computing lesson can be represented as a journey or a time-line. Figure 5. below indicates the 5 principle phases: entry and logging-on, introduction or scene-setting, the body of the lesson, warming-down and plenary and the final exit from the computer room.

Figure 5 lesson time-line

"The lesson is a voyage with a beginning as pupils board the train; we settle them and prepare for the journey telling them of the interesting places we shall visit. Towards the end we will prepare them for disembarkation, re-telling stories of the places visited and experiences" (Woollard, 2002c).

Further schemas are described by Mark Johnson including those listed in Figure 6.

container	*balance*	*compulsion*
blockage	*counterforce*	*restraint removal*
enablement	*attraction*	*mass-count*
path	*link*	*center-periphery*
cycle	*near-far*	*scale*
part-whole	*merging*	*splitting*
full-empty	*matching*	*superimposition*
iteration	*contact*	*process*
surface	*object*	*collection*

(Johnson, 1987: 126)

Figure 6 image schemata

George Lakoff and Mark Johnson argue that much of our linguistic and conceptual structure is shaped by a relatively small number of conceptual metaphors which draw primarily on source domains structured by bodily experience. Basic bodily experience, such as that of object manipulation with containers, generates inferential patterns which are then projected to make sense of more complex domains of experience. Research on the conceptual metaphors of the human computer interface, for example, has shown the extent to which the desktop metaphor successfully exploits basic patterns of bodily experience (Rohrer, 1995).

basic-level categories

George Lakoff describes basic-level categories as - when considering an object it becomes a basic-level if it is high enough in the taxonomy to be representational of some objects below it, and it is low enough to be represented by a mental image“(Lakoff and Johnson, 1999: 26). Mark Johnson describes our everyday understanding of the world and our experiences of it as of two types; basic-level categories being one and image schema being the other (Johnson, 1987: 208). It is the basic-level that we categorise objects. For instance, we experience the object and can visualise the concept “chair”. A subordinate category object is “rocking chair” and furniture is the superordinate category. Chair can be represented by a single mental image (Lakoff and Johnson, 1999: 26) but not furniture making chair a basic-level category. Figure 7. below represents the basic-level categorisation of the object “PC” with the superordinate category (computing devices) and subordinate devices (tablet, laptop, tower…). The PC is a basic-level category. The iconisation of basic-level category objects is common in computing.

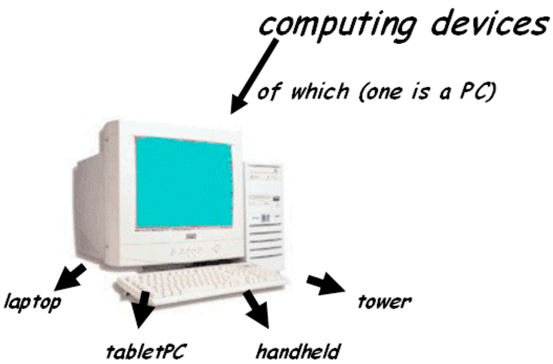


Figure 7 basic-level categorisation of a PC

The icons  (Microsoft XP™) and  (Microsoft ME™) apply equally to a laptop, tablet or handheld computer.

2.7 Metaphor and everyday language

“Metaphor is the omnipresent principle of language” is the assertion of IA Richards. It reflects the influence of 18th and 19th century writers on rhetoric and his own analysis of writing: fictional, rhetorical and scientific. “We cannot get through (even so much as) three sentences of ordinary fluid discourse without it…. Even in the rigid language of the settled sciences, we do not eliminate or prevent it without great difficulty” (Richards, 1936).

Metaphor is a feature of everyday language. George Lakoff’s and Mark Johnson’s treaty Philosophy in the Flesh substantiates the assertion that all speech is underpinned by a system of unconscious metaphor. As James Lawley explains “embedded metaphors are especially important because they often indicate how the speaker is “mentally doing” the abstract experience they are describing”

(Lawley et al, 2000: 12). He asserts that the pervasive use of metaphor embedded in everyday speech is a reflection of the underpinning embodiment of metaphors in physiology.

Donald Schön talks about metaphor as being both:

a certain kind of product, a perspective or frame by which things can be structured and also

a process by which new things can be perceived, “new perspectives on the world come into perspective” (Schön, 1979: 254).

George Lakoff and Mark Johnson state “we have found that most of our ordinary conceptual system is metaphoric in nature. And we have found a way to begin to identify in detail just what the metaphors are that structure how we perceive, how we think, and what we do” (Lakoff and Johnson, 1980: 4). George Lakoff showed how much of our thinking and acting can be explained by common metaphors. They have shown that much of our everyday language, including what we would ordinarily call literal language, is structured by conventional metaphors (Lakoff, 1987).

2.8 Using metaphor as a tool…

A technological example given by Donald Schön illustrates powerfully the value of metaphor to aid thinking about a situation. Some years ago researchers were considering the properties of natural and synthetic paint brushes in an attempt to understand the reasons for the differences in performance. Someone observed “You know a paintbrush is a kind of pump!” (Schön, 1979: 257) A brief explanation of how the action of the bristles as they are bent is to force paint onto the surface justifies the claim. The observer was thinking of the paintbrush as a pump and so able to articulate its actions. This new understanding of a paintbrush being a pump leads to further developments in the theory of paintbrushes and the enhancement of the design of synthetic bristles. This use of metaphor brought illustration of the situation and therefore a method by which further understanding could be established. The general case of understanding a thing by calling it another is central to this work. In the case of the researchers, they cannot, at first, map the elements and relations in “pump” and “paintbrush” onto one another. They cannot see paintbrush as pump. The cognitive work involves the participants in attending to new features and relations of the phenomena, and in renaming, regrouping, and reordering those features and relations (Schön, 1979: 276). The conflation is illustrated in Figure 8. The metaphor is therefore seen to be emotive, stimulating and illustrative. This example meets the definition of metaphor presented by Mark Johnson “…a pervasive mode of understanding by which we project patterns from one domain of experience in order to structure another domain of a different kind” (Johnson, 1987: xiv).

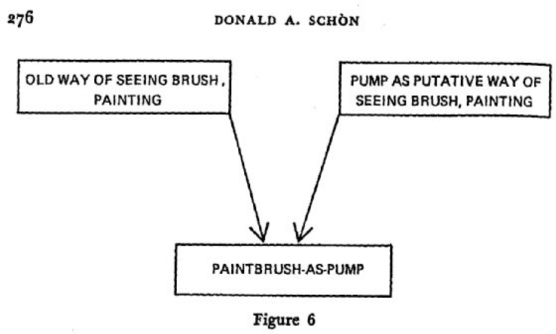


Figure 8 paintbrush is a pump metaphor

Andrew Ortony suggests three main effects of metaphor use:

- introduce colourful imagery into what otherwise would be an ordinary (or plain) expression (decorative);
- convey information inexpressible, or at least not easily communicable by ordinary language (explanative); and
- express something more concisely than possible with ordinary language.

Each effect is admirable but each has the potential for misconception and error (Ortony, 1975: 45).

2.9 Physiology and metaphor…

In this section the physiological explanation of metaphor is considered. The phrase "the embodied mind" is used by those cognitive scientists (Johnson, Lakoff, Rohrer, Rosch, Thompson, Varela and others) to signal the importance of the relationship between the physiology, the structure of knowledge and language. Important work in this area has taken place at the International Computer Science Institute in Berkeley, USA under the Neural Theory of Language Project (NTLP, 2004) including the development of a paradigm that bridges the gap between the consideration of metaphor by linguists and the findings of neuroscientists working at the physiological level.

As early as the late 1940s scientists were postulating theories relating brain physiology to understanding. Donald Hebb suggested that learning could be based upon in changes in the brain based upon neuron interaction. Frank Rosenblatt built a simple device called a "Perceptron" which emulated neuron like components which had a capacity for recognition (Rosenblatt, 1962). William Ashby carried out studies of the dynamics of large systems with random interconnections showing that they exhibit coherent global behaviours. From these early ideas have arisen many theories that relate brain physiology to knowledge and understanding. An interesting strand of development is that of "connectionism" (Feldman and Ballard, 1982) and more recently called Parallel Distributed Processing (Rummelhart, 1986) described by Francisco Valera and others as "with a whole army of neurallike, simple, unintelligent components, which, when appropriately connected, have interesting global properties. These global properties embody and express the cognitive capacities being sought" (Valera et al, 1991: 87).

This embodiment of understanding is a parallel to the ideas of the physiological embodiment of metaphor. Computational neuroscience is concerned with the modelling the brain by considering the circuitry of axons and dendrites. Cognitive systems are seen to be built, not by starting with symbols and rules but, by starting with simple components that dynamically connect to each other, in other words, neurons and clusters of neurons. Within the cognitive system there is global cooperation that spontaneously emerges when the states of all participating "neurons" reach a mutually satisfactory state. In such a system there is no need for a central processing unit to guide the entire operation. This model of embodiment is called in various works self-organization, emergent or global properties, network dynamics, non-linear networks, complex neural systems, or synergetics (Valera et al, 1991: 88).

Tim Rohrer describes embodiment as "constituted and constrained by the kinds of organization reflected in the biological, anatomical, biochemical, and neurophysiological characteristics of the body and the brain" (Rohrer, 1995: 2). He draws together the threads of philosophical, cognitive and neurophysiological ideas regarding metaphor by citing evidence from the study of different groups of brain damaged patients (Winner and Gardner, Brownell et al, Beeman et al, Keysar). He also draws on the arguments, recalled earlier, of George Lakoff (1987) and Mark Johnson (1987) that our ordinary use of language is largely structured by metaphoric and metonymic principles relating spatial movements, bodily functions and sensory perceptions to non-physical concepts. For example, understanding is seeing, sorrow is a heavy load and you are my heart throb. A primary claim of George Lakoff and Mark Johnson's position is that these metaphors are not arbitrary but are a natural "outgrowth of the manner in which our minds and brains are constituted" (Lakoff, 1999).

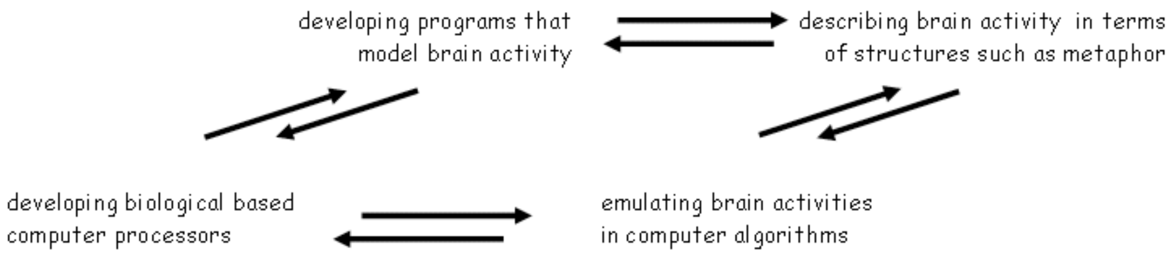


Figure 9 interconnections between the neurosciences, cognitivism and metaphor

There are exciting developments in the connections between biologically based computers, computer algorithms based upon neural network models, creating computer models of brain activity and describing brain activity in terms of neural structures such as metaphor. Figure 9. illustrates interconnections between the neurosciences, cognitivism and metaphor.

2.10 When metaphor is wrong…

A similarity is drawn between metaphor and gestalt images where the same figure/thing can be seen in two contrasting ways. This indicates a caution that needs to be taken. If the illustration (Figure 10.) below is that of a vase then the observer is mistaken to think otherwise. In the same way, the metaphor can imply a meaning that is not true.

Figure 10 gestalt characteristics of metaphor

blinds mankind to the real truth

Perhaps the original research question relating to metaphors being emotive, stimulating and illustrative should be extended to include the word wrong. Perhaps it should read "How are metaphors used to be emotive, stimulating, illustrative and wrong?"

The theme of the wrongness of metaphor continues when considering Plato's attitude to poetry and the use of metaphor in rhetoric. Plato viewed poetry and rhetoric with suspicion and banned poetry from his Utopian Republic because it gives no truth of its own, stirs up the emotions, and thereby blinds mankind to the real truth (Lakoff and Johnson, 1980: 189-190). Aristotle in his work Topica was wary of the ambiguity and obscurity of comparison (metaphors) but acknowledged their value. However, poetry survived. The literary application of the metaphor enables writers to express feelings of love, hope, wonder and pain through the physical, practical and everyday experience. The metaphor means that when we are at a loss for words then the substitute can be used.

philosophers against metaphor

In a piece entitled “Philosophers against Metaphor” (as quoted in the Introduction) H Horsburgh writes that, “with the decline of metaphysics, philosophers have grown less and less concerned about Godliness and more and more obsessed with cleanliness, aspiring to ever higher levels of linguistic hygiene. In consequence, there has been a tendency for metaphors to fall into disfavour, the common opinion being that they are a frequent source of infection.” (Horsburgh, 1958: 231) This piece of writing is, in modern eyes, interestingly metaphoric with its play upon cleanliness, hygiene and infection. It is not unlike the modern-day negative associations created with the use of virus vocabulary when discussing software that automatically carries out functions. Horsburgh argues that the metaphor is a means by which a greater understanding can be achieved. The rejection of metaphor (at the start of the 20th century) is motivated by a desire for clarity but he illustrates this through the example “the insistence on light be made an instrument of darkness. The rehabilitation of metaphor can therefore be regarded as a small part of the work which must be done if this campaign is to be brought firmly under control” (Horsburgh, 1958: 245). This is evidence of the tension that exists when considering the role of metaphor in philosophy, linguistics and cognition.

lies that tell the truth

Using metaphors can be considered to be lying. Like most science educators I tell lies. The best demonstration I've seen of the phases of the moon took place in a darkened lecture theatre with 90 would-be teachers seeing a Heath Robinson driven globe, a football and a torch. The presenter speaks, “…and this [pointing to the torch] is the sun and this [pointing to the football] is the moon,” and for the next minute in the minds of sane adults, that truth is solid and the learning is secured. The football encircles the globe in the beam of the torch. The phases of the moon are revealed. The house lights go up and the spell is broken. The sun and moon are just a torch and an ordinary football but the phases of the moon are “understood”. This is an instance of "lies that tell the truth" (Pinkard, 2000).

untrue statements that are not lies

Another example from science education is the description of the atom and its “shells” of electrons. The inner shell is complete with just 2; the other shells require 8. Learners’ experience is usually limited to the idea that shells are hard spherically shaped objects. We describe how atoms “share” electrons so that they can get a full complement. The covalent bond is described as a collaboration as strong as any human work. Other atoms give up or receive electrons in a cooperative way to become ionic. We place almost human-like features upon the atoms (anthropomorphism). We do this because the inexpressibility of some concepts in mere nouns, verbs, adjectives and adverbs forces the use of other cognitive devices to help our learners understand. Davidson (as cited in Coyne, 1995: 262) refers to metaphor groupings as untrue statements that are not lies. Perhaps the admission “Like most educators I tell lies” is perhaps wrong and should be reported “Like most educators I tell untrue statements that are not lies”. When it is said “a spreadsheet is a set of small boxes that are arranged in a (2-dimensional) grid and each box can…” when in fact it is a (1-dimensional) linked list of values, it is not a lie – it is just untrue. It is a metaphor we use to help learners understand long before we consider linked lists. Metaphors by “their power of extension” (Ratzan, 2000) have the power to trap the unwary by promoting faulty logic (Cooper, 1997).

2.11 Summary and definition of metaphor

From Plato’s rhetoric with no real truth and Aristotle’s ambiguity to Cooper’s faulty logic, there is significant evidence from the literature to suggest that metaphor may not be a panacea for learning but could in fact have negative consequences. However, the body of evidence in support of the metaphor acting as a vehicle for cognitive awareness (understanding) is growing. The late 1970s saw the turning point in the amount of literature supporting the notion of the ubiquitous metaphor, its use in everyday language and the role it plays in understanding.

Metaphors exist in many fields of contemporary philosophical thought including language and communication, literature and rhetoric, cognitivism and physiology. The current premise within cognitive science is that understanding is an embodied feature of physiology and that metaphor is a major structure of that embodiment. However, metaphor is also an aspect of the everyday language we use and is described in a number of ways using a range of terms. Figure 11. illustrates the various aspects of metaphor discussed.

This thesis will take as its definition a **model-product** structure of **metaphor theme** with associated **tensions**. Metaphor is any description or utterance that is not the literal truth and, based upon the work of Nelson Goodman, metaphors are sets of **alternative labels** or **reorganisations** including diagram, model and algorithm.

The other tropes of the English language associated with metaphor are described to more clearly sharpen our image of metaphor by describing that which is and which is not metaphor.

The categorisation of metaphor accepted as the basis for future discussion is based upon an embodied physiological model postulated by Christopher Johnson, Mark Johnson, George Lakoff, James Lawley, Terry Regier, Mark Turner and others. The description of computer-based metaphor focuses on the **image schemas** such as: container, surface, source-path-goal, link, part-whole, near-far, centre-periphery, up-down, front-back, linear as described by George Lakoff and how the understanding of concepts can be represented by the image schema.

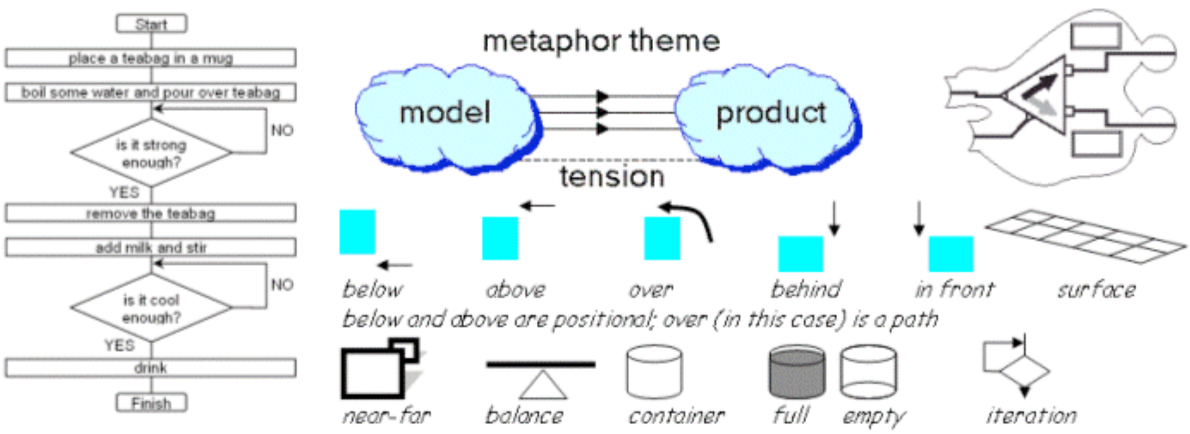


Figure 11 a collage of the diagrammatic, metaphor theme and exemplar image schema

Metaphor has two facets - it is that which naturally occurs as a result of subconscious cognitive activity and appears as utterances and acknowledgements of understanding. The other aspect of metaphor is that constructed device that is used as a means of explanation.

The description of the use of the metaphor in the teaching of computing and the description of the metaphors themselves will rely heavily upon the image schema, the associated use of other tropes of language and the rhetorical use of the metaphor theme in everyday language. The next chapter, metaphor in the world of computing, continues the literature review by considering the particular role the metaphor plays in the development and use of computing.

Chapter 3 Metaphor in the world of computing - a literature review

This chapter addresses aspects of the research question “what do teachers do to turn content knowledge into pedagogic content knowledge with special emphasis upon the use of metaphor and analogy within computing and the use of computers?” through answering:

why are metaphors used in the computing world?
what metaphors are used in the computing world?
what is the pedagogic consequence of that use?

The chapter (illustrated in Figure 12.) divides the world of computer metaphors into groups reflecting the key features of: categorisation, virtual activity, human computer interaction and, again, problematic metaphors. The first half considers metaphoric aspects of **being, doing, naming** and **located**. The second part covers the metaphoric aspects of the computer graphic user interface (**organisation**) including an analysis of the use of icons. The wrongness of metaphors is again considered in “**a metaphor too far**”.

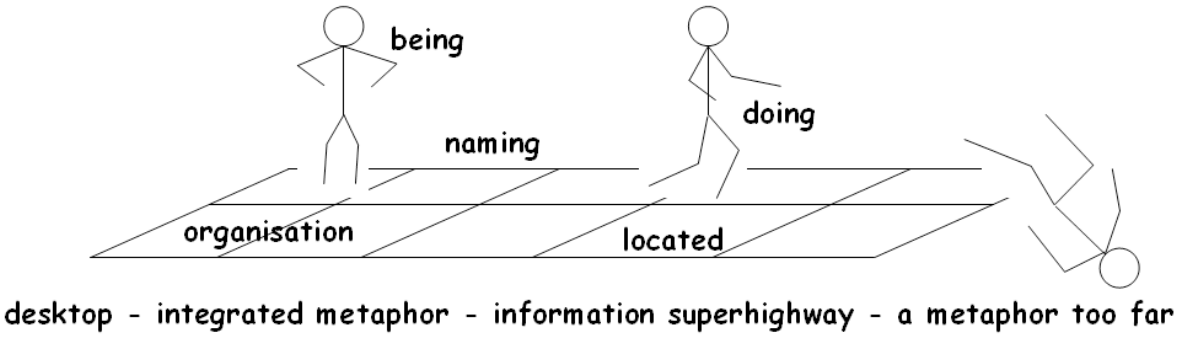


Figure 12 metaphor in the world of computing

The presentation of the first selection of metaphors is based upon an analysis structure of: container schema (Lakoff, 1999: 31); source-path-goal (Lakoff, 1999: 32) or positional; bodily or virtual physical activities; time or chronology; and the embodied concept of colour (Lakoff, 1999: 22) and image schemata (Johnson, 1987: 126).

This chapter identifies a number of different metaphors used in the computing world. Many can be considered to be traditional model/product relationships (described in the previous chapter) when the metaphor has been purposely established to aid computer users. They are named to make a direct connection with another more familiar system, object or concept. Others exemplify the metaphor categories and the image schema concept (also described in the previous chapter).

Metaphors, like jokes, lose their effectiveness if they are explained in detail. We know that a semantic integration is destroyed if we switch our attention from its meaning to that of which it is the meaning-in-other-words, from the point of focal attention to the subsidiaries which bear on that focus (Polanyi and Prosch, 1975). This is a warning that the metaphoric meaning or significance, under this close analysis, perhaps will vapourise. Michael Polanyi adds that sometimes a shattered semantic integration can be replaced, even profitably replaced, by an explicit relationship; but in many cases this is impossible. It is under this tension that this analysis of the use of metaphor in computing falls. Each of the following examples of metaphor usage within the world of computing occurs naturally and, in the main, without comment. However, this analysis is likely to leave those metaphors less emotive, stimulating and illustrative as a result of the explanation. They may, indeed, appear trivial under the spotlight of analysis. With that warning the following metaphors are presented and explained using metaphor theme and metaphor categorisation outlined in the previous chapter.

Chapter contents:

Many of the metaphors described in this chapter are included in the A-Z of computing metaphors (appendix 1) and described in Chapter 6 - implementing the research design.

3.1 Why are metaphors used?

Murray Middleton wrote at the start of the last century “the metaphor is the result of the search for a precise epithet. It is no more ornamental than a man’s Christian name. For most of the things whose quality a writer wishes to convey there is no precise epithets, simply because he is always engaged in discovering their qualities, and, like the chemist, has to invent the names for the elements he discovers” (Middleton, 1922). This statement can be paraphrased and forms the lead into this chapter on the metaphor in the world of computers - “and, like the computer scientist, has to invent the names for the features he invents”.

The people who are responsible for developments in computing are working in a fast changing world; they are working at the extremes of human knowledge and they are specialised in what they do. Consequently, communication is challenging because it needs to explain new functions and properties yet do so in an effective and efficient manner. Also, computers and their functions are pervasive in their use with few areas of commerce, leisure and home free from their influence. In other areas of science, breakthroughs are often accompanied by long periods of development, production and presentation. Unlike scientific and medical developments which have considerable testing and evaluation time, new developments in computing have almost immediate impact upon the everyday user of computers. The challenge to communicate is not limited to the computer scientist’s immediate colleagues but there is a need to communicate to the world at large. Examples of the fast uptake of new inventions include the mouse, the desktop environment, mobile telephones and the Internet. New functions and new concepts enter into the mass-communication field extremely quickly - the words have to be pithy (to be efficient) and memorable (to be effective).

Mary Hesse argues the explanatory function of metaphor in scientific pursuits (Hesse, 1980: 111-124) and Joseph Harmon reviewed 89 journal articles to “gain a better sense of the metaphorical nature of the scientific research paper” (Harmon, 1994: 179). The forms of metaphor referred to include: conceptual models, experimental designs, technical analogies, standard technical names, conventional figurative expressions and original figurative language. Both works (Hesse, 1980 and Harmon, 1994) emphasise the value of metaphor in communicating the meaning of difficult scientific concepts.

John Sowa defines metaphor as a normal means of adapting existing words to new situations and draws the important connections between metaphor and the developments in computer functionality (Sowa, 1983: 270). He establishes the role of metaphor (:38) by considering the interaction of perception (:70). Concrete concepts have percepts (can be matched to icons); abstract concepts do not have percepts and therefore this has implications for icon-metaphor relationships. For example, “Albie is one of our key employees” (:227) uses of the word “key” meaning fundamental or indispensable relating to the relationship between key and lock and accessibility. A literal phraseology would be “the caretaker (janitor) is a key employee” (because he carries keys). These images (Figure 13.) have been used across the web to represent key ideas or accessibility issues:

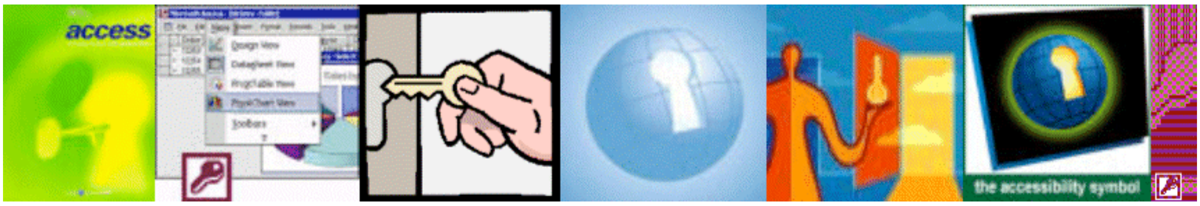


Figure 13 the images of key relate to access and key-lock relationship

Yvonne Rogers’ work relates computer interfaces and the effectiveness in terms of cognition. She describes the new paradigms (metaphors) for computing to be especially “ubiquitous, pervasive and tangible interfaces”. Her research focuses on augmenting everyday learning and work activities with interactive technologies especially dynamic visualisations, to support more effectively “external cognition” (Rogers, 2003). Earlier work by John Carroll and others describe the relationship between interface metaphors, user interface design and active learning (Carroll et al, 1995, 1998). Alan Blackwell identifies the value of the visual image when describing programming systems. Here the syntax elements (illustrated below) are represented by purely geometric symbols, and components are connected by unadorned lines.

Figure 14 using the visual image as a metaphor for electronic systems

This representation (Figure 14.) is typical of commercial dataflow languages, where the metaphor is that of electrical wiring. Alan Blackwell's work compares the learning of two groups, would-be programmers and expert programmers, who are introduced to new programming concepts in metaphoric ways and non-metaphoric ways. The conclusions (Blackwell, 1999: 7), however, do not support the use of the instructional metaphor in this area. It is suggested that proficiency in direct manipulation interfaces, such as the navigation of Microsoft™ Windows™ by a mouse and pointer would be equally successful with or without the use of an instructional metaphor. However, cited work does suggest the value in other cognitive areas (Kahn, 1996: 95).

The 1997 Microsoft slogan, "Where do you want to go today" (Microsoft, 2003b) implicates metaphoric thoughts that using the Internet is like a vehicle ("we go to web pages") and exploring the Internet is like travel. Unfortunately for Bill Gates, many thousands of people took it literally and their 0800 freefone switchboards and email boxes were swamped with calls and messages saying "the moon", "Los Angeles", "to the toilet". "I was just answering their own question," said one caller, who asked to be identified, begged to be identified, even offered to pay to be identified. "Microsoft asked me where I wanted to go today, so I told them" (Denounce, 1996). Metaphors are powerful things and used ill-advisedly can cause problems.

3.2 Being or located…

Positional metaphors (being or located) are represented by the concept absolute and the features of breadcrumbs and bookmarks.

Absolute is an example of unconscious use of a metaphor. Absolute is a term used in computing in three different but connected ways. There is the absolute path associated with a file or document, there is absolute addressing in a spreadsheet formula and there is the absolute position of a program in the computer memory. George Lakoff suggested a number of metaphor themes or genus that describes the range of metaphor. Interestingly, he does not make reference to the concept of 'absolute' (Lakoff, 1987: 12-13). However, he describes basic-level categorisation that organises basic cognition around the middle with generalisation being upward and specialisation downward. This accommodates 'absolute' if it is considered to be the most specialised/specific form:

name.doc is the file named name.doc in the folder where the user is;

..\name.doc is the file named name.doc in the folder above where the user is;

&\name.doc represents a file in the user's home;

& represents home, the most precise of places because everyone has only one home;

http://www.soton.ac.uk/~wjw7/addressing/index.htm is an absolute address of a single, unique (within the whole world) resource (Woollard, 2003).

The example below (Figure15.) illustrates relative and absolute concepts within a spreadsheet and its expected usage within the Framework for teaching ICT capability (DfES, 2002).

Relative examples			
Cell location	Contents	Copied to	New contents
A1	=A4	B1	=B4
A1	=B4	C5	=D8

Absolute examples			
Cell location	Contents	Copied to	New contents
A1	=$A$4	B1	=$A$4
A1	=$B$4	C5	=$B$4

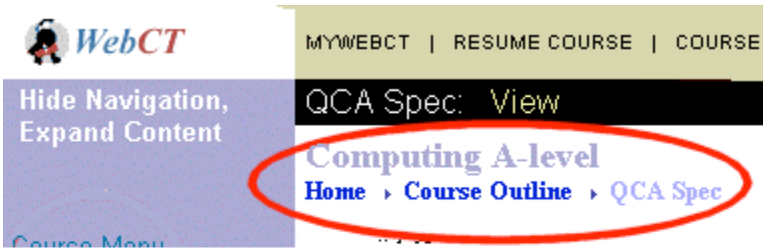
Figure 15 relative and absolute addressing within a spreadsheet

Absolute addressing is preceded by a $ symbol and makes the reference fixed even when it usage is moved to another cell. Here George Lakoff's basic-level categorisation does not explain this usage.

The third meaning is in "absolute address allocation". Each instruction or data word in the source program must be allocated an absolute machine address (its physical location). Actions made by the program or made upon the program can be relative to the base or absolute address (Knott and Waites, 2000: 427). Again, there is not an equivalent basic-level categorisation associated with this usage as defined by Joseph Lakoff.

Another metaphor used in computing is 'home'. This is a form of absolute. The internet home page is the most common usage of the word. It is iconised, for example, as  or . The usage has two outcomes. The "absolute" nature of its position gives a sense of security (like our own homes) and if lost in a website the option to "go home" gives a greater level of confidence. The second aspect of home page is one generated from the public use of the world wide web to represent themselves and their lives/family in, what is, their virtual home. In this sense, home is not a form of absolute but a form of 'self'. This is my home page; this is my home; this is me.

The term breadcrumb relates to the tale of Hansel and Gretel from the Brothers Grimm (Owens, 1993), where they dropped little bread crumbs while they were entering the forest in order to find their way back (also at http://www.mordent.com/folktales). As websites have become deep dark forests of information, where the users can easily get lost, a need has arisen for help with navigation. The breadcrumb allows the user to see where they have come from and the route taken (Stafford, 2003). For example, the breadcrumb trail (Figure16.) on a web page would indicate that a link was taken from the home page to the "Course Outline" and then chosen the QCA Spec" option and finally are viewing the "Computing" page.



Home ► Course Outline ► QCA Spec ► Computing

Figure 16 breadcrumbs indicating location and route

There is a colour coding and formatting protocol associated with this display which would indicate what options were available to the user at a particular moment. For example:

Home ► Course Outline ► QCA Spec ► **Computing**

would indicate that you could "go home" or chose to go to the "Course Outline" but not go to the "QCA Spec" page. The emboldened "Computing" emphasised the current location of the user.

"Normal" colours of blue or purple with the underscore are hypertext links enabling you to go to that location. Blue indicates that the user has not been there before and purple indicates that the page has already been visited. Those computer users with a full knowledge of the fable of Hansel and Gretel may have an enriched concept of the functionality of "breadcrumbs" beyond that of the simple trail. They will certainly realise the frailty of the trail and how it disappears because the birds eat the bread. It should be questioned whether this may lead to errors and misconceptions.

These three metaphor usages: absolute, home and breadcrumbs all relate to the term 'lost'. People sitting in front of their computer in very familiar physical situations become metaphorically lost in their virtual world. "Lost" is one of many words that have particular concept within computing and are used because of their implicit subconscious metaphoric meaning. Other worthy of comment are memory, saving, compression, normalisation and recursion. These are discussed in Chapter 7.

Bookmark (Figure17.), like many computing metaphors, is an old word applied to a new concept and giving an implied meaning. The model is the bookmark, a piece of paper or card with the owner's name on it or some picture or pattern that can readily identify it, placed in a book, magazine or journal to physically locate text of interest or, more usually, the point reached in a reading session. The computer term bookmark, the product, is a facility of a web browser to remember locations visited like a bookmark identifies a position in a book (Netscape, 2003). The browser enables a number of bookmarks to be placed and those to be organised into groups and hierarchies. It has a value in enabling web users to organise (place a construction upon) their usage which leads to higher efficiency.

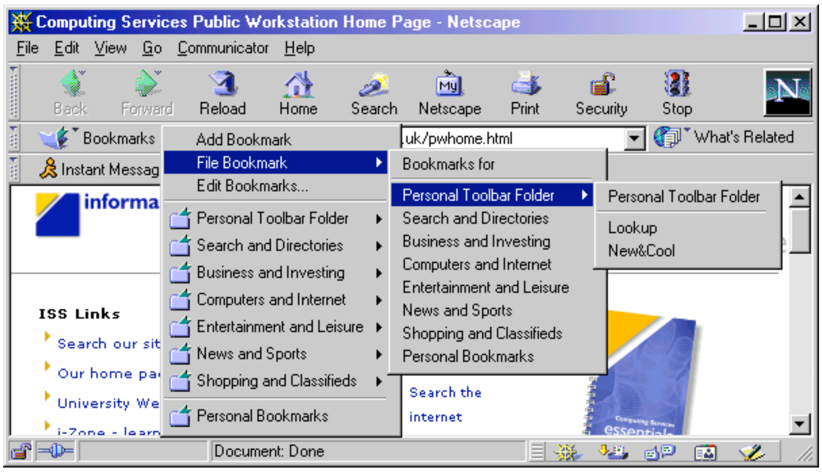


Figure 17 web browser bookmarks

The Microsoft meaning of the work bookmark is different (Figure18.) A bookmark is a point in a webpage that is "marked" so that links can be made to go directly to that position. As a concept, this device is more strongly similar to a traditional bookmark. "A bookmark is a location or selected text on a page that you have marked. You can use bookmarks as a destination for a hyperlink. For example, if you want to display a certain section of a page to the site visitor, add a hyperlink with the bookmark as its destination. When the site visitor clicks the hyperlink, the relevant part of the page is displayed, rather than the top of the page. You can also use one or more bookmarks to find locations on a page" (Microsoft, 2000). Both meanings of the term "bookmark" relate to George Lakoff''s positional category.

Traditional bookmark	Netscape™ bookmark	Microsoft™ bookmark
individually labelled with the name of the person placing the book mark	yes, it is in their bookmark list or the computer's bookmark list	no, it is anonymous – just a mark called an anchor
located with the resource and if the resource is moved then the bookmark is moved	no, the bookmark fails to work if the resource is moved or deleted	yes, bookmarks are embedded into the script of the resource
can take on different appearances	yes, if renamed or repositioned	it does not have an appearance, it is a position
can be personalised	yes	no, same for all users
listed, ordered, sorted, searched	yes	no

Figure 18 a comparison of the features of bookmarks

3.3 Virtual physical activity

The next selection of computer metaphors is associated with "doing" whilst the previous selection was related to "being" or "location". They are the physical or pseudo physical activities that are associated with virtual activities. As such, they typify the "single concept" use of metaphor in the world of computing. It is a single verb, noun or adjective that is used metaphorically. They represent the same use of metaphor as described as "everyday language" metaphor. The examples chosen are "cut and paste", "drag and drop" and "rubber banding".

"Cut and paste" refers to the paper, scissors and glue method of document production. It is a function supported by most document editing applications (e.g. text editors) and most operating systems that allows you to select a part of the document and then save it in a temporary buffer (known variously as the "clipboard", "clipbook", "cut buffer", "kill ring"). A "copy" leaves the document unchanged whereas a "cut" deletes the selected part. A "paste" inserts the data from the clipboard into the current position in the document (usually replacing any currently selected data). This may be done more than once, in more than one position and in different documents. GNU Emacs uses the terms "kill" instead of "cut" and "yank" instead of "paste" and data is stored in the "kill ring".

"Drag and drop" (DND) is a physical activity (usually, but not necessarily, of the hand and finger). However, it can be considered a virtual activity in that there is no physical or literal change to the physical world. The user moves the pointer over an icon or selection and selects it. While holding the selection the pointer is moved (dragging the selection) to another place. Usually the place is a directory viewer or application program icon. The selection is released and the file is (metaphorically) dropped. Holding certain keys on the keyboard at the same time can often modify the meaning of this action. Some systems also use this technique for objects other than files, for example, portions of text in a word processor. Drag-and-drop is considered a requirement for commercial-quality applications. On most operating systems, support for DND is built-in, so everybody uses it and all programs can communicate with each other. On X, however, there is no standard, so various groups have developed their own protocols, with the result that programs written for one protocol cannot talk to programs written for a different protocol. Clearly this does not satisfy the fundamental requirement that DND allows the user to drag data from any program to any other program. What is required is a single protocol that everybody can use so all programs can exchange data via DND. The basic requirements for such a protocol are that it provides visual feedback to the user during the drag and that it allows the target to choose whatever data format it prefers from among all the formats that the source can provide. In addition, it must be efficient so that the visual feedback does not lag behind the user's actions, and it must be safe from deadlock, race conditions, and other hazards inherent in asynchronous systems (New Planet Software, 2003). Drag and Drop is a term applied to a virtual activity that has parallels with the physical activity of the same name.

The action of rubber banding is purely of the graphic user interface. It occurs when points (usually called handles) are dragged across the screen or lines representing the selected object or area are, in real time drawn on the screen. They are like rubber bands in that they are straight and stretch as the shape is enlarged and they shrink as it is reduced in size.

3.4 Metaphorically doing…

The previous discussion of movement made reference to the verb “dragging”. There are a number of verbs used in the computer world that are based upon the metaphoric relationship with verbs of the non-computer world. These include: bombing, booting, browsing, camping, chatting, cracking, flaming, fragging, hacking, mining, saving, spamming, spoofing, surfing, zipping and zapping. The next section considers those examples which derive a meaning from metonymic association.

For example, fragging is a colloquial term used to describe a computer maintenance procedure. In contemporary file systems as space is used and files are deleted and created, the total free space becomes split into smaller non-contiguous blocks (composed of “clusters” or “sectors” or some other unit of allocation). Eventually new files being created, and old files being extended, cannot be stored in a single contiguous block but become split and scattered across the file system. This degrades performance as multiple seek operations are required to access a single fragmented file. Defragmenting consolidates each existing file and the free space into a continuous group of sectors. This action is termed fragging.

Surfing, browsing and searching have been referred to with regard to the use of the Internet. Two words have meaning in the world of computing that is different from their usage in everyday English. Surfing relates to the sport of riding the surf of large waves – a high adrenalin sport. “The other day I saw another Microsoft commercial on TV: sublime choral music drifts through the background as the unseen user surfs through the Internet” (Lori, 2003). There is no apparent connection in meaning of surfing the net and surfing the waves. In contrast, browsing refers to the action of skim reading a book. Alternatively, when associated with shopping, is looking rather than buying. The internet usage of browsing is similar. The computer usage of surfing is metaphoric whereas the use of browsing, like the use of searching, is literal.

3.5 Container and surface metaphors

The concepts of container and surface metaphors are identified by cognitive linguists as basic categories of human experience. Their importance is emphasised by a study of image schemata in children’s books which revealed that containers and surfaces are the first and most frequent spatial concepts taught (Freundschuh and Sharma, 1996). As Mark Johnson asserts, we experience our bodies both as containers and things in containers; they are spatial concepts. “Like most image schemas the internal structure is arranged so as to yield a basic logic… and forms the Boolean logic of classes” (Lakoff, 1987: 272). A container affords putting things into and out of it, whereas a surface enables support, that is, put things onto and off the surface (Lakoff and Johnson, 1980).

The “containers” include the Internet as a whole, the web site, the web page, network enrolment, files, folders, directories, page, websites, disks, drives, virtual drives, memory sticks, walled gardens… “surfaces” include desktop, window, page, memory, motherboard, integrated circuit, CD ROM… The file is a good example of a container; it also can be used to illustrate a further analysis of metaphor, radial metonymy. Files and folders have fairly clear but not necessarily precise meanings in everyday life. They have a precise meaning in regard to storage structures within a computer. However, their meanings, in both environments, are so similar they take on the parallel effect of metaphor. What is learnt in one structure can be applied to the other quite naturally. Folders are organised in a hierarchy or taxonomy in the way that file to folder, folder to drawer, drawer to cabinet and cabinet to office can be considered. The metaphor connection is three-fold: (1) the naming suggesting the parallelism or metaphor theme; (2) the primal order of position, generation and linkage (Johnson, 1987: 126) and (3) the radial structure of metonymy (Lakoff, 1987: 83). The parallelism exists between the computer-based file, folder, folders within folders, indexing etc. with the physical device of a filing cabinet with files and folders. Developing the radial structure of metonymy associated with file creates vocabulary based upon the concept of a file have characteristics like people. People are unique, possess different internal features, they have position in social structures, they can be classified, they do things such as work, play, interact and change and they can have things done to them. The same analysis is applied to “file”.

Uniqueness: file pathway; file descriptor; file naming conventions.

Features: housekeeping files; master files; file type; file structure; file format.

Position: archive file; file pathway.

Can do: file transfer; transaction file; boot file; auto boot file; script file.

Done to: archive file; file compression; file conversion; file handling; file management; file ownership.

From this consideration of files-as-people comes the concept of radial structure. The kinds-of-file can all be considered as variations (deviations) on the basic definition (central case) and the subcategories of file are established. The central case, where all of the perceptions or files can be encompassed, is a unique object in a precise position (pathway) with delimited size containing data or instructions of a predetermined structure.

The concept file has a stereotypical character. George Lakoff gave the example of the married woman. It sounds normal to say “She is a mother, but she isn’t a housewife” but it would sound strange to say “She is a mother, but she is a housewife”. It is not the negative statement that causes the strangeness. “She is a mother, but she has a job” sounds normal whereas “she is a mother, but she doesn’t have a job” sounds strange. These strangenesses occur because of the stereotypical concepts relating to mothers, housewives and work. The stereotype supports the concept of representativeness – how an object name can represent one or many objects in a metonymic sense. Here are some kinds of files presented in the style of George Lakoff's metonymic models by taking the name of the whole to represent the individual (Lakoff, 1987: 83). "Information is stored on mass storage systems in large amounts called files. A typical file may consist of a complete text document, a photograph, a program, or a collection of data…" (Brookshear, 2000: 34). The file theme contains the following components:

- the image file (of type GIF, JPEG, BMP, TIFF) contains data that can be rendered on the screen as a picture;
- the data file (of type CSV, TAB, XLS, XML) can be rendered as tables or grids of text and numbers which in itself may not be immediately interpretable by a user (unlike the pictorial image);
- the text file (of type TXT, DOC, PUB) contains data that can be rendered as prose on the screen;
- the script file (of type PHP, PAS, QIZ) contains instructions to direct the actions of the computer usually stated in a human-friendly language such as DRAW CIRCLE 20,30,10 or PRINT "Hello World" or SELECT NAME="Fred" FROM data.file.

The "central case where all the models converge" can be described as "a data structure saved as a discrete entity on the hard drive of a computer containing information".

The stereotypical nature of our understanding of file makes these statements acceptable:

- it is a data file but it cannot be read by a spreadsheet;
- the HTML script is created in a text editor but cannot be modified in Word;

but these statements do not sound right:

- it is a word processor file but it contains text;
- it is not a script file and it can be edited.

It is now possible to define some sub-categories of the central case:

- both script files and text files can link to other files including, in particular, image files and also text files and data files (for example the HTML script file may link to one or many other files) and give the apparent inclusion of the images in the original file;
- some files can embed file type data within the file structure including, in particular, image files and also text files and data files structure (for example, a word processor document that contains images);
- files can be compressed (for example, zip files) and this reduces the amount of space required to store the file;
- file suffixes (for example CSV, TAB, XLS, XML) indicate the file type (This labelling is metaphoric and not literal. JPEG images (.jpg) are used in web pages; bitmap images (.bmp) cannot be. A mistaken idea is that by renaming a file, for example, renaming myimage.bmp to myimage.jpg will mean that it will render on a web page).

These subcategories of file are all understood as variations from the central case but not all possible variations on the central case exist as categories. For example, there is no category of file that is an image that has embedded data or text information. There are exceptions to the compressibility rule in that some image formats to not get smaller under compression. The point is that the central case does not productively generate all the subcategories. In every aspect, this consideration of the metaphoric nature of file is the same as the radial structure nature of person, animal, furniture. They are based upon the same metaphoric structure of radial structure.

Radial structures are common and are characteristically different from those structures that are created by stating the general case and generating all others by principles or functions based upon the central case. George Lakoff gives the example of the natural numbers – from a central/general position “1” all natural numbers can be made by adding 1. A binary tree (Figure19.) is an example of a non-radial category: a node has a single parent and zero, one or two children; a node with no children is called a leaf; a node has one parent except a node with no parent is the root.

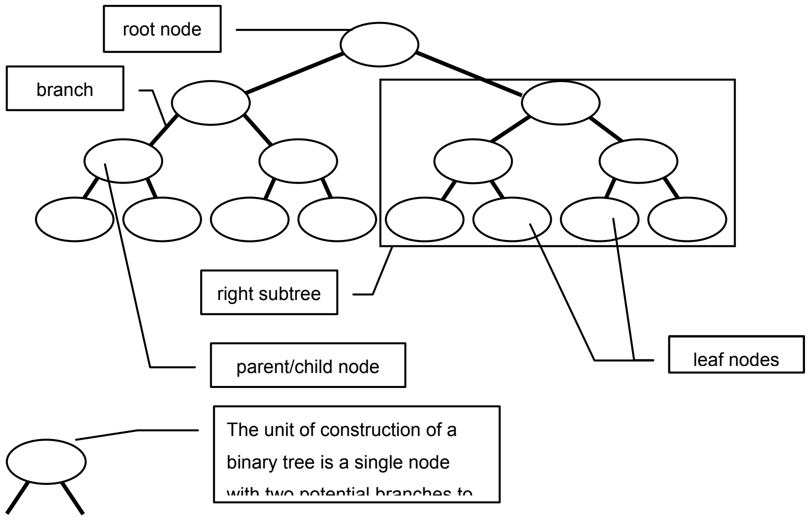
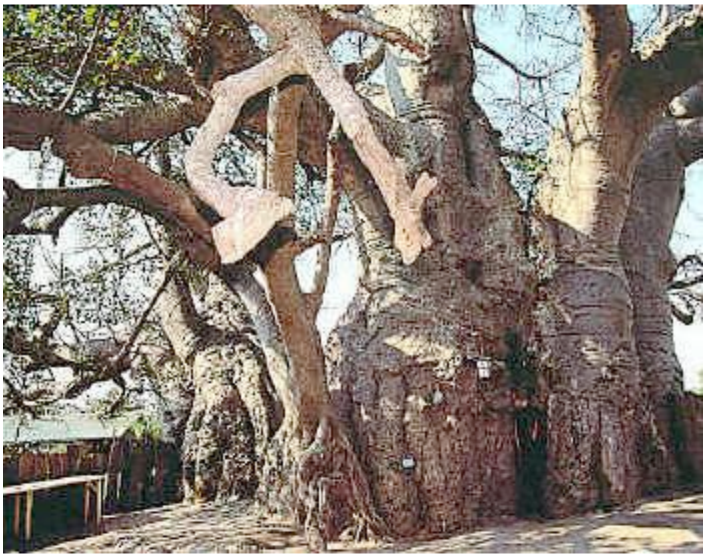


Figure 19 tree structure showing leaf, node, branch, child and root

Note: leaf, node, branch, child and root have little metaphoric meaning and are names applied specifically to the binary tree structure. Its pictorial representation, for the purposes of use and teaching, are invariably with the root at the top of the tree and branches going downwards with leaf nodes at the bottom. The up-side-down tree (Figure20.) has been used as a means of illustrating this incongruity.



The Baobab tree looks as if it has been pulled out of the ground and stuffed back in upside down!

(Govindan, 2002)

Figure 20 the Baobab tree

The upside down tree is used as a metaphor for many contradictory ideas and is the source of much mythology in African culture.

3.6 A whole apparatus of organisation…

Nelson Goodman's structure of appearance describes the metaphor as a whole apparatus of organisation that takes over new territory. We see this with word processing. The word processor design, concepts and labels are drawn from different territories and encompass them within one. Later discussion will describe the combination or inter-relationship of many metaphors in a computer setting to constitute a single metaphor as being an integrated metaphor.

Figure21. illustrates the different territories of an integrated metaphor. The table contains many of the common features of a word processor and the way in which those features have been based upon the functions or features of earlier writing methods. It clearly demonstrates that the current naming of many facilities has its origin in past systems. Where the concept has not existed before, such as hyper-linking within a document, a new metaphoric representation (icon) has been devised.

Another example of a word processor metaphor is the recent software release from Apple. "NoteTaker's user interface metaphor uses a visually rich "spiral" notebook pages with section tabs. Some users will simply have one tab and a long list of outlines while others will organise entire project and research journals with many sections and many pages within those tab sections. And it makes no difference how you decide to organise and use NoteTaker; it's flexible yet easy to understand. It's like having electronic paper on your OS X desktop." NoteTaker (Moore, 2003).

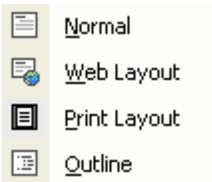
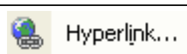
Word processor features	Different territories:			
	Ancient scrolls	Early print era	Typewriter	New concept
page	scroll			
positioning	scrolling, scroll bar,			
new document		template		
page set up		wooden block	tab settings	
cut, copy, paste				
find	linear search, up and down concept			
save	put in a secure place	no concept – block dismantled for the next print run	no concept	
save as… something else	no concept	no concept	no concept	
clipboard		lithographs		
undo				
	equivalent to Normal and Web Layout view – a single scrolling page	equivalent to Print layout view	equivalent to Print layout view	Outline view
Text Direction	catered for	catered for	no concept	
Text box	an area of writing	catered for	primitive white space	
HTML frame	frieze or border	catered for	no concept	
Hyperlink	no concept	no concept	no concept	
Desktop Publishing	text and images	exact match	no concept	

Figure 21 the different territories of an integrated metaphor

3.7 *A rose by any other name and the value of the icon…*

This next short section considers the metaphoric use of language that is designed to aid understanding by the selection of appropriate words. It considers the naming of objects or systems that implies a particular property or function. The examples: firewalls; camping out; gateways and bridges, can be explained in terms of the model-product and metaphor theme. A firewall is a dedicated computer with special security precautions on it, used to service outside network, especially the Internet, connections and dial-in lines. The idea is to protect a cluster of computers (or a single computer) from crackers and hackers. The typical firewall is an inexpensive microprocessor-based Unix machine with no critical data, with modems and public network ports on it, but just one carefully watched connection back to the rest of the cluster. The special precautions may include threat monitoring, call-back, and even a complete iron box keyable to particular incoming IDs or activity patterns. Firewalls are designed to "prevent hackers from being able to access your LAN via the Internet" (Bradley, 1999: 43). Some hackers use the technique of "camping out" (Graham, 2001) that is, waiting for something to come along that can be exploited. For example: an intruder monitors a range of ISP dialup lines with pings. As soon as a user dials-up, the hacker is notified and automated attack scripts are run to attempt to connect to File and Print Sharing and read files from the hard disk. When dialing up to an ISP, the first few minutes are the most dangerous because a hacker can be in and out of the system before the user even realises they are connected to the network.

A firewall is a gateway. A gateway, or router, is used to connect two LANs (Knott and Waites, 2000: 144). It is also known as a bridge. This metaphoric use of language is established by giving the name of a known object, action or concept to an unknown object, action or concept in a way that aids understanding. Considering firewall, gateway, camping and bridge each in turn:

- a firewall is a part of a building that is particularly resistant to fire; it has doors which too are fire resistant and self closing but allow the passage of people and goods in and out; a computer firewall is part of the network that is particularly resistant to the passage of data; there are routes through but these do not remain open for unfettered access;
- a gateway is necessary to allow passage through a fence but once open gives free and easy access to anyone; a computer gateway gives free access from one network through into another;
- camping out is staying outdoors in a tent but has become associated with waiting outside and overnight in a queue waiting for the opportunity to buy; hackers set up systems that wait (for long times) for the opportunities to act;
- bridge has become an established metaphor for joining two objects, actions or concepts (dentist bridgework, bridge the gap and bridge our differences) and can be considered to be used quite naturally in its metaphoric state in computing as much so as anywhere else; thus, bridge is used to describe the device to join two networks.

This section now identifies those elements of metaphor that relate to the visual image and, in particular, icons. The term icon has been adapted from its Russian origins -'ikon' meaning a religious painting or statue. Within the context of computing, the word is used to refer to a small image which embeds 'meaning'. More specifically, an icon is a symbol or graphic representation (on a VDU screen) of a program, resource, state, option or window. As such, icons form an important part of graphical user interfaces (Barker, 1989: 323). Icons used in such interfaces are usually (but not always) 'reactive' - that is, they can be used to initiate various types of process when selected by a user.

Icons are an important element of computer usage. Thomas Erickson in 1990 suggested (writing under the recent developments in metaphor understanding) that the permeation of metaphors is not restricted to human-human interaction lives but also crosses into the human-computer interaction. The use of metaphors impacts the interface in many ways. Metaphors first play their part in the development of functional specifications. If metaphor use is made explicit in the design stage of application then maximum benefits can be achieved by identifying range of functions. The use of metaphors can have a significant impact on the end-user interface by providing cues for the recognition of iconic symbolism (Erickson, 1990). Tony Nott's musing on the role and use of icons states "interface design is a constant search for metaphors" (Nott, 1999: 1). Indeed, most computer applications have an underpinning metaphor. Tony Nott challenges the use of icons by asking whether they cease to be representative of a physical experience (like using scissors to cut paper) and become "a representation of an assumed knowledge of deeper meaning" (like deleting a section of a sound file and concatenating the two separated segments). "They [icons] blend or smear the interface into our experiential world making it appear as more integrated part of our everyday world, more user friendly." The extension of this rationale is that the icon ceases to be metaphoric when it no longer signifies something of the everyday world but is representative of the computer function itself.

The icon  is something that can be moved to change the size or position of an object; it is a handle. The idea that metaphor ceases to exist as the situation becomes literal (described as metaphor fossilisation) does not fit easily with the concepts of neural embodiment of metaphor such as Regier-style models of spatial relationships (Regier, 1995 and 1996) and Narayanan's neural models of concepts (Lakoff and Johnson, 1999: 102). They possess some of the characteristics of language such as morphology, syntax and semantics and have become institutionalised into accepted iconisation by, for example, Microsoft Messenger and inclusion in advertising such as the Smile campaign (Smile, 2003). The metaphoric value may exist in more fundament rules of cognition such as up/down, left/right, the arrowhead (directionality) and 'good' icons at a phenomenological level (conscious or subconscious). Terry Regier's work in identifying algorithms for assessing spatial relationships using computer programs and his integration of those principles with a rigorous review of the linguistics literature (Regier, 1995: 15) supports the rationale that good icons work at the same fundamental levels as other linguistic devices of the written and spoken word.

Stephen Richards and others at the Interactive Systems Research Group (Richards et al, 1994: 73) report that much of the success of iconic interfaces has occurred within applications in which consistent metaphors are maintained. They identify the problems associated culturally based icons. Separately, Hoyt Alverson argues that "the most novel, compelling, apt ones found in powerful use of language are irreducibly *cultural*" (Alverson, 1991: 102). Identifying a generic metaphor to support the development of cross-cultural applications may not be possible. “Even when a suitable metaphor can be found, the problem remains of developing icons (within a given metaphorical framework) for all the functionality that may be required” (Richards, 1998). Stephen Richards’ team identify the universality of the “book” and “travel” metaphors within information applications. The “go to a web page” is an aspect of this. Through case study they describe their use of “multiple metaphor techniques” and develop the “mixed metaphor” idea considered in the previous chapter.

The examples of Apple OS™, Windows™, and Xerox Star™ all make use of icons to represent major components of the system or actions supported by the system in their interface design. Some of the most popular of the new developments are 'picons', 'micons' and 'earcons'. Picons are essentially icons that embed a picture (as opposed to a symbol). Similarly, micons are composed of moving pictures or video clips. Earcons, or auditory icons, are based upon the use of sounds and are usually embedded in sonic sequences (Gaver, 1989; Brewster et al, 1993; Richards et al, 1998). Emoticons themselves represent a form of communication lying somewhere between the picture and the word. They exist in a similar context to regular languages.

3.8 Integrated metaphors

The following are called “integrated metaphors” because they are complex instantiations being composed of a range of basic level categories and or a complexity of “mixed metaphors”. They are also frequently used metaphors and they are representative of aspects of computing metaphors – virus, desktop, software and situated computers. John Carroll describes the necessity of having a formal theory of metaphor when designing effective user interfaces (Carroll et al, 1988: 67-85)

The virus metaphor is not simply a relationship between one aspect of computing and a single other concept but a complex development of the theme extending into a range of other metaphoric concepts. The desktop metaphor is the “big one”. It has been applied to the whole human-computer interface and has complexities that impact upon almost every aspect of computer usage. The third aspect considered in this section is the use of metaphor in the design of computer software interfaces. Finally, there is a discussion of a new aspect of computer based technology, the situated computer, and how the metaphor for a computer is changing.

In the use of the computer term virus the biological metaphor is strong and gives an understanding of the way in which viruses affect our lives. In the following description of a computer virus many aspects could be applied directly to a biological virus thus emphasising the metaphoric theme.

“*The virus has three ambitions: to be transmitted between computers; to establish itself undetected and to deliver its 'pay load' (cause the symptoms or side effects). A virus spreads by making copies of its self, usually surreptitiously. A computer becomes infected when it executes a program that contains a virus. In themselves, the virus need not be bad. Their side effects may be benevolent, benign or malignant. Usually the side effects are undesired. In order to infect a computer, a virus has to have the chance to execute its own program. As in the biological world, different strains of virus behave in different ways. The common practice is for them to attach themselves to the code of the host program (cell). Each time the host program is run the virus code is run and further replication occurs. Similarly, a biological virus attaches its code (RNA) to the host cell's replication system. The best hosts for viruses are those that are frequently executed or are regularly passed to other* *computers. The successful viruses are those that replicate the most frequently and spread the most quickly. Viruses have to combine both characteristics. Evolution dictates that the successful virus will be easily transmitted and remain undetected. Some viruses attack files on the computer that are run every time the computer is started thus ensuring that the computer is continually infected and ready to transmit to other computers. Other viruses attach themselves to documents which contain macros executed whenever that document is used. As long as the virus is active on the computer, it can copy itself to other files or disks that are accessed.*

The virus attack can come from many directions. The computer can become infected if it is booted from an infected floppy disc. This is favoured by the virus because the computer's immunisation is at its weakest point and perhaps is even inactive. It's less easy for the virus to attack if the computer is running because virus protection may be in place. Viruses that are embedded in files are spread around by human action and if the computers immune system is not up to par then they have easy access to the computer. They can move between electronically isolated systems. Their code is an inbuilt macro and is automatically run when the file is opened. The virus tricks the cell into believing that its RNA is the normal code of the nucleus. Like useful macros, viruses can show their symptoms automatically on infection or the symptoms may remain suppressed until the conditions trigger it into action. Other viruses parasitically attach themselves to programs. This is a slow dissemination method for the virus as infection only occurs if a human installs the program on their system. But it is powerful and hard to remove without surgery and the loss of parts of vital organs. E-mail is wonderful for viruses because systems can be made to transmit over wide areas, to large numbers of computers and at a time when the computers are expecting to receive foreign bodies." (Woollard, 2000c)

This example, typical of technologists writing in the popular press, illustrates the more emotive, stimulating and illustrative aspects of the use of metaphors.

In reality, the computer virus is not dirty but the cognitive associations between: virus, bacteria, germs, dirtiness, soil, contamination, infection etc. is strong and associated writing and descriptions of the technology play upon the metaphor theme. The theme is also extended by the use of other biological terms. The following example emphasizes the "dirtiness" aspect of metaphor as a pedagogic device. Interestingly, not all biological viruses are infectious, dirty, contaminating or harmful. However, there is not a cognitive tension, the computer use of virus unfortunately reinforces the scientific misconception.

Would you eat a sandwich offered to you by a person passing you in the street?
Would you install a program sent to you, unsolicited, over the Internet?

Would you eat a sandwich offered to you by a colleague who had just come out of the toilet?
Would you load a file into your computer without knowing that it is clean?

Would you eat a sandwich which had been passed around the classroom?
Would you install a program given to you when you were not sure where it had been?

(Woollard, 2000c)

Further biological metaphors include worms and bugs. A trojan horse is a term coined by MIT-hacker-turned-NSA-spook Dan Edwards. It is a malicious, security-breaking program that is disguised as something benign, such as a directory lister, archiver, game, or in one notorious 1990 case on the Mac a program to find and destroy viruses! (Symantec, 2003) A trojan horse is similar to a back door - another metaphoric reference to the front/back of an entity.

A worm is an agent that infects the computer and causes that infection to be replicated. The word worm originates from the “Tapeworm” in John Brunner's novel “The Shockwave Rider” and describes a program that propagates itself over a network, reproducing itself as it goes. When the worm arrives by email, it uses a MIME exploit allowing the threat to be executed by reading or previewing the file (Microsoft, 2002). Also, the worm will create open network shares on the infected computer, allowing access to the system. During this process, the worm creates the guest account with Administrator privileges.

During the writing of this section of the thesis, on Monday August 11th 2003 the author’s computer was attacked by the Blaster-A worm causing it to shutdown with minimum warning (Microsoft, 2003a).

3.9 The ubiquitous desktop

The “desktop” is the near ubiquitous metaphor of computing. The vast majority of computer users access the facilities of the computer through the desktop. Microsoft and Macintosh (Apple, 1987) have by far the most predominant operating system and both use a desktop metaphor because it is a powerful means to control the complexity in human computer interaction (Carroll, Mack and Kellogg, 1998). It is beyond the physical scope of this work to fully analyse and represent the “desktop” metaphor and its implications for computer users. However, it cannot be neglected because many metaphors used in computing are underpinned by acceptance of the “desktop” metaphor. Examples of “desktop” environments that challenge the Microsoft/Macintosh model include the UK based Acorn environment, Unix (Linux in particular) and a range of experimental designs. Importantly, Werner Kuhn and others describe how the understanding of interface metaphors underlying our formalisation derives from the work in cognitive linguistics citing George Lakoff and Mark Johnson (Kuhn and Frank, 1990: 420).

The desktop metaphor began with the Xerox Alto and was refined on the Xerox Star. The designers chose what they referred to as the “physical-office metaphor” because the Star was intended as an office information system, so reflecting the familiar world of the potential users (Smith, 1982: 246). The designers saw their metaphor as providing a 'physical' environment rather than a language of interaction - the desktop is the principle Star technique for realising the physical-office metaphor. The icons on it are visible, “concrete” embodiments of the corresponding physical objects. Star users are encouraged to think of the objects on the desktop in physical terms (Smith, 1982: 247).

Boxer is an alternative approach to the windows environment by Andy DiSessa. He had a vision that, like the underpinning programming structures, that users navigate around boxes on the screen. Unlike the desktop metaphor where all software deceptively takes on a similar look yet carries out distinctly different functions, the boxer solution enabled very different functioning applications to coexist and manipulate the same data but in their different ways and, importantly, possessing different appearances. Bill Gates (Microsoft) worked towards a computer system for business men and it is not surprising that he produced the desktop metaphor. Andy DiSessa and Hal Abelson are university professors who are highly motivated by doing 'the right thing'. Their work has not been 'commercially' successful although academically more defensible (Liddy, 1997).

A most important application of metaphor in the world of computing is the role in the design features of software interfaces (Figure22.) All software is a virtual experience. Most software has a basis in a physical model or based upon a development of that model. There are eight models that represent the majority of software titles. These approaches have, since the early 1990s become accepted frameworks for software development. When titles are developed that do not meet one of these models then a new metaphor is adopted or developed to guide the user.

Scroll: traditional word processors, questionnaires
Page: desktop publishers and some multimedia authoring packages; page turning
Table: spreadsheet/accounting based upon a cellular structure
Card: flat file data bases likened to library card index drawers
Slide: presentation software likened to the slideshow
Cartoon: style based upon one still frame following another in quick succession
Script: programming/scripting approaches where the computer executes instructions on-the-fly
Video: equivalent to film sequence with video control

Figure 22 software design metaphors

Some applications cannot or do not adopt one of these generic metaphor presentations and alternative devices are used to communicate the facility and structure of the program interface. A classic example is the multimedia authoring package from Macromedia called Director. The metaphor is the process of making a film in a conventional studio using the agents: director, script, scene, cast, and the interplay between them. Both the graphic user interface and the packaging/publicity use the metaphor to support the training, advertising and user processes (Macromedia, 1995). The rôle of extended metaphors in interface design is further described in John Carroll's work "Interface metaphors and user interface design" (Carroll, 1988). For example, the video control interface is characteristic of dialogue windows that have become standardised across a range of software and operating systems. The Lakoff timeline or source-path schema (Lakoff and Johnson, 1999: 32) is exemplified in the video control interface. Figure 23. below illustrates the same type of device which enables users to navigate a sound file.

Figure24. illustrates a similar device created to navigate through a slide presentation.

A move forward along the source-path

C move to the start of the source-path

D move to the end of the source-path

F move to any location along the source-path

Figure 23 a dialogue window representing the source-path schema

It is the linear nature of video and sound file formats that enable them to share the same human computer interface. The slideshow metaphor, used in presentation software such as Microsoft PowerPoint, uses an iconic representation but does not have a standard interface for navigation. Many users adopt standard buttons (icons with actions) to emulate their own navigation system. The figure below illustrates a solution to this problem.

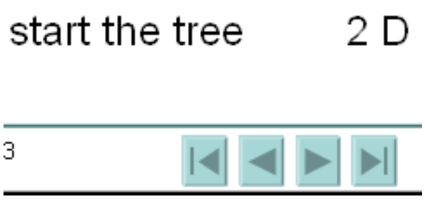


Figure 24 navigation bar from a PowerPoint teaching resource (Woollard, 2003c)

3.10 Metaphors and accessibility

The following two examples illustrate the use of metaphors to enable accessibility to computer systems. The first is the Language Through Reading (LTR, 1998) software which demonstrates the feasibility of providing an interactive environment which employs button-up dragging, allowing a child to select a sentence and place it under a picture. Buttons make it possible to enter text, select individual words to make up a sentence from a pop-up, dispose of unwanted objects in the bin and move to the next screen. The child's responses are fed into a second program which assesses and reports on the grammatical, syntactic and semantic validity of the input. The package, authored using MyWorld2, employs the pick-drag metaphor, sometimes known as the fuzzyfelt approach for moving objects around the screen.

In contrast, students working at the other end of the cognitive scale learn programming through metaphors. Alan Blackwell describes the value of metaphors in understanding the processing of visual programming languages (Blackwell, 1999: 1). He cites other metaphors used previously to support programmers and warns against not providing metaphors to support learning.

“If learners are not given an explicit cover story of this type, they still construct their own mental model of the machine, as has been observed by Young (1981) with pocket calculators and Tauber (1987) with operating systems. Similarly, if novice programmers are not given a model of a virtual machine, they may invent an inappropriate explanation (Booth, 1992; Eisenberg, 1987 and Eisenstadt, 1984), working from sources of information such as observing a debugger (Cañas, 1994) extrapolating from tutorial code examples (Noble, 1992), or imagining the behaviour of the machine from the viewpoint of an internal agent (Watt, 1998)." (Blackwell, 1999: 64)

Alan Blackwell concludes that it seems reasonable that teachers should anticipate this by providing some explicit story of what is happening inside the virtual machine – what duBoulay, O'Shea and Monk (1981) called "the black box inside the glass box".

These two contrasting examples, fuzzy felt and machine metaphor, illustrate the rôle of metaphor in providing an insight or mastery of the processes.

3.11 The superhighway metaphor

The nature of the World Wide Web is unfamiliar to most people, that is, the technicalities, the full range of the facilities and the consequences of its use are not familiar to most people. In order to make sense of this foreign environment the unfamiliar is described in terms of the familiar. Metaphors are often used for this purpose.

> *"Think of the Internet as a Superhighway.*
> *There it is again. Some clueless fool is talking about the Information Superhighway. They don't know didley about the net. It's nothing like a superhighway. That's a rotten metaphor. Suppose the metaphor ran in the other direction. Suppose highways were like the net... a highway hundreds of lanes wide. Most are with pitfalls for potholes. Privately operated bridges and over passes. No highway patrol. A couple of rent-a-cops on bicycles with broken whistles. 500 member vigilante posses with nuclear weapons. A minimum of 237 on ramps at every intersection. No signs. Wanna_get_to_Ensenada? Holler out the window at a passing truck to ask directions. Ad hoc traffic laws. Some lanes would vote to make use by a single-occupant-vehicle a capital offense on Monday through Friday between 7:00 and 9:00. Other lanes would just shoot you without a trial for talking on a car phone. AOL would be a giant diesel-smoking bus with hundreds of Ebola victims on board throwing dead wombats and rotten cabbage at the other cars, most of which have been assembled at home from kits. Some are built around 2.5 horsepower lawns engines with a top speed of nine miles an hour. Others burn nitro-glycerine and idle at 120. No license plates. World War II bomber nose art instead. Terrifying paintings of huge teeth or vampire eagles. Bumper mounted machine guns. Flip somebody the finger on this highway and get a white phosphorus grenade up your tailpipe. Flatbed trucks cruise around with antiaircraft missile batteries to shoot down the traffic helicopter. Little kids on tricycles with squirt guns filled with hydrochloric acid switch lanes without warning. NO OFF RAMPS. None."* anon (Google, 2004a)

The quotation illustrates the problems associated with metaphoric language in the computer world. For rhetorical reasons, the term superhighway is used and seized upon as a means of being able to convey meanings related to volume, speed, mass communication, of-the-age and dynamic nature of the system. However, the imagery does not convey a precise understanding of the function or actuality of use. The parallels are present in sufficiency to sustain the metaphor – it is well grounded. However, the conflict in concepts is high – there is a great tension. (See Figure 2 and Figure 3 and supporting text.) As an introductory description, it signifies many of the important features but, when a deeper understanding of how to use, why to use and when to use the facilities is required, then the metaphor fails to elucidate. The quotation above fails to recognise the rôle and nature of metaphor. Metaphors arise as a natural consequence of rhetoric. The utterances are valid at the time and place but are not universally valid. Their nature is that of transition and their rôle is that of communication. Interestingly, the highway metaphor for the Internet can be considered in two ways. It represents the physical existence of the system but it also represents the time-based development. The speed of change in the developments of internet based technologies is also represented by the highway metaphor. “As we travel along the highway, through time, we will see new things, we will have to take actions and things will happen to us. However, there is no turning back - no “U-turns” are allowed.” This is an example of conceptual blending - “the metaphor of the information superhighway and the contrast between the highway connecting places and the highway as a timeline mapping out the future” (Rohrer, 1997)

The alternative metaphor relates to the bioelectronic frontier “calling to mind as it does the spirit of invention and discovery that led ancient mariners to explore the world, generations of pioneers to tame the American continent and, more recently, to man's first exploration of outer space - it is cyberspace” (Dyson et al, 1994). Cyberspace, like the superhighway, implies size, importance and modernity and so feels appropriate. Unlike the highway metaphor, the space metaphor goes on forever, it is both boundary-less and timeless. The visualisations of both cyberspace and the highway relate to surface image schema. This is reflected in the results of Lee Ratzan’s enquiry. “Men tend to prefer absolute addressing (4 Arbit Road) while women tend to prefer relative addressing (Second house on the right)” (Ratzan, 2000: 11). The worldwide web is perceived as being locations similar to geographical locations (on the surface of the world) and not a three, multi or uni-dimensional structure. It is not a container - objects are not put into the web but they are put onto the web. Interestingly, Lee Ratzan’s work identified a strong relationship between the worldwide web and information. People saw the Internet as a source of information as opposed to a conduit for information. It is described by some as a “dysfunctional library” (Ratzan, 2000: 12).

3.12 A metaphor too far

The virtual pseudo-physical activities (discussed above) include drag-and-drop, click-and-drag, rubber banding, highlighting, hover, mouse-over, mouse-entry, mouse-leave are all part of the windows-desktop metaphor. In particular, the conceptual aspects of drag-and-drop utilise the Lakoff-type container metaphor. Objects can be dropped into containers such as windows and icons. One such icon is the “Trash Can” (Macintosh) or “Recycle Bin” (Microsoft). The user interacts by using a mouse (or other pointing device) to move an object across the desktop and drop it by releasing the mouse button. To get rid of a physical document from a physical desktop one throws it in the bin (trash can, rubbish bin, wastepaper basket…) To delete an electronic document in the virtual world one drops the document onto the icon representing the bin into which the document disappears.

“Deleting a document from the computer is patterned after the action of throwing out a paper document - in both cases, place the document in the trashcan. Like the real world trashcan, the electronic documents tossed into the Macintosh trashcan remain there until the trash is emptied” (Rohrer, 1995b).

However, the metaphor too far arises when one tries to delete a floppy disk (diskette) from a Macintosh computer.

“But while deleting a file using the trashcan makes perfect sense to most users, ejecting a diskette by placing it in onto the trashcan meets with reluctance and dismay. Many experienced users even confess to feeling a twinge of anxiety every time they eject a disk using the trashcan, though they know from experience they are not deleting the information on their disks. I have known some users who, when faced with a need to eject a disk, prefer to shut down the system and have the disk eject automatically rather than throwing their disk into the trash can.” (Rohrer, 1995b)

David Mark describes the cultural issues.

“The use of metaphors, however, does potentially increase the cultural dependency of an interface. The “trash” can on the Apple desktop had to be renamed for other countries, and the icon used should also be changed - not every office in the world contains this object so familiar to most North Americans or Europeans. (Actually, few North American offices contain things that look like a Standard outdoor household garbage can, and refuse receptacles seldom sit on desk tops!)” (Mark and Frank, 1990)

Werner Kuhn describes the problems associated with the electronic clipboard metaphor included in the Apple desktop. He describes the tensions created by the differences from a regular clipboard. For example, adding something to a real clipboard does not destroy the previous contents (Kuhn and Frank, 1990).

Allan Collins introduces the concept of the “magical metaphor” (Collins, 1987) and cites such things as:

- the spreadsheet as a sheet of paper divided into rows and columns as its metaphor - it is magical in that calculations (totals and averages) occur automatically as figures are changed on the paper;
- the database has, for instance, a card index for its metaphor - it can magically order itself in terms of one field, say name and within an instance re-order in terms of, say author;
- the weather page on the web has today’s weather forecast, yet tomorrow it will, magically, have tomorrow’s weather forecast.

These metaphors are aspects of what was termed “provisionality” (DfEE, 1998) - those aspects of a computer that do not remain constant but change subject to time, context, user or action. The “magic” of the computer is subsumed into the metaphors we use to understand it.

Allan Collins notes that the “extension to the spreadsheet metaphor to automatic recalculation is an example of sympathetic magic which surprises and delights users”. The extension of the trash can metaphor to ejecting diskettes, however, is baffling rather than sympathetic magic. As explained above, it is counterintuitive (Rohrer, 1995b). It is that which is “a metaphor too far”.

3.13 Summary

There are three main thrusts to the literature review. The first chapter establishes the importance of metaphor across a range of disciplines within physiology, linguistics, cognitivism and understanding and then identifies, by considering a range of writers, the words (and therefore the model) of metaphor description. This chapter describes the use of metaphor in the world of computing. The following chapter considers the third aspect, pedagogic content knowledge.

It has been shown that metaphor has many facets. Metaphor is of our cognition, our understanding or our thinking (Abrams, 1998; Burbules, 1997; Johnson, 1987; Melnick, 1999). It is with metaphor that cognitive scientists explain how thinking is structured through categorisation of conceptual structure and image schema (Johnson, 1987; Lakoff, 1993; Regier, 1996). Metaphor is a most powerful trope of language and communication (Hickey, 2000; Ortony, 1993; Searle, 1993). Metaphor is of literature and rhetoric (Aristotle; Barthes, 1973; Richards, 1936). Metaphor is of everyday life and language - our conversational wanderings whether that is plodding through a description, stumbling through an interview or stepping through an argument (Jacobson, 1988; Lodge, 1990; Glucksberg, 1989). Metaphor is of the design of computer software and the human computer interface (DiSessa, 2000; Barker, 1993). Metaphor is seen to be an important tool of the computer scientist (Polanyi, 1975; Richards, 1998; Erickson, 1990).

Metaphors are used to describe more easily the novel and the difficult concepts or facilities of computers. They can be categorised as being, doing, located and organisational. The doing metaphors include virtual activities and those adopted to imply a meaning by word association like spamming and zapping. The located concepts include the image schema container, surface and pathway. Organisational metaphors refer to the integrated metaphor where many metaphoric features form a complete system like the desktop metaphor.

It is the aim of this study to investigate and contextualise the role of metaphor in teaching about computers. It is those metaphors that will now take centre stage in the discussions. It is those metaphors that will be elucidated through the research methodology. The raison d’etre of this study is pedagogy; the next chapter reviews the literature on pedagogic content knowledge.

Chapter 4 Pedagogic content knowledge - a literature review

This chapter reviews the literature regarding the strategies employed by teachers to teach and reviews the theories associated with those strategies. The aim is to create the context for the research and a foundation for the grounded theory approach. This literature review underpins the major focus of this work:

what do teachers do to turn content knowledge into pedagogic content knowledge with special emphasis upon the use of metaphor and analogy within computing and the use of computers?

The review directly addresses the subsidiary research questions:

what is the nature of teaching methodology?

how do teachers/trainers/tutors teach computing?

how do teachers/trainers/tutors teach how to use a computer?

[These original questions have been subject to review during the research process. The second is better asked "how do teachers/trainers/tutors teach the concepts of computing?" The third question is not focussed upon directly in the methodology. It asks "how do teachers/trainers/tutors teach how to use a computer?" and implies a consideration of ICT capability. The focus upon the more difficult concepts, although relating to many ICT capabilities, does not comprehensively address the broader issues. This thesis is much narrower in investigation and conclusion.]

The major focus is the study of pedagogic content knowledge (PCK) as described originally by Lee Shulman in 1986. Pedagogic content knowledge is concerned with how teachers reason pedagogically. It is the ability of a teacher to change their understanding and action

"*from being able to comprehend subject matter for themselves, to becoming able to elucidate subject matter in new ways, reorganize and partition it, clothe it in activities and emotions, in metaphors and exercises, and in examples and demonstrations, so that it can be grasped by students*"
(Shulman, 1987: 13).

Through reading and analysis, four models are identified; they are very different perspectives upon pedagogic content knowledge. They are representative of the different possible constructs of PCK. Figure25. below illustrates the constructs. One model places PCK at the heart of teaching with other factors having an impact upon and input into PCK (Turner-Bisset, 2001). A second model considers PCK to be one of a small number of important factors in teaching (Leat, 1998; Askew, 1997) where it, with teachers' beliefs and pupils' responses, impact upon teaching. The third considers PCK to be a small factor in teaching (Enfield, 1999). The fourth model places PCK at the top of a pyramid indicating its most important status (Veal et al, 1999) and being supported by other aspects of teaching including knowledge of the curriculum, knowledge of the pupils and classroom management issues.

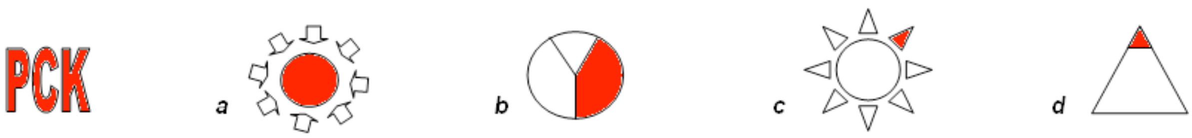


Figure 25 models of PCK: a) Turner-Bisset, b) Leat c) Enfield d) Veal

Chapter content:

An additional section, 4.6, is included that considers the teacher training in the UK in the early 21st century.

This final part is important because the respondents in the research, although experienced and trained before the current standards were introduced, are working with trainee teachers and are using the standards on a regular basis to assess those trainees. This study will focus upon the work of teachers involved in initial teacher education. They will be exposed to the statutory standards provided by the TTA. Those standards might be an important influence upon the teachers' thinking about teaching.

4.1 Introduction - Lee Shulman's position

The challenge to teachers is to enable children to gain the skills, knowledge and understanding that we possess. In the field of information and communications technology, the content of our subject is ever changing. We need to continually raise our own awareness of computer-based facilities and features. However, that is just part of the challenge of teaching in the computer world. We have to also raise our awareness of how to teach the new facilities of computing. The situation takes on a further importance as those facilities have a unique facility to support specific areas of the curriculum.

We have a sufficiency (to say the least) of documents that define the content students should learn. They include: the National Curriculum for Information and Communication Technology (ICT), QCA Schemes of Work and the Key Stage 3 Strategy for ICT. These tell us what the children have to know or be able to do. We then have to develop the means by which we teach subject content knowledge. This is pedagogical content knowledge.

Lee Shulman in the late 1970s developed the construct of "pedagogical content knowledge" (PCK) in response to some of the problems encountered in teaching, especially science teaching in the United States. The principles he postulated have a bearing upon our work today. Shulman observed the sharp contrasts in the teaching paradigms through history – notably the change from the late 19th century emphasis upon content (knowledge) through phases of pupil centred learning, meeting individual needs, cultural awareness, understanding youth, classroom management, behaviour modification, instructional materials and adherence to educational policies and procedures.

There is a growing body of thought that now turns the emphasis of good teaching towards the process of changing content knowledge into pedagogic content knowledge. However, Lee Shulman rejects the usual dichotomy as ineffective and adds a further stage.

He breaks content knowledge into three parts:

- Subject Matter Content Knowledge
- Pedagogical Content Knowledge
- Curricular Content Knowledge

Subject matter is knowledge per se. It is the skills, knowledge and understanding of computing possessed by proficient and experienced computer users, those who have passed examinations within the subject, and those who have applied that knowledge in the commercial world. Pedagogical content knowledge consists of knowledge of effective ways of representing and reformulating the content, and an understanding of students' specific learning difficulties and misconceptions, characterized by teachers' transformation of the subject matter knowledge per se into a kind suitable to students of different ages and abilities. Curricular knowledge includes knowledge of curricular and instructional programmes available for teaching a subject at various levels (AERA, 2004).

The National Curriculum (QCA, 1999), examination specifications and prevocational success criteria provide much of the first; that is, the curriculum is defined in terms of what to teach and not how to teach. Interestingly, during the recent past we have been given a lot of the latter. The QCA schemes of work and the Key Stage 3 Strategy training materials and sample lessons provide us with a curricular content knowledge (QCA, 2003; TTA, 2003). They tell teachers how to organise the learning experiences.

But Lee Shulman's contention is that we have to consider the pedagogic content knowledge – how will we enable the children to learn? Pedagogical content knowledge is the "particular form of content knowledge that embodies the aspects of content most germane to its teachability.... the ways of representing and formulating the subject that make it comprehensible to others." When questioned in a more recent interview (Shulman and Sparks, 1992a: 14-16) what do you think are the most valid objections that are raised about your work, and how do you respond to those criticisms?
Lee Shulman responded:
"There are two kinds of valid criticisms. One is that I don't give enough credit to the impact that generic approaches have had. That's an absolutely valid criticism. My rhetoric in the past has been too negative about generic approaches, and I think I was wrong. My argument now is not that they are evil, but that they are incomplete. The incompleteness leads to a deficiency in staff development that we have an obligation to overcome.

"The second objection is that it is unrealistic to expect staff developers to know everything they know now and also know enough about the content as well to do what I'm asking for. My response is that it is unrealistic for staff developers to think that at a time when our national goals are very heavily content based, they can continue to provide generic solutions to content-specific problems. The realistic thing to do is for us to change the set of understandings that we as staff developers have. We have got to change with the times, and this is a change that is long overdue."

Lee Shulman summarises:

"Teachers must have commitments to a vision of educational excellence in fair and just societies, a vision that motivates their choices and lends wisdom to their exercise of professional autonomy... But

the teacher must remain the key. The literature on effective schools is meaningless, debates over educational policy are moot, if the primary agents of instruction are incapable of performing their functions well. No microcomputer will replace them, no television system will clone and distribute them, no scripted lessons will direct and control them, no voucher system will bypass them" (Shulman and Sparks, 1992b).

The nature of pedagogic content knowledge is not fixed. It is a construct and as such is constructed differently in the heads of researchers and teachers and from place to place and over time. Drawing from a wide range of literature (Appendix 2) the following terms build a picture of the commonality of those constructs. They paint a broad brush picture of pedagogic content knowledge:

unique body of knowledge; professional understanding, the pedagogue; elucidate subject matter in new ways; special knowledge; ideas are arranged for teaching; reorganize and partition; common sense; clothe it in activities and emotions; pedagogically powerful; relation to the learning mind; learner's standpoint; professionalisation of subject matter; good reasons; practical knowledge; exercises; examples; demonstrations; deep understanding of content; intersection of content and pedagogy; lens for teachers; metaphors; illustrations; explanations; representational repertoire, analogies.

(Bullough, 2001; Clermont et al, 1994; Enfield, 1999; Grossman, 1989, 1990; Hulshof and Verloop, 2002; Perkins and Simmons, 1988; Shulman, 1987; Tamir, 1988; Turner-Bisset, 2001; Veal, 1999)

The fundamental questions asked by Lee Shulman of our understanding of an expert teacher is “what does she believe, understand, and know how to do that permits her to teach as she does?” and “can other teachers be prepared to teach with such skill?" (Shulman, 1987: 3). He describes that as a special form of professional understanding – it is what expert teachers do to make the subject content learnable. It is the blending of content and pedagogy into an understanding of how topics, problems, or issues are organized, represented and adapted to the diverse interests and abilities of learners, and presented for instruction. Those three words are important - organised, represented and adapted - and will be reflected upon when the teachers express the way in which they teach different areas of the curriculum. The most important aspect is “represented”. This study reflects upon the metaphoric representation of the curriculum. Whereas a teacher's knowledge of the subject area may be personal and applied in many personal situations and experiences these experiences in themselves and of themselves do not necessarily foster understanding of subject or concepts for students. “Successful teachers cannot simply have an intuitive or personal understanding of a particular concept, principle, or theory. Rather, in order to foster understanding, they must themselves understand ways of representing the concepts for students” (Wilson, Shulman and Richert, 1987:12).

The models chosen to represent PCK in this literature review are demonstrably different to each other in structure and approach. When searching the literature a model was excluded from consideration if it:

- is the same or similar in structure; or
- is different but inappropriate to the aims of this study.

Some models were inappropriate because they focussed upon curriculum content that had few connections with the scientific nature of the computing curriculum, for example, the models of the literacy curriculum described by Douglas Anderson in the field of literacy (Anderson, 2001). Some models focus upon the changing attitudes to learning and the learner in general. This quotation from Life in the Fourth Millennium illustrates that aspect “For anything more challenging than absorbing new information, we need to be coaxed, cajoled, precipitated, pressurized and tricked into really difficult learning… teaching has more to do with developing resilience, confidence and strategies than imparting knowledge” (Pinker, 2000). Although an important element, pupils’ beliefs are not of primary importance in this study.

In trawling the literature, a number of metaphors used to describe the teaching process were discovered, for example, the factory model or the apprenticeship model (Brink, 2001). Although valid in their own right they did not add a further understanding to the class-based model of education.

An important aspect of education is enabling the learner. Some models are based upon a cognitive viewpoint and the use of meta-cognitive skills. “Modern pedagogy is moving increasingly to the view that the child should be aware of his or her own thought processes and that achieving skills and accumulating knowledge are not enough (Bruner, 1996). This facet of pedagogy did not relate curriculum to teaching but focussed upon relating the learner to teaching and therefore not appropriate.

An early model to be considered was that of Gary Fenstermacher. He identifies the type of knowledge that PCK is and concludes that it has both practical and formal elements, each requiring testing and justification (Fenstermacher 1994: 32, 38). The model proposed by Rosie Turner-Bisset also includes aspects of knowledge. However, her model better meets the needs of the research in that it identifies teaching approaches and related those to pedagogy (Turner-Bisset, 2001).

Consequently, the following review considers in detail four perspectives of Shulman’s pedagogic content knowledge drawn from the literature (Enfield, 1999; Veal, 1999; Askew, 1997 and Turner-Bisset, 2001). It also considers the implications of the current requirements of teacher training in the UK (TTA, 2003).

4.2 "Science for all"

In the "Science for all" model (Enfield,1999) the curriculum is described as a complex relationship between a range of factors including the curriculum, environment, teaching styles, the nature of science, assessment and professional practice. (Figure 26.) Pedagogic content knowledge is the connection between content and pedagogy.

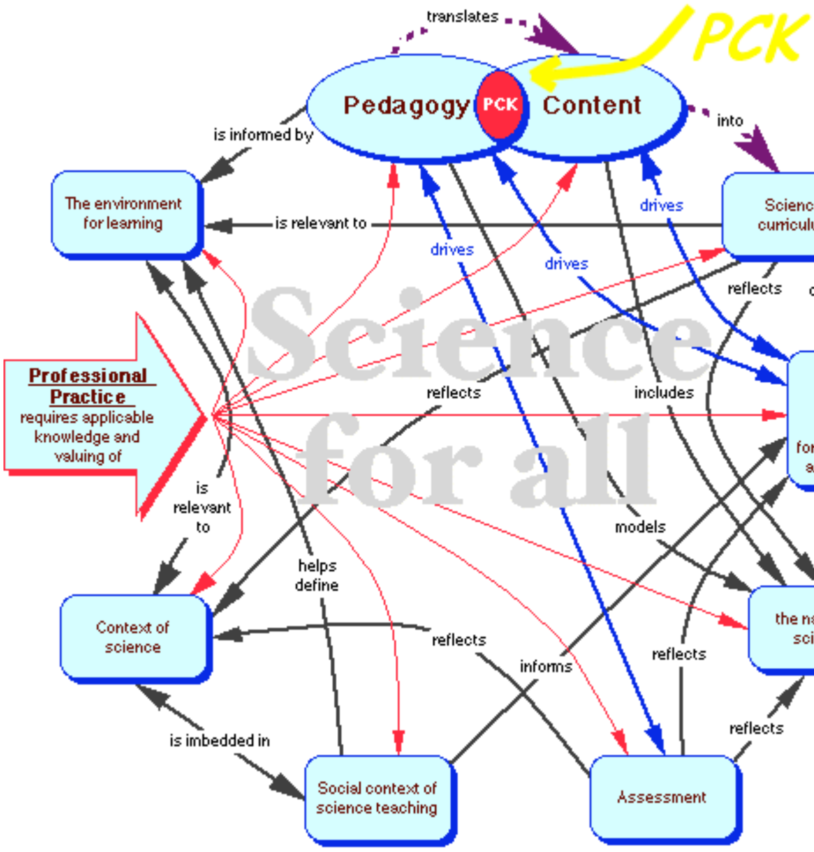


Figure 26 "Science for all" (Enfield, 1999)

The Enfield model is designed to reflect the characteristics of science teaching. The following discussion is based upon an interpretation of that diagram and the stated and implied characteristics of science teaching in the US and computing teaching in the UK.

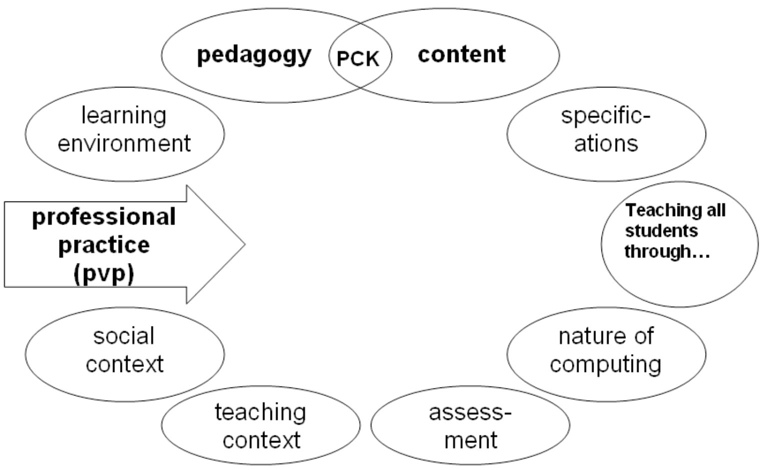


Figure 27 computing in the UK based upon the "Science for all" model

The first important point to make relates to the mantra or strap line “Teaching all students through enquiry for understanding and application” associated with science teaching in the US. The teaching of computing in the UK does not possess such a clear unifying statement of intent – rather, the teaching of computing, ICT, IS, IT etc is motivated by the general pressures of raising attainment as measured by examination performance and examination result league tables. (This claim is illustrated and justified in section 4.6 Qualifying to Teach - a UK perspective.) Perhaps the lack of such a mantra is a consequence of the short history of computer teaching. Perhaps it is because computing is not such a large movement within education and it is dividing into smaller, disconnected interest groups, that it does not have a unifying statement. The implications for teaching arising from that situation are that a source of models is not available. “Teaching all students through inquiry for understanding and application”, as declared by the incoming arrows (Figure 28.) motivates and guides most aspects of the teaching of science.

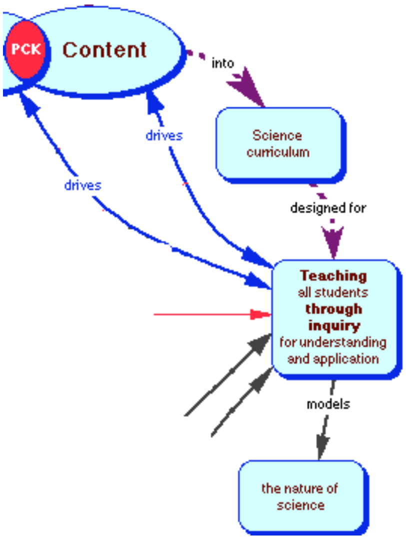


Figure 28 curriculum aspects of pedagogic content knowledge

The motivations for the design of the computing curriculum need to be sourced from elsewhere. The US science curriculum is designed to foster “inquiry for understanding and application”. There is no parallel for the computing curriculum in the UK. We need to turn to the National Curriculum, the Key Stage 3 Strategies, the QCA Specifications and the Key Skills initiatives for guidance. They are: “the knowledge, skills and understanding… [pupils] are expected to have”; “teaching ICT capability”; “the knowledge, understanding, skills and assessment objectives” and “essential skills that underpin success in education, employment, lifelong learning and personal development”.

The UK computing curriculum is driven by an emphasis upon outcomes – the objectives – and not upon process – teaching – and this has a significant implication for the relationships within the curriculum that will impact upon pedagogic content knowledge. This is evidenced by scrutiny of the official documents associated with computing. The National Curriculum and the specifications for examinations both originate from the Qualifications and Curriculum Authority and list what is to be taught and not how it should be taught. The other major commentary upon the curriculum is offered by OFSTED. Those reports are about outcomes and not pedagogy. Indeed, there is a general acceptance within the computing field that pedagogy is less well examined that other areas of the curriculum. There is considerable research into the use of ICT to support other areas of the curriculum and aspects of learning but little emphasis placed upon how to learn and teach ICT. This tension is described by Michelle Selinger in her analysis of learning ICT skills and the subject context of the learning (Selinger, 2001).

The Enfield model (Enfield, 1999) for delimiting and describing the place of pedagogic content knowledge places it solidly at the interface between pedagogy and content with a number of factors impacting upon it (Figure 29.)

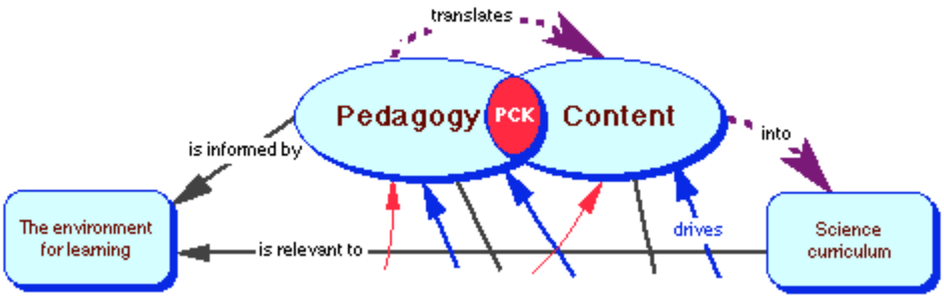


Figure 29 pedagogic content knowledge at the interface between pedagogy and content

Lee Shulman wrote "the key to distinguishing the knowledge base of teaching lies at the intersection of content and pedagogy" (Shulman, 1987 p15). It is in this area that a model of pedagogic content knowledge in computing must be focussed. In the “Science for all” model, the impacts upon content arise from professional practice. Those impacts include the nature of science and the contributors into the science curriculum. The content of computing has similar factors impacting upon it. However, as described earlier, the driving of the “Teaching… through enquiry” is not present in computing and is replaced by a curriculum based upon objectives, assessment and outcomes. The model represents a wide range of factors in teaching and learning, many of which, for example the social text and assessment, do not feature strongly in this research. This model locates PCK but does not illuminate its full nature.

4.3 PCK at the head of pedagogic practice

In contrast to the “Science for all” model, the model developed by William Veal and others implies that pedagogic content knowledge subsumes a range of teacher activities and responsibilities (Veal et al, 1999). This model implies that all teacher training – professional values, subject knowledge and classroom management are called pedagogic content knowledge and it does not draw special attention to the intellectual process carried out by teachers to change the curriculum knowledge into a form that is learnable. It is that focus that is important in this study.

In this alternative model (Figure 30.), pedagogic content knowledge is seen to be the pinnacle of a pyramid based upon content knowledge and knowledge of students. This construct of pedagogic content knowledge perhaps follows the spirit of Lee Shulman’s early work in which he identifies the aspects of teacher training deemed important to make the “seismic shift” in teaching in the United States. It is worthy of consideration at this point because it re-emphasises the factors that impact upon the pedagogic content knowledge decision making process.

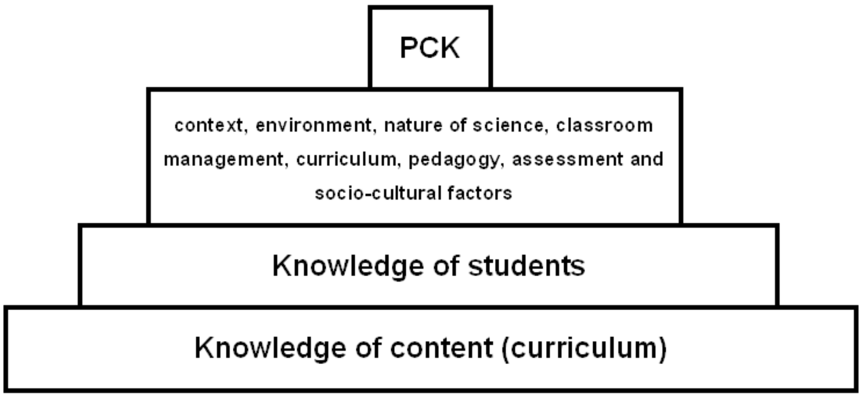


Figure 30 based upon Veal and MaKinster (1999)

Questions that this model begs are:

- Is knowledge of content filtered through the knowledge of learners and the consideration of the mechanics of teaching before impacting upon pedagogic content knowledge?
- Does knowledge of the learner have any impact upon the processes of pedagogic content knowledge?
- Do the mechanics of teaching have any bearing upon the process of making the subject content learnable?

These questions are addressed in the discussion of the thesis findings.

4.4 Teachers' beliefs and PCK

Another model of pedagogic content knowledge considered is one that incorporates an important element of teaching – teacher beliefs. The analysis focuses upon work arising from the 1997 report to the United Kingdom Teacher Training Agency regarding preparation for the National Strategy for Numeracy. The model (Figure31.) illustrates the relationships between pedagogic content knowledge, teachers' beliefs and teachers' practices. It identifies the contributory factors of subject knowledge, knowledge of teaching approaches and knowledge of pupils. It also indicates that pupil responses will have an influence upon pedagogic content knowledge.

Based upon a study in initial teacher training at Newcastle University, David Leat and others observed that trainee teachers frequently became "locked into patterns of teaching based on teacher exposition, textbooks and worksheets". They considered studies relating to a rich variety of pedagogic and cognitive approaches including: cognitive acceleration; Instrumental Enrichment; Philosophy for Children; reciprocal teaching; scaffolding; research on talk; social constructivism; self-theories and collaborative group work. Through the model proposed by Mike Askew and others (1997), they identified and described "powerful pedagogical strategies". Such strategies are "teaching strategies, which allow teachers to experiment with the parameters of learning environments" (Leat, 1998). The characteristics of the strategies are described in terms of: size, flexibility, openness, applicability, oracy and the richness of the learning experience (Leat and Higgins, 2002: 3-6).

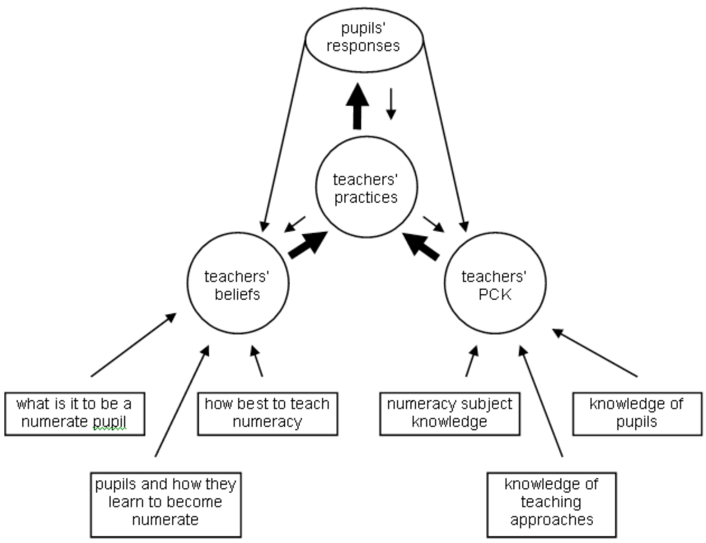


Figure 31 based upon Askew et al (1997)

4.5 PCK and the forms of knowledge

Rosie Turner-Bisset has an alternative perspective upon pedagogy driven by the desire to better teachers train. In her model, content knowledge can be broken into substantive knowledge and syntactic knowledge. Substantive knowledge within a discipline is composed of the facts and concepts of the subject and the substantive structures of a discipline are the frameworks used to organise these facts and concepts. Syntactic knowledge can be described as the ways and means by which the propositional knowledge has been generated and established. It is the way in which new knowledge becomes accepted by a scholarly community, through various procedures of experimentation and verification (Turner-Bisset, 2001: 10). She establishes the argument that expert teaching is based upon a number of knowledge bases including: curriculum and the aims of the educational process; models of teaching and learning; learners and cognition; educational contexts and, importantly, of themselves (Turner-Bisset, 2001: 153-157). Together these form the concept of pedagogic content knowledge. She draws upon the work of Jerome Bruner to illustrate the importance of analogy and metaphoric approaches in pedagogic content knowledge.

“there are three characteristic ways of representing the world: enactive representation, or understanding by activity, by doing something actively; iconic representation, or understanding by pictures, maps and diagrams; and symbolic representation, or understanding through the use of symbol systems such as spoken and written language, mathematical symbols or musical notation. Bruner considered that children first came to understand and represent the world enactively, then iconically and then through symbol systems, but he stressed that as adults, we use all three forms of representation and move back and forth through them as the occasion demands” (Turner-Bisset, 2001: 126).

This appears to have direct parallels with the different forms of presentation within the world of computing. The enactive is represented by the activities associated with virtual actions, of click and drag, highlighting and cut and paste. The iconic representation is exemplified by icons, diagrams such as flowcharts, dataflow diagrams and circuit diagrams. The symbolic is represented by programming code, pseudocode, instructions, and the symbolic representation of logic. Jerome Bruner’s ideas can help teachers think about what kinds of representations they generate for particular age-ranges, and how to reinforce an idea through the use of different representations. Rosie Turner-Bisset’s model is reflected in the presentation of the results of this study (Chapter 8).

4.6 Qualifying to Teach – a UK perspective

The professional standards for qualified teacher status and the requirements for initial teacher training are clearly set out by the UK Government. Replacing the statutory document, Higher Standards, Higher Status (DfES, 1997) the Qualifying to Teach (TTA, 2003) divides teacher training and career preparation into 3 areas: (1) professional values and practice, (2) knowledge and understanding and (3) teaching. The second aspect focuses heavily upon subject knowledge and understanding and not pedagogy – the defining statement "for those qualifying to teach secondary pupils this knowledge and understanding should be at a standard equivalent to degree level" alludes to the singular importance of specialism and high academic knowledge. The teaching section fairs little better in having a pedagogic expectation.

Those teachers awarded "qualified teacher status" must demonstrate that they set challenging teaching and learning objectives. It does not use any word that implies that objectives should be "effective" nor how those challenging objectives should be identified or constructed. It continues that those objectives should be based upon knowledge of the range and content of the work but it makes no implications that the teachers need be aware of how to teach that content. The nearest that the requirements get to interpreting the content of the curriculum is the statement that they are expected to "select and prepare resources… taking account of pupils' interests". This is not a powerful pedagogic analysis of the curriculum.

The statutory requirements placed upon trainers and trainee teachers are explained by the supplementary material "Handbook of guidance" (TTA, 2002b). This does imply an expectation that teachers should engage in some pedagogic analysis of the curriculum but the references are few. They are weak inferences to thinking about the curriculum at a depth greater than setting objectives based upon the National Curriculum. The strongest statements are: enable teachers to judge how ideas and concepts can be broken down (:18) and how ideas and concepts can be… sequenced logically (:18). The others are:

- how they present complex ideas (:19);
- communicate subject knowledge (:19);
- select and put together a coherent programme (:24);
- plan sequences of lessons designed to extend pupils' knowledge, skills and understanding (:38);
- resources that are of interest to pupils are more likely to motivate them (:39).

Qualifying to Teach does not elucidate the means by which these aspects of pedagogy can be achieved. In contrast, the teacher focussed aspects of the training (teacher behaviours and classroom management) are very detailed. Also, pupil centred aspects are clearly delimited and supported by a plethora of supporting materials and guidance of a statutory and advisory nature. Teacher training is a balance between teacher focussed activity and pupil-centred attitudes. The teaching of curriculum is defined by a set of minimum standards (the National Curriculum of England and Wales) and standards-based objectives with little emphasis upon the presentation of that curriculum – little (no) emphasis upon pedagogic content knowledge. The National Curriculum has encouraged a view of subjects as bodies of knowledge to be learned (Leat and Higgins, 2002: 76). Learning, as viewed from a constructivist perspective, requires that learners use what they already know to grapple with new information and scenarios. The diagram below (Halnan et al, 2004: 2) illustrates three important viewpoints of the education and teacher training process: teacher centred aspects, learner centred aspects and the curriculum. (Figure 32.) The curriculum focus in the UK describes the content rather that the pedagogic processes.

The National Curriculum for the UK explicitly describes curriculum content. In Qualifying to Teach there are strong and detailed expectations about teacher behaviours and learner entitlements but little detail about how the curriculum can be presented to ensure effective learning. Pedagogic content knowledge does not have a high profile.

Figure 32 foci of teaching: teacher, learner or curriculum

These observations of the UK teacher training culture do not fit easily with the idea of enabling learning through analysis and reflection upon the curriculum. They do not relate well to pedagogic content knowledge and its description as a unique body of knowledge that is "*the province of teachers, their own special form of professional understanding*" (Shulman, 1987: 8). Pedagogic content knowledge is concerned with how teachers “*reason pedagogically*” (Bullough, 2001: 655); how they shift from knowing their subject matter to being able to communicate their subject matter stated as "*from being able to comprehend subject matter for themselves, to becoming able to elucidate subject matter in new ways, reorganize and partition it, clothe it in activities and emotions, in metaphors and exercises, and in examples and demonstrations, so that it can be grasped by students*" (Shulman, 1987: 13).

4.7 Summary

This research is about how teachers make the link between the curriculum and learners' understanding. It is also about the rôle of metaphor in that process. Pedagogic content knowledge is defined in a range of ways with different emphasises including developing a cognitive process, incorporating assessment and the environment, placing PCK as the ultimate skill, focusing on teacher beliefs and developing areas of pedagogic knowledge (Shulman, 1987; Enfield, 1999; Veal, 1999; Askew, 1997 and Turner-Bisset, 2001). For the needs of this research, the emphasis upon the wider dimensions of the context of teaching, the “Science for all” model does not place enough emphasis or clarity upon the process of PCK. William Veal’s model too describes the underpinning and general influences upon pedagogic knowledge but Rosie Turner-Bisset’s model most closely emphasises the approaches and strategies of the teaching process of this research. That model will be returned to in the analysis of the results.

This research is concerned directly with the substance of Shulman’s work. He has identified a body of powerful analogies, metaphors, illustrations, examples, explanations, and demonstrations (Shulman 1986), all of which are useful forms of representation of the subject knowledge. In Shulman’s ‘model of pedagogical reasoning and action’, taken from the point of view of the teacher, comprehended ideas must be transformed in some manner if they are to be taught. Shulman emphasises the use of a ‘representational repertoire’ that includes analogies and metaphors.

There is a potential tension in placing this study of PCK in an environment where education is described in terms of curriculum content and teacher behaviours. However, it will be seen that the respondents in this research are a group of teachers whose motivations in the classroom are also coloured by a desire to improve their own practice through in-service training and be involved in the training of other teachers. This study is about how teachers make the cognitive bridge between the curriculum (their curriculum knowledge) and learners' understanding - it is that knowledge, skills and understanding of the teacher that is called pedagogic content knowledge.

Chapter 5 Developing the research design

This chapter describes the research design and contains a discussion of the research methodologies that were considered and adopted to enable the collection of empirical data. It contains a brief overview of the cycles of enquiry undertaken and the rationale for the initial organic nature of the research. The writing reflects the challenges caused by the developments in:

- the author's understanding of the situation as the research progressed;
- the issues raised by respondents, co-workers and supervisors;
- the teaching environment (caused by on-going changes is policy and practice within the schools).

The chapter is therefore divided into areas to enable the best articulation of those, often conflicting, developments.

The following discussion describes the formation of the research methods and the over-arching research design reflecting the precise focus of the research question and subsidiary questions:

what is the role of metaphor in the construction of computer pedagogic content knowledge?

what do teachers do to turn curriculum knowledge into pedagogic content knowledge with special emphasis upon the use of metaphor and analogy within computing and the use of computers?

The qualitative versus quantitative division is identified and a justification for qualitative practice is stated. The interpretative nature of enquiry is described and the use of grounded theory method justified. The rationale for the appropriateness of interviews and the interview process is outlined and the challenges that the approach presents are described. Interview schedule writing and the cautions are clearly stated as well as a review of alternative interview practice. The ethical issues are presented as part of the full description and rationale of the selected methodology.

Chapter contents:

The process of research based upon a grounded theory method and developing over a period of years means that significant changes take place to the initial plans. Figure 33. (below) represents the situation as of August 2002. At that time it was clearly established that this research would be based upon the analysis of teaching methodology as reported by teachers of computing in interview. However, prior to the development of interview schedules there would be a time of preparation to contextualise the research. An important aspect of that preparation was the development of an A-Z of

Metaphors. That document was established and revised in collaboration with a wide range of teachers and trainee teachers. The precise details of the preparatory methods employed and the results of those methods are reported in the next chapter.

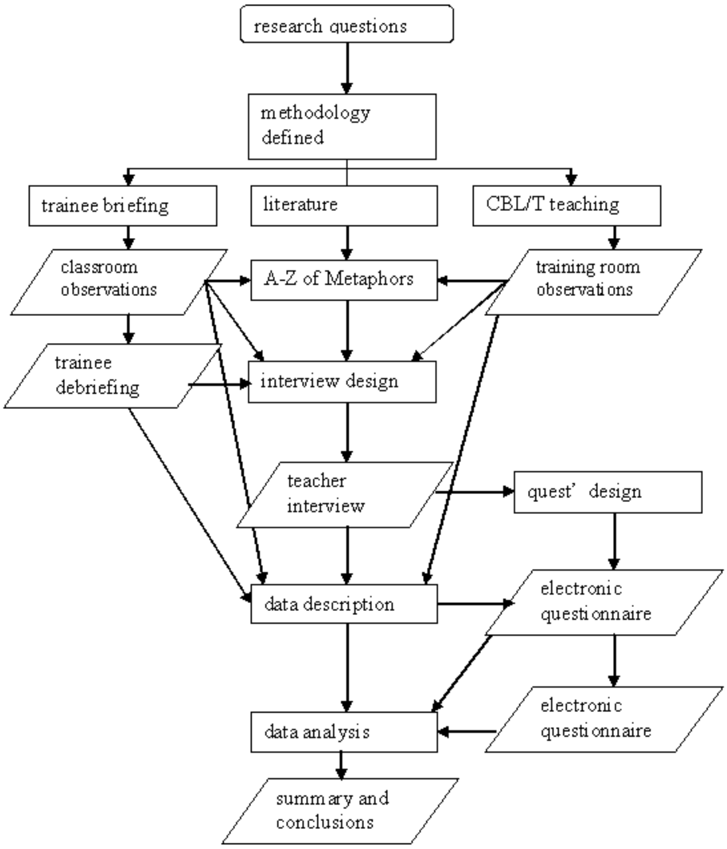


Figure 33 the research plan (August 2002)

The critical data of this research arises from experienced and successful teachers of computer science. The focus of this methodology chapter is the means by which data about the use of metaphor to support teaching is gathered.

5.1 Qualitative versus quantitative approaches to research

At the very start of this investigation into teaching methodology, the qualitative-quantitative debate was considered. In choosing research approaches in the social sciences, quantitative research is frequently not attractive for a number of reasons. Some of the philosophical assumptions are outlined by Martyn Hammersley. There is an assumption from some quarters that what is taken to be the quantitative method of the natural science is the only rational source of knowledge. Perhaps it is because they (the supporters of the quantitative approach) are not sensitive to the impact of research upon people and the social environment that this method ("scientific") is applied in social research irrespective of any supposedly destructive features of the social reality [paraphrased from the original text] (Hammersley, 1995: 1). Further, that quantitative measurement, experimentation and statistical manipulation of variables are seen to be, by some, essential features of scientific research. Even in the face of understandings of social constructivism, some still insist that research can and should be concerned with producing accounts which correspond to an independent reality. This, the realist position, contends that objects have an independent existence and are not dependent upon the knower (Cohen et al, 2000: 6). The final assumption is that research must be objective, with subjective biases being overcome through commitment to the principle of value neutrality.

5.2 Qualitative approaches and the socio/personal context

Reason and Torbert (1999) suggest that research can be first, second or third person in nature. Second person research is co-operative inquiry more focussed on sociological research than classroom pedagogy issues (Heron, 1996). Heron draws parallels; it involves the researcher and the subject of the research to be in a close and cooperative relationship with each other. Aspects of second person research include conversation, dialogue, empathy and collaboration. The subjects of the research become co-researchers and so through conversation (Gillham, 2000: 1), or other communication, participate in the cognitive processes of the research. Alternatively described as "fourth generation" (Guba and Lincoln, 1989: 260) this approach requires the researcher to share control "...however much that appears to threaten the "technical adequacy" of the evaluation". That is, the evaluator must solicit and honour stakeholder inputs not only about the substance of constructions but also with respect to the methodology of the evaluation itself. "On the political front, it [qualitative research] has not grasped the right of informants to participate in formulating the research design, so that they can manifest fully their values in the way knowledge about them is generated " (Heron, 1996: 28). John Heron also provides examples (Heron, 1996: 1-18) of where research is "concerned not just to understand but to empower" (Heron, 1996: 28). This potential for empowerment and deciding upon the design of the investigation reflects the situation of my research (within the context of UK Higher Education in 2003) and from the alternative approaches best meets the needs of this research. In particular, one research question queries which are the areas of computing that are "difficult to teach". The teacher has to acknowledge the difficulty. My research is focussed upon challenge, and in a sense, some of the negative connotations of difficulty. However, it celebrates the success in the face of adversity in that it is reporting in detail upon the positive strategies adopted to meet the identified weaknesses, needs or challenges.

The methods are therefore based within the primacies of qualitative, fourth generation, second person research. This forms the research paradigm.

A cautionary note comes from Martyn Hammersley. "*There has been a tendency within educational research, and indeed within social research generally, to treat different research strategies as competing methodological paradigms involving contrasting assumptions. This has led to the development of distinct research traditions with their own separate literatures. Such a state of affairs impedes rather than advances the development of classroom research. In my view [Martyn Hammersley] all social research faces the same basic methodological problems, though researchers differ in their awareness of them, the weight they assign to each and the remedies used. If there is to be any significant progress the work produced by different research traditions must be brought together and the effectiveness of different research strategies examined*" (Hammersley, 1986).

His cautionary note is heeded and that consideration is reflected in the catholic collection of referencing drawing from key literature in a number of areas.

5.3 Researching teachers and teaching

There is much documentation in the ways in which the actions of the teacher impact on the learning of the students in their class. For example, the reviews of Leach and Moon (1999), Porter and Brophy (1988) and Jarvis et al (2003) have been considered. One important review, with regard to this research, is that of Neville Bennett (1976). He established the connections between teaching styles and pupil progress and the impact of different styles. With colleagues, he subsequently re-analysed their data and completely changed their conclusions, indicating instead that the "significance of the differences as reduced" (Aitkin, 1981: 419-461). The re-evaluation of the findings is summarised (Gray and Satterly, 1981: 187-196) as follows: "Differences between teachers within teaching styles were far greater than differences between styles. Differences between teaching styles were so small as to be overwhelmed by differences between other systematic effects" such as the resources, methods, curriculum analysis or pedagogic content knowledge. "The direction of differences between styles did not consistently favour one style over another." This adds credence to this study of how individual teachers tackle the problem of teaching particular concepts within the curriculum and disregarding the overall "style" of teaching that the teacher adopts.

Because knowledge continually evolves, particularly in the field of computing, the effective educator needs to be current in his or her understanding of new ideas and issues within the curriculum. Porter and Brophy (1988) and McNergney and Herbert (1995) stress the importance of teacher content knowledge as well as pedagogical knowledge. Understanding the subject matter is the prerequisite of effective teaching. Jere Brophy (1999: 8) underscores the importance of content knowledge in order to plan and facilitate learning experiences that encourage students to then construct knowledge based on prior experiences. Knowledge of pedagogic issues is also essential to good teaching. Lee Shulman's (1986) work emphasises knowledge of ways to represent topics for learners and ways of understanding why topics might be difficult or easy for students to learn, through practices such as use of examples, demonstrations, and analogies. Again, this underpins the reason for interviewing and the sorts of information that the schedule needs to be designed to capture. One research question is "what is the nature of teaching methodology within computing?" The important aspect is "how do teachers use their subject knowledge and their knowledge of the learning processes to create learning opportunities?" This is determined by asking the teachers.

5.4 Planning the interview; structuring informality

It is considered that the interview is the best way to enable the researcher to have a second person interaction with teachers, for there to be a full interaction (discussion) of the teaching issues and to give a better reflection of the inter-personal context of the teaching process. The interview reflects the social constructivist stance "towards regarding knowledge as generated between humans, often through conversations" (Cohen et al, 2000: 267). Steinar Kvale sees interviews: as an interchange of views between two or more people on a topic of mutual interest; based around a centrality of human interaction for knowledge production; and with an emphasis on the social situatedness of the research data (Kvale, 1996 in Cohen et al, 2000: 267). This is most pertinent to the research question "which concepts are difficult to teach?

The nature of the interview has been analysed by Bill Gillham and he describes 5 types: medical, selection, therapeutic, market research and research. (Gillham, 2000: 2). At first glance it might be obvious that the research type “to obtain information and understanding of issues relevant to the general aims and specific questions of a research project” would be the most appropriate. The adoption of the grounded theory method (GTM) (Glaser and Strauss, 1969: 1-2) does tend to skew the interview style towards therapeutic style - “to enable the client [teachers] to develop a perception of his or her difficulties [challenges] which leads to insight and changed behaviour [teaching]”. It is not the primary intention of the research to bring about change but to bring about a greater understanding. It is that understanding that needs to come from the participants; it is their experience and it is their behaviour that requires understanding and it is they who can understand. It is the rôle of the researcher to bring order, structure and theory to those understandings. This is a central tenet of the grounded theory method (discussed in the final section of this chapter).

Michael Patton describes four types of interviews: informal conversation; guided; standardised open and closed. For each there are both strengths and weaknesses and the evaluation of these determined the design decisions (Patton, 1980: 206).

The guided interview approach has prescribed topics and issues to be covered. These are specified in advance in outline form; the interviewer decides upon the sequence and working of the questions in the course of interview. The outline increases comprehensiveness of the data and makes the data collection more systematic for each respondent. As a result, logical gaps in data are anticipated and closed. The interviews can remain conversational and situational. However, important and salient topics may be inadvertently omitted and as a result of the interviewer's flexibility in sequencing and wording questions, substantially different responses can be experienced. The schedule must be designed to reduce this probability.

Conversation and exposition are the tools of the teacher. It is the natural medium for the research process. However, there is much debate upon the subjectiveness or objectiveness of the interview process. At one end of the spectrum there is the perception that the interview is a potential means of pure information transfer and collection (Cohen et al, 2000: 265) and at the other as an “encounter necessarily sharing many of the features of everyday life”. Ranjit Kumar’s definition “Any person-to-person interaction between two or more individuals with a specific purpose in mind is called an interview” (Kumar 1999: 109). He goes on to re-emphasise the difference between structured and unstructured interviews rather than the levels of social interaction discussed by Heron (1996). Like Kumar, other researchers focus on the functionality of the interview methodology “[the] interviewer’s main job is to ask the questions in such a way as to obtain valid responses” (Burns, 2000). It is through the schedule that the rigour of structure and the freedom of exploration can be achieved.

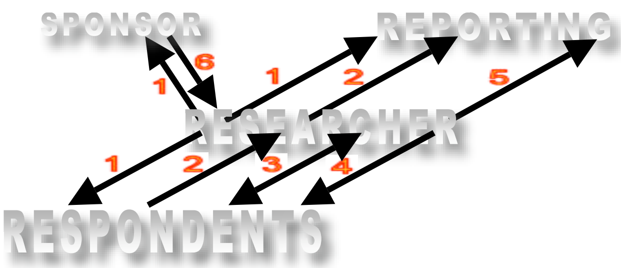
The schedule is a **list of questions** that ensures a **sameness of experience** between interviews. It **outlines the topics** from which the interviewer is **free to choose** for the respondent to further **elucidate and illuminate**. The schedule **suggests the order** on which to build a **conversation**. The interviewer is free to take in **any order** to establish a **conversational style** but making judgements upon how to make **best use of limited time** and to best reflect the interests and motivations of the interviewee.

The “interview schedule” is structured upon a consideration of the schedules produced by Michael Patton (Patton, 1980: 201), Bill Gillham (Gillham, 2000: 27) and John Lofland (Lofland, 1971).

The format of the interview is based upon a clear structure of introduction, warm up, main body, cool down and closure (Robson, 2002: 277). The introduction includes explaining the purpose of the interview, assuring confidentiality by stating that any comments are not to be attributed to the respondent or the school/college, asking permission to tape record the interview. It is important to discuss at this point whys of research, to establish a frame of mind and to contextualise the research (Bell, 1999: 144).There is a reassurance that if the respondent does not teach many of the items identified then it does not matter but that the concentration is upon those elements that the respondent does teach. The warm up questions are designed to be easy and non-threatening to settle both interviewee and interviewer. After the main body of the interview there is a cool down period with a few straightforward questions at the end to defuse any tension. The closure is a thank you and goodbye. However, some interviewees will come out with a lot of interesting material at the end. “Handle this session consistently - make notes and continue to tape record” (Robson, 2002: 277).

5.5 The ethical dimension

The primary consideration must be that this research meets the requirements of the University. "Both supervisors and students should observe due ethical standards in the design, conduct and reporting of the research. Ethical considerations must be addressed in experiments involving either human subjects or animals. Academic departments/colleges should establish a formal channel to consider and determine any such ethical issues" (University of Southampton, 2002). The reading about the ethics in research planning identifies a small set of phrases that forms the basis and essence of the ethical dimension of this work and has been represented by the author in a diagram of interacting relationships. The following discussion details those relationships they are illustrated in Figure 34..



1 professional conduct

3 informed consent

5 disclosure of public interest

2 pursuit of truth

4 protection of anonymity

6 endorsement of research

http://www.soton.ac.uk/~wjw7/ethics

Figure 34 the ethical dimension

professional conduct

This is the strongest of all factors and it has implications for the researcher with respect to the respondents, the reporting process and the sponsors of the research. Professional conduct is the combination of following the ethically correct and the methodologically correct process and underpins all other responsibilities.

pursuit of truth

Pursuit of truth is the responsibility of the researcher and is reflected in the reporting process. It is also the responsibility of the respondents in their communications with the researcher. Although the researcher must be aware of the issues of bias, the interviewee has a moral responsibility to be truthful.

informed consent

In pursuit of truth does not release us from exercising "*due ethical standards in the design, conduct and reporting of the research*" (University of Southampton, 2002). Informed consent is a responsibility of the researcher to inform the subjects of the research (LeCompte and Preissle, 1993: 66 and Denscombe, 1998: 109). It is also the responsibility of the respondents to be informed before giving consent. This may take the form of contracts between stakeholders within the research process (Blaxter, 1996: 146 and Hart and Bond, 1995: 198). Martyn Denscombe takes another attitude. All interviews can be (should be) considered to be "on the record" and therefore an assumption that the details maybe disclosed unless the interviewee purposefully and directly declares that the comments should not be made publicly available (Denscombe, 2003: 163).

protection of anonymity

The protection of anonymity can be easily promised yet less easily achieved when the discussion of the outcomes in a contextualised format. It is therefore an important consideration (Blaxter, 1996: 148) with bearings upon statements regarding confidentiality and anonymity. Promises of confidentiality should not be readily made if verbatim comments are to be the source of evidence for the research. Anonymity can be more easily achieved by not associating the comments with a named individual but the contextualisation may imply the identification of the person. There are legal and professional issues relating to the promises of anonymity that cannot be achieved because of the nature of the reporting of research. Interview anonymity strategies include coding, pseudonyms, data aggregation, passwords (Cohen et al, 2000: 61).

disclosure of public interest

There is a conflict of interest between the two dimensions "public interest" and "pursuit of truth". This is a moral dilemma – is the disclosure of truth more important than the public interest when that disclosure may mean suffering? There is a conflict of interest between the two dimensions "public interest" and "protection of anonymity" - is the protection of the individual more important than the public interest when that disclosure may mean suffering by the individual? If the research did not take place then the information would not be in the "public domain" and therefore, it could be argued, that not disclosing a discovered fact is not putting the public in a less favourable position. The counter argument may be that because no disclosure was made that the "public" is falsely confident that no area of concern exists. There are ethical stances that protect the rights of individuals from all disclosures of "their personal attitudes, opinions, habits, eccentricities, doubts and fears" (Cohen et al, 2000: 61).

endorsement of research

The ethical issues are made explicit through codes, policy, guidelines and protocols. This research is subject to the codes of good practice endorsed and asserted by the University of Southampton. The guidelines that advise this research come from a number of areas – the primary being the guidance of the University staff and policies.

The fourth generation approach to this research has implications for the ethical situation. Egon Guba warns that researchers have higher demands (than first to third generation researchers) "…indicated by the political, ethical, and methodological ramifications of the hermeneutic, dialectic process..." He describes four areas for consideration; the fourth is the most important (Guba, 1989: 261-262) A fourth generation investigator is not a passive (non-interventionist) observer and recorder but rather an "instrument of change" and needs to take a responsibility for that change. The researcher, through the data gathering process enables the respondents to articulate, and perhaps for the first time publicise, their thoughts. The researcher "creates a new and more sophisticated reality… that has built into it direct and immediate implications for action".

The ethical dimension to this research is summarised by the following statement made to respondents and the identification of the stakeholders with their responsibilities and entitlements.

"Would you mind me using a tape recorder as it means I do not to take notes as we talk? The information will be treated confidentially. That is, I will not make any reference to you personally or your institution when I write up my research."

The sponsor of the research is the University of Southampton. Its endorsement makes it responsible for ensuring that the research is appropriately supported and directed - it has an entitlement to protection of its rights and welfare. The public reporting should be underpinned by the professional conduct of the researcher, be a factual and fair "reporting of the truth" and disclosure of any "public interest". The respondents have entitlement to protection of anonymity and subject to the professional conduct of the researcher. By giving consent they enter into a contract; they have a responsibility to ensure that the pursuit of truth is maintained through honest and fair response. They have an entitlement to being informed of the consequences of that consent. The researcher must: inform respondents, ensure consent, act in a professional way, disclose the public interest, pursue the truth and protect anonymity.

5.6 Towards a theory (grounded theory method)

This chapter of the thesis is concerned with the methodology of the research but thus far has only considered the method "interview". However, that method alone simply provides a mechanism for the collection of data. The second, and arguably, more important method is the mechanism for data analysis. The data is essentially qualitative and any quantitative analysis would reveal features of the research size but not provide a major insight into the nature of the observations. However, having said that, the interview provided an immensity of data that cannot be numerically analysed. To avoid being dismayed by the mountains of data confronting and troubled by the ensuing questions a strategy of analysis must be adopted. "How can I make sense out of all of this material? How can I have a theoretical interpretation while still grounding it in the empirical reality reflected by my materials? How can I make sure that my data and interpretations are valid and reliable? How do I break through the inevitable biases, prejudices, and stereotypical perspectives that I bring with me to the analytic situation? How do I pull all of my analyses together to create a concise theoretical formulation of the area under study?" (Strauss and Corbin, 1998).

The grounded theory method (GTM) provides a basis for the analysis of qualitative data and is the means by which this study formulates its conclusions. However, the earlier assertion that the interview procedure should be handled consistently can be challenged. The interview method is not independent of the analysis method when utilising grounded theory. The interview is fully integrated into the analysis. Indeed, major conclusions of the research may be formulated and first articulated within the “cut and thrust” of interview exchanges.

The grounded theory approach is a way of thinking about and studying social reality and traditionally is based upon a set of procedures and techniques for gathering and analysing data by first coding and then conceptualising and integrating it to form theory. The characteristics of a good grounded theorist include:

- the ability to step back and critically analyse situations;
- the ability to recognise the tendency toward bias;
- the ability to think abstractly;
- the ability to be flexible and open to helpful criticism;
- sensitivity to the words and actions of respondents;
- a sense of absorption and devotion to the work process (Strauss and Corbin, 1998: 7).

Anselm Strauss and Juliet Corbin use the term "grounded theory" to mean theory that was derived from data, systematically gathered and analysed through the research process. In this method the data collection, its analysis and the eventual theory stand in close relationship to one another. It is based upon description: the use of words to convey a mental image of an event, a piece of scenery, a scene, an experience, an emotion, or a sensation; the account related from the perspective of the person doing the depicting. From that comes conceptual ordering: organising (and sometimes rating) of data according to a selective and specified set of properties and their dimensions. And finally, theory: a set of well-developed concepts.

An important aspect of the methodology of this study is the process by which a theory can be established. This introduction to the process falls appropriately in this methodology chapter; however, its application lies within the analysis and discussion of the results. For that reason, this chapter is written within the context of interview-based research yet avoids exemplification by reference to the focus of the study - metaphor usage in pedagogic content knowledge. In this study, there is no formal, established theory that on which to base the hypothesis. This study endeavours to establish the theory from the “ground up”.

There are several versions of grounded theory method, the main two being Glaserian and Straussian. "Students of Glaser and Strauss in the 1960s and 1970s knew the two had quite different modus operandi" (Glaser, 1992: 116-117). Despite criticisms of grounded theory method (Stern, 1994: 213), this study is based upon a description and exemplification of the method in the published literature and takes elements of practice drawn from a range of authors including Borgatti (2002), Corbin (1998), Fawcett (1991), Glaser (1967, 1992, 1998), Morse (1964), Stern (1964, 1994) and Strauss (1997, 1998)

The grounded theory method has much flexibility and is interpreted in a range of ways by different researchers. There is a commonality in that this is a staged approach with a distinct chronology. This is represented diagrammatically (Figure35.) below.

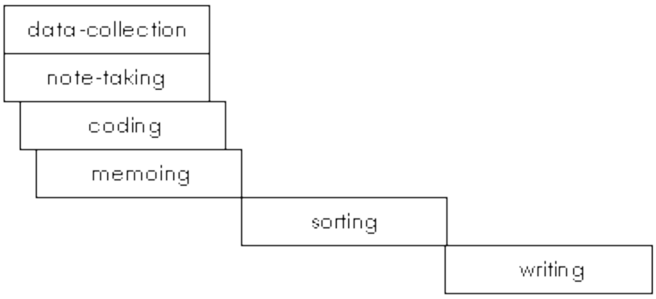


Figure 35 the staged aspects of grounded theory method (ALARPM, 2003)

The methodology of the study can be superimposed upon this structure. Each element has a corresponding activity. However, the ALARPM model has a missing element; it is 'what data needs to be collected?' It is not just a question of collecting for the sake of collection but it needs to be focussed and based upon a basic understanding or knowledge of the area. Jacqueline Fawcett argues that the grounded theorist enters the scene bereft of preformed theory. However, she admits that observation and questioning are guided by hypotheses generated in the field (Fawcett, 1991). In the case of this work, those hypotheses were generated through the researcher's own experiences of: teaching computing, work in the world of computers, reading about research methods and professional observation and assessment of the quality of teaching.

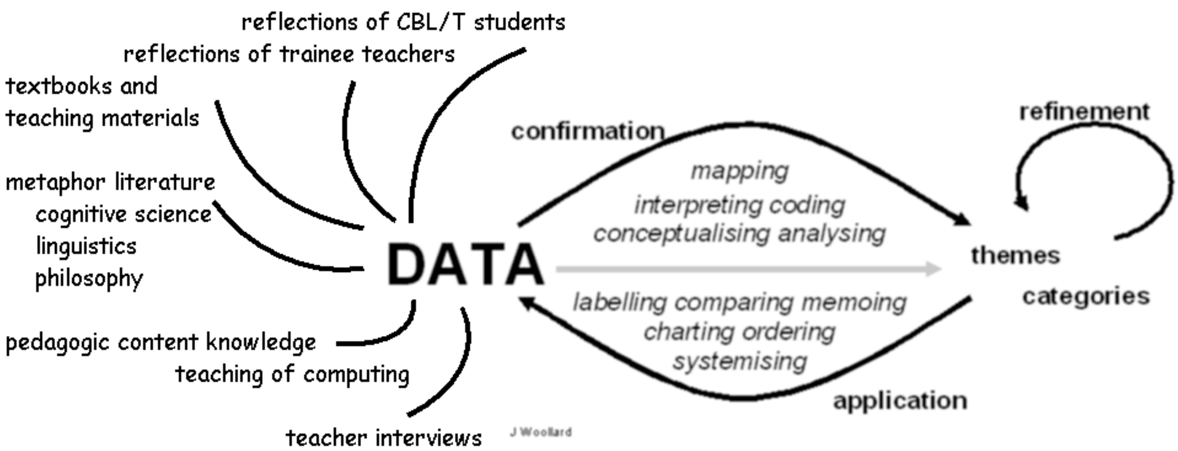


Figure 36 the grounded theory method and the elements of data gathering

Placing grounded theory method into the context of the study of metaphor in pedagogic content knowledge requires the construction of a framework which can bind the method of analysis to the data collection of the phenomenon. The diagram above (Figure 36.) shows the sources of data and the processes of grounded theory method. The final validation process of this research includes a consideration of the sources of information and the degree of saturation of the data. That is, once a theory has developed based upon current data, data collection continues until no changes to the theory need to occur to accommodate new data (Glaser and Straus, 1967: 67). In support of the validation process the full methodology will also possess a degree of triangulation.

The major components of the triangle (Figure 37.) are: the literature review, the interview data and analysis and the focus group reflections.

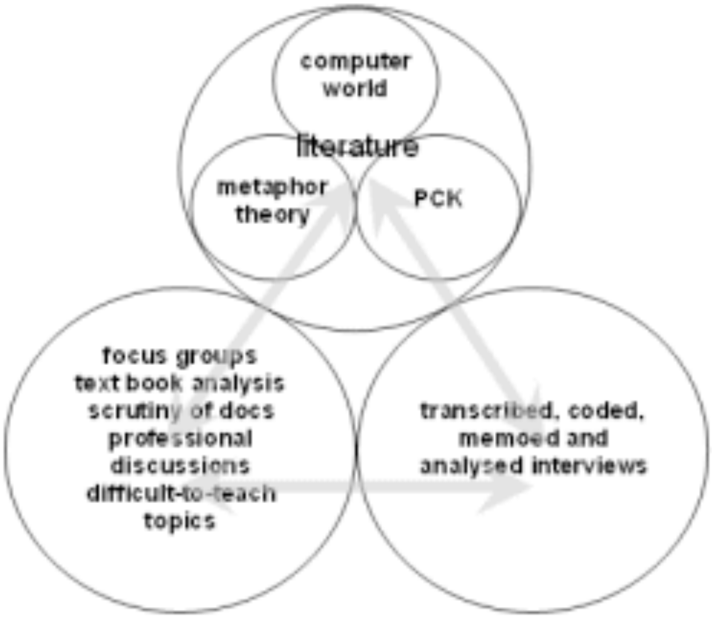


Figure 37 aspects of validation through triangulation

5.7 Summary

This chapter identified the two major methods of the research - the guided interview and the grounded theory method. It identified the research as being second person and fourth generation with a therapeutic style of interviewing. The importance and function of the schedule has been emphasised.

The ethical aspects of the research have been considered and the issues discussed. Finally the grounded theory method has been described and a diagrammatic representation presented to reflect the data sources, aspects of processing and validity checks.

The next chapter presents a description of the implementation of the methodology and includes:

- identifying key players/stakeholders in the situation;
- identifying metaphors;
- identification of the sample group;
- the identification of the difficult concepts of computing;
- the schedule design and
- the coding principles.

Chapter 6 Implementing the research design

The previous chapter described the underpinning principles to the research design and outlined the methodology adopted to gain the insight of teacher practices. That account included: the rationale for interviews; a description of the interviewing practice and schedule; a description of the grounded theory approach and the ethical principles of the research. This chapter describes the implementation of that methodology, the pre-requisite activities and the subsequent coding process.

The aim of the methodology is to underpin the major focus of this work and answer the research question:

what do teachers do to turn content knowledge into pedagogic content knowledge with special emphasis upon the use of metaphor and analogy within computing and the use of computers?

The methodology directly addresses the subsidiary research questions:

what is the nature of teaching methodology?

how do teachers/trainers/tutors teach computing?

There are four distinct phases to the research implementation that take place before carrying out the interviewing of teachers. They are: identifying and describing the stakeholders of the research; gathering and describing metaphors (teacher inset groups); identifying and describing the sample group (teachers of computing) and identifying and describing the difficult concepts of computing (focus group). The interview schedule is informed by: the ethical statement; A-Z of metaphors; difficult topics of computing and the literature review. The major data sources are the transcripts and documents of the interviews of experienced and successful teachers of computing. These are processed and encoded using QSR-NVivo software.

Chapter contents:

Figure 38. “informing and implementing the research method design” (below) reflects the plans for the order and implementation of the research. It identifies the major source of data being that of the experienced and successful “teachers of computing” and illustrates the major processes of the research design with the important inputs of teachers, trainees, the ethical consideration and the literature review. The products of the process are the difficult-to-teach list of topics, A-Z of computer metaphors, the interview schedule, the encoded transcripts and documents, the ideas relating to pedagogy and the final summative representations.

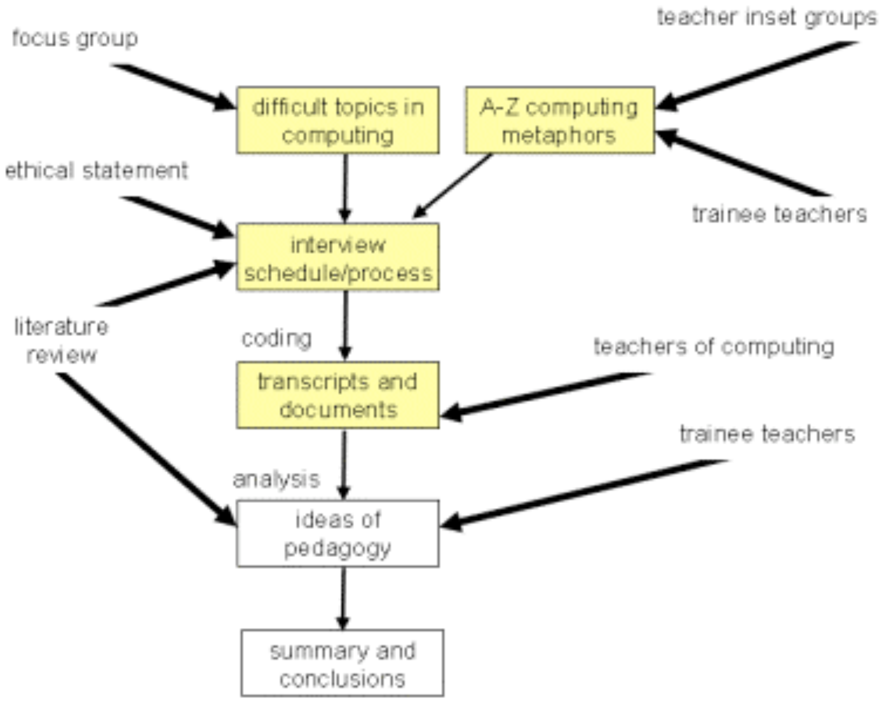


Figure 38 informing and implementing the research method design

Research is not an isolated activity but it takes place with interaction with "normal life" at a number of levels. In particular, this "fourth generation" (Guba and Lincoln, 1989: 260) approach involves a wide range of people in conversation, dialogue, empathy and collaboration (Gillham, 2000: 1). In addition, the influences upon the results of the research and those on which the results of the research may impact and extend beyond the immediate and include: national organisations; statutory bodies; local schools and so on…

6.1 The stakeholders of the research

The stakeholders of the research are first considered when generating an ethical statement and rules for proceeding with the research. There are both responsibilities by and responsibilities for various people associated with the research. The stakeholders and their rôles are identified in the table below and their interrelationship is described in the previous chapter and illustrated by the diagram Figure39.

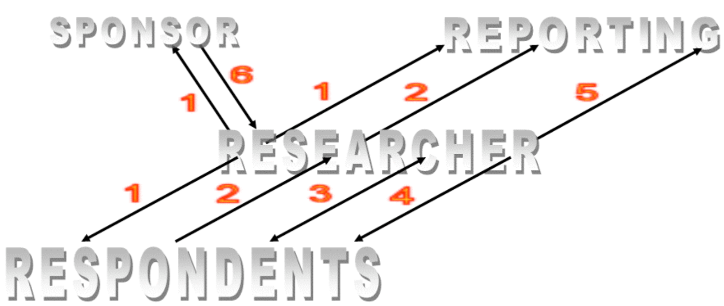


Figure 39 the ethical basis for the research

However, it is also important to consider those people who would, through their experience and responsibility have pertinent comments to contribute to the research procedure, data and findings.

stakeholder	experience and responsibility	contribution to the evidence base
UK Government (DfES, TTA, QCA, Becta)	providing the statutory context for education in the UK 5-19 years	mostly web-based statutory documents and advisory materials reference the curriculum and teaching organisation
Examination providers (AQA, OCR, Edexcel)	providing the accreditation and direction in some curricula	specifications, examiners' reports, researcher's experience of examination work
Masters students (cpd and inset)	ensuring good quality and appropriate teacher training in University based sessions	formally recorded responses to metaphor discussions (A-Z of computer metaphors)
colleague teacher trainers	informal support and advice, collegiate responsibility for published work	field notes of feedback at research seminars
researchers in the field	professional exchange in discussion groups and informal meetings	literature review; field notes of feedback at presentations (research seminars, paper presentations)
trainee teachers	ensuring good quality and appropriate teacher training in University based sessions	field notes of discussions; electronic resources; presentations made by trainees
training mentors (and partnership teachers)	supporting, complementing and informing the training process	being part of inset, focus and sample group

Figure 40 stakeholders in the research

The contribution of these other stakeholders is both formal through the scrutiny of the documentation and less formal through discussions, conversations and feedback after research seminars. Table 40. lists the stakeholders of the research. Appendices 3 and 4 describe the content of the seminars.

6.2 The identification of metaphors

Identifying metaphors is a general data collection and contextualisation exercise.

This research focuses upon practice - "what do teachers do to turn content knowledge into pedagogic content knowledge with special emphasis upon the use of metaphor and analogy within computing and the use of computers?" That practice is both practical (physical activities within the classroom) and cognitive (mental strategies of the lesson planning processes). In the words of Peter Jarvis, "there are certain topics that cannot legitimately be researched by traditional methods… …we cannot discover any "facts" about the practice process through the use of a questionnaire to one hundred practitioners because practice itself is not a fact. All we might be able to discover is what practitioners think at the time of the research about specific aspects of their practice" (Jarvis, 1999: 120). The phase of contextualisation is to establish a "piece of scenery" (Strauss and Corbin, 1998) into which we can place the statements of the teachers. In this research that scenery is the use of metaphor in its widest sense - in the use of language (speech utterances), the devices of the computer and, importantly, the processes of teaching.

A starting point for identifying the metaphors in use in computer teaching is the internet. The following table (Figure 41.) describes the results obtained by carrying out a search using the Google search engine in 1999 (Google, 1999).

A consequence of browsing such references is the identification of the "popular" such as popular authors, popular researchers, popular software, popular topics, popular themes and further keywords. The activity also acts as an informal citation index. For example, a search on "Shulman" reveals more papers referring to Lee Shulman than papers written by the author himself.

keyword search	results	time	category (if any)
metaphor computing	86400	0.49	Computers > Internet > Web Design and Development > Web Usability
computer metaphor	263000	0.68	
metaphor teaching	172000	0.50	Computers > Multimedia > Authoring
metaphor teacher	138000	0.88	
metaphor pedagogy	19000	0.47	
metaphor concepts	193000	0.74	Computers > Internet > Web Design and Development > Web Usability
teaching tropes	6680	0.47	
pedagogy literal	5960	0.48	
computer curriculum metaphor	28200	0.34	

Figure 41 results for searching Google in 1999

The identification of metaphors in computing arose from listing those that are stated by others (internet authors) to be metaphors and those examples that had, according to the author, “names being not literally true”. An initial list of some 30 metaphors formed the basis of discussions with experienced practitioners of computer based teaching and learning and presented as an A-Z Computers listed below (Figure 42.).

A to Z of computer metaphors in teaching with and about computers:

absolute; bookmarks; breadcrumbs; click, beep and bug; cookies; cut, copy and paste; desktop; drag and drop; files and folders; firewall; fragging; “go to” on the worldwide web; icons; memory; metonymy; recycle bin; rubber band; slideshow; software metaphors: book, director, spreadsheet; spamming; surfing, browsing and grazing; trashcan for delete; trojan horse; video controls; virus; walled garden; worm; yahoo; zapping; zip (Woollard, 2000a).

Figure 42 A to Z of computer metaphors

These metaphors are described in the literature review - the majority in Chapter 3 - metaphor in the world of computing. The metaphor list was further refined during sessions of the Masters level continuing professional development course in computer based learning and training. Arising out of the presentation of a provisional list of metaphors and their descriptions, discussion identified the construct metaphor. As a result of small group work (based upon discussion and internet searching) a larger selection was identified by the group and this list used to support the interview schedule design. The initial idea of presenting the metaphors as an anthology obviated the necessity to present them in a classified order. However, their classification does enable a better understanding of their use.

A possible broad grouping of computer metaphors is a division between those that relate to the functions of a computer (processes that are transparent to the user); those that are visible yet virtual features of the computer and those that are activities carried out by the user. (Figure 43.) It provides a structure for presenting computer based metaphors.

functions carried out by the computer…	absolute cookies firewall memory trojan horse virus walled garden worm
features of the computer interface…	bookmarks breadcrumbs desktop files and folders icons recycle bin slideshow software metaphors trashcan for delete video controls yahoo
activities carried out on the computer…	cut, copy, paste drag and drop “go to” a web site fragging rubber band spamming surfing, browsing… zapping zip

Figure 43 the categorisation of computer metaphors by function

The following table (Figure44.) reclassifies the same metaphors against the image schema proposed by George Lakoff and others.

	functions carried out by the computer…	features of the computer interface…	activities carried out on the computer…
source path journey		bookmarks breadcrumbs slideshow	cut, copy, paste
source path time		video controls	
source path 1D structure	absolute		“go to” a web site
surface	memory	desktop icons	fragging drag and drop rubber band surfing and browsing…
container	trojan horse firewall walled garden virus worm cookies	files and folders recycle bin trashcan for delete	zip
colour			
other (or classifiable)		software metaphors	spamming zapping

Figure 44 the categorisation of computer metaphors by image schema

Software metaphors are diverse and individually fall into many categories. They are described as integrated metaphors (Chapter 3, section 7). Spamming, from the perspective of a spammer, could be described as a centre-periphery concept. However, the term is more often used by the victim of the process and is a source-path-goal concept. Zapping is an activity of transformation. The image schema categorisation was described in Chapter 2 and the image schema listed in section 8.

6.3 *The identification of respondent teachers*

The next stage of the research process is the identification of the interview participants. The selection of respondents is based upon a filtering system illustrated below (Figure 45.). The access to schools is limited to those that participate in initial teacher training (ITT) through the local University. The selection process employed is more likely to identify schools with teachers who have considered the pedagogical issues. In this particular geographical area there is a tendency for post-16 education to be provided through specialist post-16 colleges offering academic based courses leading to advanced level GCE, AVCE and GNVQ qualifications (QCA, 2003) in preparation for higher education at university or college. In the area there are the following secondary and post-16 establishments:

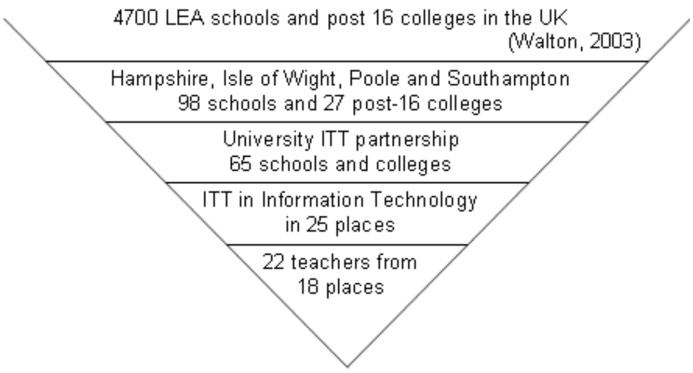
Isle of Wight (5 schools + 1 college of further education),

Hampshire (71 schools + 23 colleges of further education),

Southampton (14 11-16 schools + 2 post-16 colleges plus 1 college of further education) and

Poole (8 11-18 schools + 1 college of further education).

65 of these establishments are members of the teacher training partnership but many partnership schools do not offer IT teacher training (25 of the 65 partnership schools and colleges offer placements for IT). The respondents are chosen from the schools and colleges who have close connections with the University School of Education and who regularly participate in continuing profession development (CPD), in-service training (INSET) or ITT activities in the ICT field. The 22 respondents are drawn from 18 establishments. The teachers selected are those who are well established in their current position. That is, they have taught computing for at least 3 years.



Sampling	school (no post-16)	school (with post-16)	post-16 college
Hampshire	71	15	8
Isle of Wight		5	1
Poole		8	1
Southampton	14		2 + 1

Figure 45 sampling structure

Appendix 5 contains a systematic record of the interview date, interviewee identity and the location. In the published list the teacher and location have been erased to ensure anonymity within the data. The ethical statement ensures the anonymity for the respondents and the names of their schools. However, some teachers are subsequently identified by reference to their teaching resources and/or accounts of their teaching strategies. In these cases the resources or accounts are publicly accessible and their permission has been sought and received. Two teachers stated that they wanted their work acknowledged.

This is purposeful sampling. The respondents are chosen from the small number of teachers with training responsibility in university partnership schools. The breakdown of the types of teacher interviewed is tabulated below. (Figure 46.) The sampling is based upon the teacher's experience in teaching GCE level computing and so explains the bias towards post-16 establishments in the profile of the interviewed teachers/tutors.

Characteristics of teacher	Teachers
Secondary school ICT coordinator (11-16)	0
Secondary school ICT coordinator (11-18)	3
Secondary school ICT teacher (11-16)	0
Secondary school ICT teacher (11-18)	3
Post-16 college ICT/computing coordinator	5
Post-16 college ICT/computing tutor	11

Figure 46 teacher backgrounds

The following 4 profiles represent types of respondents. Although each profile does not exist as an individual, identifiable teacher, the characteristics are such that any one of the respondents could say "that is like me". These profiles give a clear description of the nature of the respondents.

Profile 1 has a science degree and a PGCE teaching qualification; began teaching as a science teacher and then teaching some ICT lessons; promoted to ICT coordinator and now responsible for a staff of some 8 teachers (mostly based in other departments) and coordinating the Key Stage 3 strategy, GCSE and GNVQ courses and contribute to the teaching of GCE computing or ICT; involved as a curriculum mentor in teacher training and studying for a Masters degree.

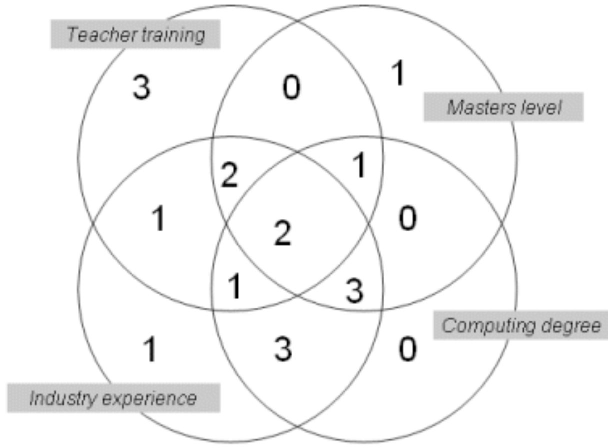
Profile 2 has a computer degree and a PGCE teaching qualification; has been teaching ICT and/or computing at GCE level for 4 years in the same school; the most qualified and experienced computer specialist on the team of full and part-time ICT teachers; supporting trainee and GTP teachers in the department; considering completing the Masters programme.

Profile 3 has a computing degree and has been teaching computer studies, computing, IT and ICT for over 10 years with 5 years experience in industry; coordinating a staff of 7 full-time teachers/tutors teaching 120 students at GCE level each year; supporting trainee and GTP teachers in the department.

Profile 4 has a history degree and has taught both secondary school history and ICT before moving to tertiary education; has a Masters degree in computer education and teaches 3 groups at GCE level computing.

An alternative representation of the characteristics of the respondents is tabulated below (Figure 47.) The key background characteristics are considered to be the involvement in initial teacher training, Masters level experience, a computing degree qualification and experience of computer work in industry and commerce. The context of the teaching is represented by being post-16 establishment (6th-Form College) or an 11-18 secondary school. (There were no respondents from selective or independent schools.)

Teacher training	Masters level experience	Industry/ commerce	Computing degree	Post-16 institution	Coordinator position
	y	y	y	y	
y	y		y	y	y
	y	y	y	y	
y					y
y	y	y	y	y	
	y	y	y	y	
y	y	y		y	
	y			y	y
y	y	y	y	y	
	y			y	
y					y
		y	y	y	
		y		y	
y			y		
y	y	y		y	
y			y	y	y
	y	y			
y		y	y	y	
y			y	y	y
		y	y		
y					y
		y	y	y	y
12	**11**	**13**	**13**	**16**	**8**



In addition there are 3 respondents who have just teacher training experience and a computer degree. There is one respondent with industry and Masters level experience. They cannot be represented on the diagram because of the limitations of 2-D presentation.

Figure 47 characteristics of the 22 respondents

This table and diagram can be summarised:

half of the respondents are currently mentoring trainee teachers
(all are involved with some aspect of teacher training);

half of the respondents have a Masters degree
(in education or computer based learning and training);

half of the respondents possess experience in the computing industry;

half of the respondents possess a computing degree;

most of the respondents teach in a post-16 establishment (6th form College);

and a third of the respondents have a coordination rôle in their establishment.

6.4 *Identifying the difficult concepts of computing*

This study considers the pedagogic content knowledge of teachers of computing and endeavours to identify the rôle of metaphor in that process. It is a premise of the work that the more challenging the teaching situation then the more sophisticated the teaching strategies will be. The work focuses upon the reflections of experienced and successful teachers. Those teachers are more likely, than inexperienced or unsuccessful teachers, to have developed successful pedagogic approaches. By considering the difficult-to-teach aspects of the curriculum, it is assumed that the most sophisticated aspects of pedagogic content knowledge will be revealed.

The nature of the computing curriculum is drawn from the current Qualifications and Curriculum Authority specifications. The analysis is made using the curriculum ideas of skills, knowledge, understanding and attitudes. From that, the concepts of the computing curriculum are identified. Finally, the concepts that are difficult-to-teach are identified.

In 2000 there was a radical change to the structure of the post-16 examination organisation for students aged 16 to 18 years. Traditionally students spent two years studying for their A-Level examinations. The new system modularised the examination awards dividing each A level into an Advanced Subsidiary (AS) and the full A Level (A2) – the awards are divided into 3 modules which could be entered and examined at different times. Students were awarded grade A to E and fail and also percentage marks. The final grade was calculated from the total of marks awarded. At the same time there was the emergence of vocationally focussed courses for 16 to 18 year-old students. These curriculum changes had a bearing upon the decisions made by teachers about what and how they would teach. For instance, the one third status of the course work submission reduced the amount of time for studying the more theoretical aspects of the courses.

The computing curriculum is determined by the Qualifications and Curriculum Authority (QCA National Qualifications, 2002) but operationalised by different private company award providers. An analysis of the specification using the terms skills, knowledge, understanding and attitude is an important aspect of analysing the teaching situation. The coding (described later in this chapter) of the QCA specification consisted of using the 4 nodes: Curr~ skills, Curr~ knowledge, Curr~ understanding and Curr~ attitudes. Figure 48. shows the coding of the Skills section of the specification.

To assist the analysis the following descriptions were used:

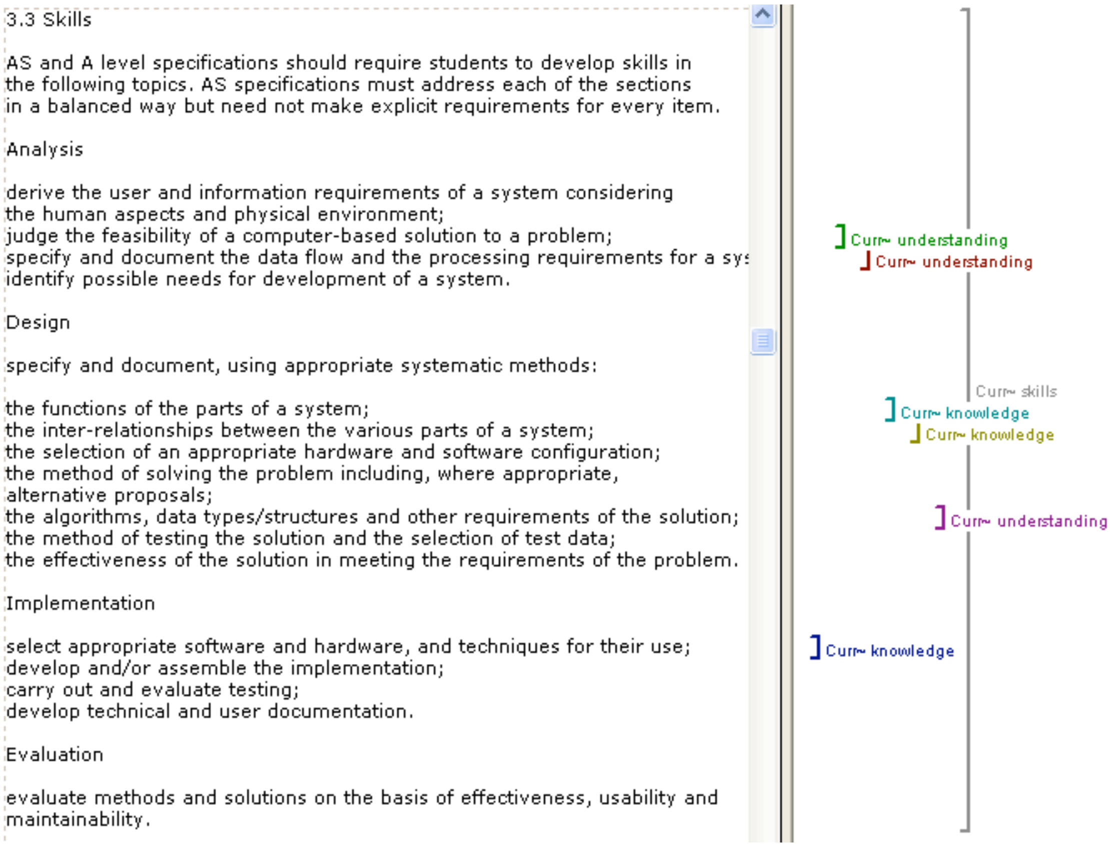
skills - repeat as an observable performance;

knowledge - recall of factual truths;

understanding - explain in other contexts; and

attitudes - describe in terms of self and others.

Adapted from the seminal work Curriculum 11-16: towards a statement of entitlement: curriculum reappraisal in action (DES, 1983)


3.3 Skills

AS and A level specifications should require students to develop skills in the following topics. AS specifications must address each of the sections in a balanced way but need not make explicit requirements for every item.

Analysis

derive the user and information requirements of a system considering the human aspects and physical environment;
judge the feasibility of a computer-based solution to a problem;
specify and document the data flow and the processing requirements for a sys
identify possible needs for development of a system.

Design

specify and document, using appropriate systematic methods:

the functions of the parts of a system;
the inter-relationships between the various parts of a system;
the selection of an appropriate hardware and software configuration;
the method of solving the problem including, where appropriate, alternative proposals;
the algorithms, data types/structures and other requirements of the solution;
the method of testing the solution and the selection of test data;
the effectiveness of the solution in meeting the requirements of the problem.

Implementation

select appropriate software and hardware, and techniques for their use;
develop and/or assemble the implementation;
carry out and evaluate testing;
develop technical and user documentation.

Evaluation

evaluate methods and solutions on the basis of effectiveness, usability and maintainability.

Figure 48 QCA computing skills coding in QSR NVivo software

To support the coding process the characteristics of skills, knowledge, understanding and attitudes are articulated prior to the coding process and reviewed after the process. Skills of computing are identified within the specification. However, it can be demonstrated that some of the knowledge and understanding aspects of the specifications can be described as a repeatable and observable performance. The specification does not discern between knowledge and understanding – it groups aspects of the curriculum together under a joint label. This analysis separates them. Figure 49.)

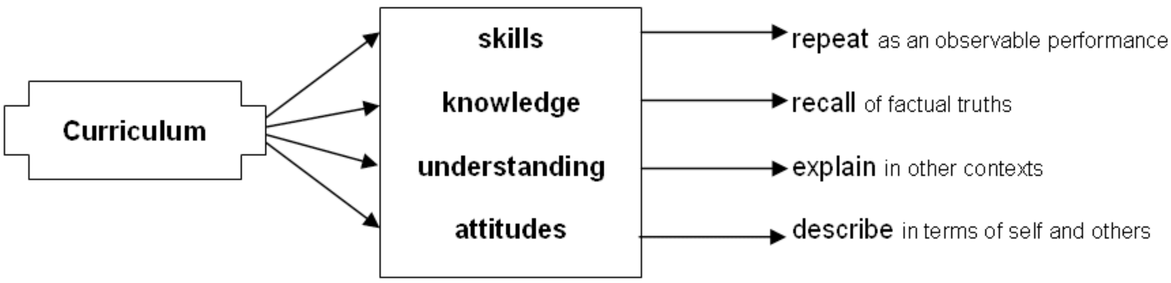


Figure 49 the curriculum in terms of skills, knowledge, understanding and attitudes

The analysis of the codes revealed that the skills section identified by QCA contained requirements of the students to have knowledge of systems – for example, the skill of design required the knowledge of system parts and structure. However, a more important conclusion is that all examples of understanding required the appropriate knowledge. This is reflected in Figure 50.

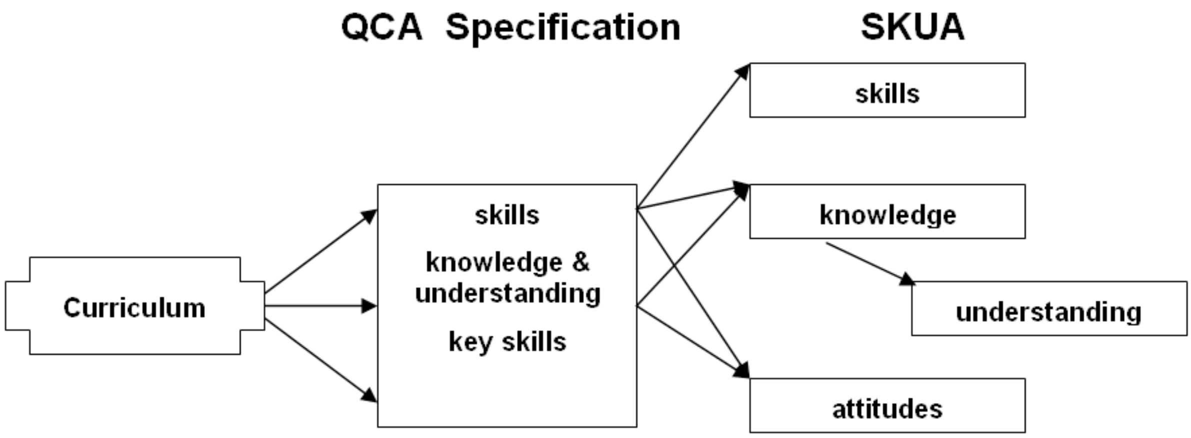


Figure 50 the whole curriculum and skills, knowledge, understanding and attitudes

Another aspect of this research involved a focus-group approach with 12 experienced teachers of ICT in which the National Curriculum ICT, European Computer Driving Licence (ECDL, 1999) and Teaching: High Status, High Standards (DfEE, 1998) were scrutinised. The resulting analysis identifies very specific areas of the curriculum considered to be based upon concepts – those areas requiring the learners to understand a situation.

A premise of this study is that the most interesting and diverse strategies to support learning will take place when the most challenging topics are being taught. The analysis is based upon difficult-to-teach because this identifies topics with a wide range of reasons for being “difficult” and it does not attempt to restrict the topics to those that are “difficult to learn”. It does include topics that are “difficult to resource”, “difficult to find time on the curriculum”, “difficult because the learners do not find it interesting”, “difficult because the learners make a lot of errors” etc…This phase of the analysis involved a focus-group approach with 12 experienced teachers of ICT drawn from the same pool of teachers as the interviewees (Figure 51.)

Characteristics of teacher	Teachers
Secondary school ICT coordinator (11-16)	5
Secondary school ICT coordinator (11-18)	3
Secondary school ICT teacher (11-16)	1
Secondary school ICT teacher (11-18)	1
Post-16 college ICT/computing tutor	2

Figure 51 focus group characteristics

The final stage of identifying the “concepts of computing that are difficult to teach” involved speaking to 4 computing teachers (all with post-16 teaching experience and later interviewed). Previous analysis considered the examination specifications for computing. This work focuses upon a particular examination specification from the Assessment and Qualifications Alliance (AQA, 2001a). In response to the question “which are the more difficult areas to teach?” the consensus agreement of the four teachers was: central processor; bus, memory; recursion; AND, OR, NOT as electronic units; sequential files, random access files; queues and stacks; binary tree; binary tree traversals;

encryption (weak and strong); bubble sort; normalisation; packet switching systems; the internet infrastructure; the Worldwide Web; digital certificates.

As the interviews took place the list was modified to better reflect the more challenging topics within the teaching of computing. The right of some topics to be in that list of difficult-to-teach is clearly displayed in some responses:

central processor, bus, memory "*I think that this is difficult because it is boring - we just have to tell them what it is, the components and some kind of process that goes on - they have to learn it off by heart - do they understand it - I don't think so*" (interview 5);

recursion "*Argh, I hate recursion; I always teach it with a fragment of program; and we plod through it, so we do a table of the moving values and we recurse through it, so I will teach it by literally moving through a series of instructions showing at the point in which I have to go back - again, very much on the whiteboard; I want to show them how this is moving*" (interview 5);

OR, NOT as electronic units; "*they don't understand the flow of data as 0 and 1 and they think of water - flip flops are impossible - do you have a way of showing them?*" (interview 9);

queues and stacks "*Oh - they like the pictures and can answer the exam questions providing that they don't have to do the algorithm - that's difficult*" (interview 14);

bubble sort - "*they just won't follow through the sequence carefully enough - like recursion*" (interview 16).

Figure 52. illustrates the full sequence of the process from the whole curriculum narrowing down to those topics that are the more difficult aspects to teach.

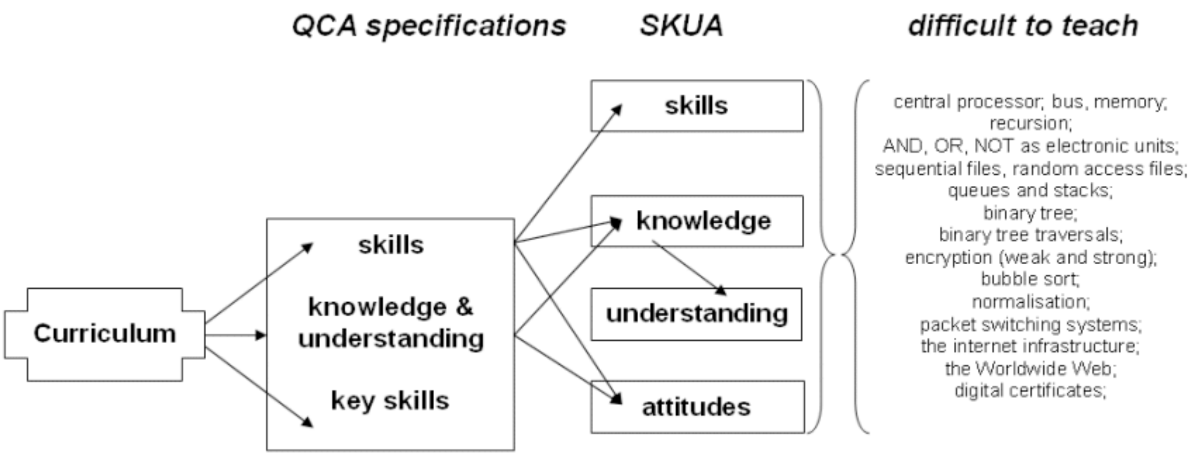


Figure 52 the whole curriculum through to difficult topics

The nature of this research, being based upon a grounded theory approach, means that the precise list of topics changes as new perspectives arise. However, there continues to be a fundamental similarity between the initial list and the final list. At this stage it is sufficient to simply map (Figure53.) them onto the skills, knowledge, understanding and attitudes construct established earlier in the section.

skills	knowledge	understanding	attitudes
binary tree traversals bubble sort Worldwide Web	AND, OR, NOT logic units binary tree cpu; bus, memory digital certificates encryption internet infrastructure normalisation packet switching systems queues recursion sequential & random files stacks Worldwide Web	AND, OR, NOT logic units digital certificates encryption normalisation packet switching systems queues recursion stacks	Worldwide Web

Figure 53 the analysis of topics using SKUA characteristics

Again, this analysis shows the same relationship between understanding and knowledge as previous analyses. All “understanding” topics appear to be dependent upon knowledge.

6.5 The schedule design

There are two versions of the interview schedule that have been preserved although other versions existed as the changes were made between the first 5 interviews and the following interviews (appendix 6). The most significant change came about very early in the interview sequence. It became obvious that the research questions were not being fully answered because the focus of the interview talk was upon “metaphor”. The respondents’ reactions were to emphasise their knowledge of metaphors and try to reflect metaphors in all of the answers. As soon as the focus of the interview was changed to “difficult concepts of computing” the nature of the responses became more balanced between different strategies of teaching. As a consequence, it was then possible to better analyse the relative value of metaphor.

The second very important change taking place is the tape recording procedure. For the first (pilot) interviews tape recording (and minidisk recording) took place but the record of the interview was simply the contemporaneous notes made during the interview. The procedure was for the interviewer to place a T (for tape) on the schedule if the interviewee made an interesting response. It was then possible to refer back to the tape/disk to obtain clarification of what was said. For the majority of the interviews a different approach was made. It was planned that the recording would be transcribed verbatim and that the analysis would be carried out using that record only. This had a big impact upon the conduct of the interview. It freed the interviewer and enabled the questions to be more responsive to previous answers. It also changed the atmosphere of the interaction.

Much of the first schedule was probing the teachers’ understanding and awareness of different metaphors in computing. This proved interesting but unnecessary to meet the needs of the research. This aspect was reduced in the revised interview schedule. The data collected from that part of the study may form the starting point for future research but has no relevance to the findings of this study.

the first metaphor interview schedule (pilot)

The original schedule required respondents to view colour diagrams (Figure54.) This is indicated by a "P" on the schedule. The interviewer placed a "T" on the schedule if interesting statements are made. The introduction was the ethics statement and a description of the research.

"Would you mind me using a tape recorder [as it means I do not to take notes as we talk]? The information will be treated confidentially. That is, I will not make any reference to you personally or your institution when I write up my research."

"I am carrying out research into the way in which we teach the different concepts of computing and how we understand how a computer works. For example, we talk about the desktop of the computer. What do you understand by the term desktop?" and then continued "What aspect of that description helps you teach/explain the working of the computer?"

The respondent was then asked "It really is not a desktop. What other metaphors are you aware of?" There was an opportunity for the respondent to voluntarily suggest their own but then… "I have a list of metaphors that I would like to discuss over the next 20 minutes. Your comments will be strictly confidential in that they will not be associated with you or your school/college."

System metaphors: walled garden; firewall; bread crumbs P;

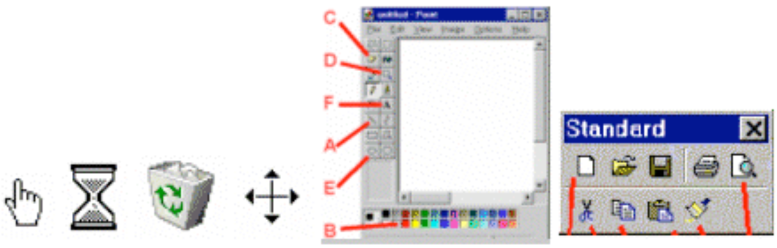
Action metaphors: click and drag; drag and drop; rubber band or rubber banding; surfing, browsing, grazing

Object metaphors: recycle bin; trash can for delete;

slide show P  video controls P 

Computing terms: information highway; tree structure; root directory

Metaphoric phrases: 'go to a page on the web'; 'burning a CD'

Images 

earcons, micons and picons; earcons (1); earcons (2); earcons (3); earcons (4); earcons (5);

micons (1)  micons (2)

Figure 54 summary contents of the first interview schedule drawn from the A-Z of Metaphors

Each metaphor had the prompt: know about [ ] do you use [ ] future use [ ] to identify whether the respondent uses the metaphor currently or might use it in the future. This is not a radio button type response - all 3 items may be ticked and for some, no ticks may be made - meaning that the respondent does not use the metaphor (because they do not know about it) and do not plan to use it in the future.

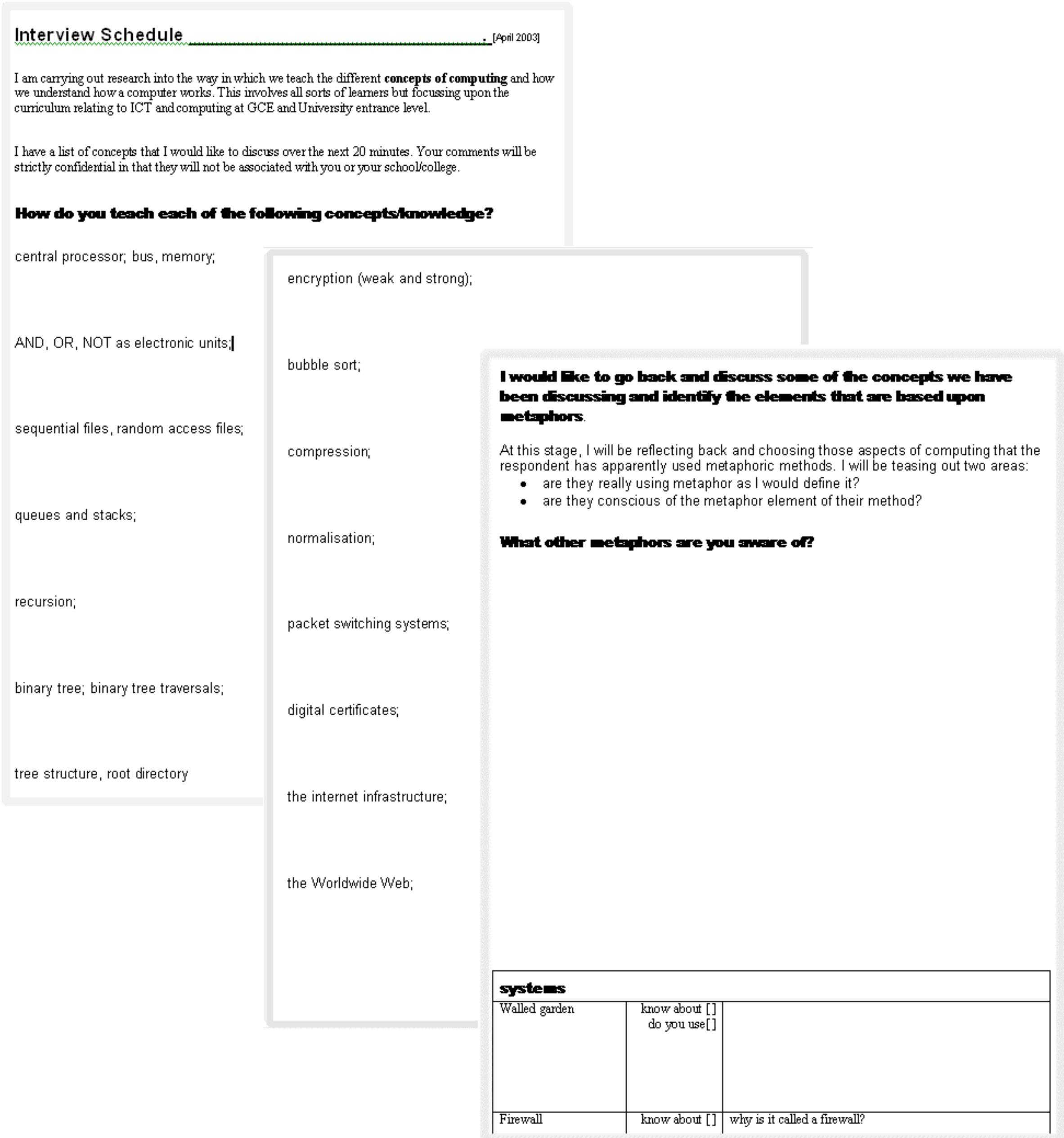
The emphasis upon metaphor in the first interview schedule resulted in a “self-fulfilling prophesy”. This research is interested in identifying the use of metaphor in teaching. The respondents were limited to thinking about the metaphors proposed by the schedule and did not have an opportunity to think about their own metaphors. This procedure “blinkers” their vision. When asked how they taught the topics (from the difficult-to-teach list) they respond with examples of metaphors. The changes to the interview schedule to focus upon the curriculum topics meant that they now propose a wider range of pedagogic approaches including those utilising metaphor. However, there continued to be minor changes to the schedule. For example, the prompt “digital certificates” was omitted as most people covered that point when talking about weak and strong encryption. The position of recursion was moved to after binary tree traversals. Some respondents thought that only the recursive solution for binary tree traversals was required whereas any solution was appropriate.

Interviews 1 to 4 were considered to be pilot events to establish the proceedings and to inform the early recording structure. The content is not reported upon directly.

There is a fourth sheet which contains the metaphors listed in the original schedule. That page is used if the interview finished quickly or the respondent showed an interest in considering further metaphoric uses. Those responses are not part of this research.

The respondents in this research are colleagues of the researcher. It is of the nature of this form of research that researcher and respondents work together and make personal as well as professional commitment to the interview. It is wrong to conduct an interview along the lines of: do you teach…? do you teach…? and go through all the topics with few being answered positively. The option of using the extra prompts meant that the respondent would not perceive that the interview had ended prematurely because of an error of judgement on behalf of the researcher. The fourth sheet provides no evidence for the research but protects the professional relationship. The schedule is represented in Figure 55.

the final interview schedule



Interview Schedule [April 2003]

I am carrying out research into the way in which we teach the different **concepts of computing** and how we understand how a computer works. This involves all sorts of learners but focussing upon the curriculum relating to ICT and computing at GCE and University entrance level.

I have a list of concepts that I would like to discuss over the next 20 minutes. Your comments will be strictly confidential in that they will not be associated with you or your school/college.

How do you teach each of the following concepts/knowledge?

central processor; bus, memory;

AND, OR, NOT as electronic units;

sequential files, random access files;

queues and stacks;

recursion;

binary tree; binary tree traversals;

tree structure, root directory

encryption (weak and strong);

bubble sort;

compression;

normalisation;

packet switching systems;

digital certificates;

the internet infrastructure;

the Worldwide Web;

I would like to go back and discuss some of the concepts we have been discussing and identify the elements that are based upon metaphors.

At this stage, I will be reflecting back and choosing those aspects of computing that the respondent has apparently used metaphoric methods. I will be teasing out two areas:

- are they really using metaphor as I would define it?
- are they conscious of the metaphor element of their method?

What other metaphors are you aware of?

systems		
Walled garden	know about [] do you use[]	
Firewall	know about []	why is it called a firewall?

Figure 55 interview schedule

6.6 The data set and the coding process

The results of this study are primarily based upon the witness statements of successful and experienced teachers of computing recorded as transcripts of structured interviews. In addition, a number of formal and less formal data gathering activities both supported and cross referenced the developing theories. This section of the thesis describes the raw data and aspects of the analysis process. In particular, it describes the use of QSR-NVivo software (Figure 56.) and the structure of the data processed. The first section lists the data which forms the basis of this research.

NVivo, NUD*IST Vivo and the NVivo logo are trademarks or registered trademarks of Qualitative Solutions and Research Pty. Ltd. (NVivo, 1999)

non-numerical unstructured data indexing searching and theorizing

Figure 56 NVivo software for handling the data of qualitative research

the data set

The work produced six data sets which were encoded and processed electronically:

- 19 interview transcripts of experienced and successful teachers (listed in appendix 5) and three paper-based notes of interviews;
- 32 journal articles relating to pedagogic content knowledge (search criteria outlined in appendix 2);
- 8 analyses of computing textbooks and 10 teaching resources provided by teachers;
- 3 examination specifications;
- 20 difficult-to-teach topics;
- 30 A-Z of computer metaphors document

The nodes of analysis arise, in the first instance, from the research questions and the difficult-to-teach topics. Further nodes occur relating to the immediate reactions of teachers (hard, easy, boring…) whilst others relate to the approaches used by the teachers. Finally, as themes emerge, nodes are identified to label theoretical aspects of the data (algorithmic, kinaesthetic, real life…).

identifying documents and transcripts for processing

The major element of data input for this research is based upon verbatim interview transcripts. As outlined above, the interviews conducted at the start of the process used a different schedule that openly focused upon metaphor whereas the majority focused upon the computing topics and the analysis process identified the metaphoric approaches. As a consequence, interviews 1, 2 and 4 did not provide any data directly contributing to the coding process. However, they remain significant members of the sample group because of their rôle in the other formal (focus group) and less formal (professional discussions) contributions. Interview 3 provided some description of the teaching process focussing upon the metaphors. The observations are pertinent to the findings, in particular the description of the sticky $ sign, and are included in the analysis process.

In addition to the transcripts, a number of textbooks were selected and analysed using the same schedule as the interviews. Each of the topics was looked up and the explanation entered into the analysis software. The identification of the textbooks was on the basis of use by the teachers. Only books recommended by the respondents were consulted.

the coding process

The rationale underpinning the design of the interview schedule was described earlier. The processes of interviewing, recording and transcription were also described above. The process of coding is now considered; this section includes the identification of nodes, their categorisation and a reflection on the coding process.

The following terms are used as a direct consequence of the use of the QSR-NVivo software. **Documents** exist either by typing them directly into the analysis software or by importing rich text or plain text files. If a number of documents come from similar sources, for example, interview transcriptions, then they can be placed in a **virtual set**. Individual documents can be assigned values called document **attributes**. **Nodes** represent ideas, things, people, concepts, **categories** for thinking about data; **tree nodes** are used to organise nodes into a hierarchical thesaurus-like system (Richards, 1999: 16).

identifying nodes

Documents are internally coded using a set of nodes. Nodes are words or phrases representing an idea or concept of the researcher's making. The initial set of nodes included the "difficult-to-teach topics" such as: algorithm, binary tree, compression… The set grew as the focus and direction of the research developed and the theories emerged. Initially, extra nodes were created to: reflect the names of metaphors suggested by respondents such as burning a CD or breadcrumbs; represent aspects of pedagogy such as difficult, real life; describing approaches to teaching such as kinaesthetic, literal; and towards the end of the analysis "why" nodes.

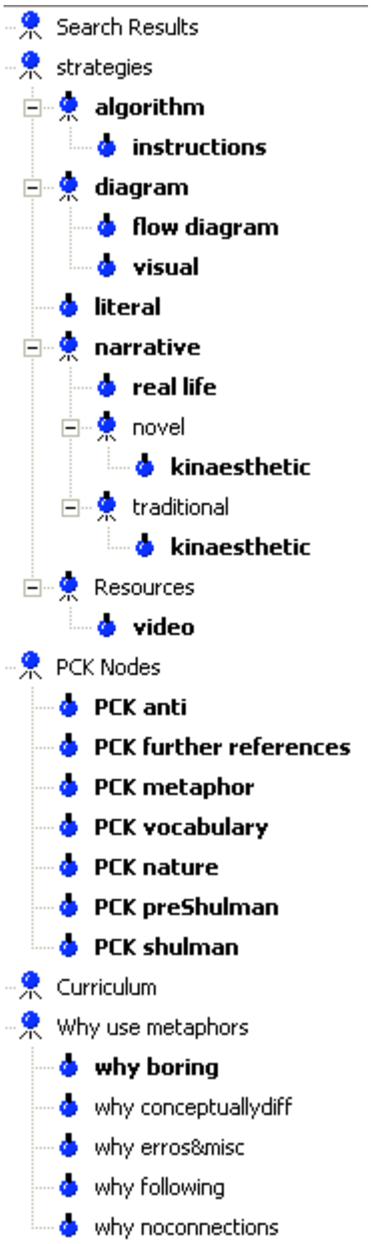
The nodes being used changed and developed over the 6 months of the investigation. The original free nodes only included the items of the curriculum on the original interview schedule. However, the final list retains those elements that are no longer pertinent to the final conclusions yet played a rôle in the earlier data gathering and analysis.

There are five nodes relating to the reasons the respondents gave to using metaphoric approaches in their work: why boring; why conceptuallydiff; why erros&misc; why following; why noconnections. These nodes developed over time as new reasons were given. Interviews are then re-read and re-coded in the light of nodes created as a result of more recent interviews.

The significance of the reasons why teachers chose metaphoric approaches only becomes important towards the end of the analysis. For example, an early concept that takes on later importance is algorithm. During the time of the interviews the idea of algorithm taking on many guises arose. The first concept of algorithm is instruction. The reading of literature (computing texts) relating to algorithm identifies flowchart and pseudocode as being important aspects of algorithm. Thus, algorithm appears as a category, an interrelationship of several nodes, within the analysis process. At this time the importance of algorithm was further, independently explored and an article was presented to colleagues for comment, used in teaching and then published (Woollard, 2003a).

The integrity of the coding process is paramount if the conclusions are to be valid. The coding process should be a systematic and automatic process of identifying features of the verbatim statements, text books and referenced materials. At the same time, it is an intellectual and analytical engagement in the material. When the encoder and the researcher are the same person there is a tension between coding and thinking. Ideas arise during the coding process that may distract the researcher and perhaps could make the coding less rigorous.

Another important aspect of the coding process is its iterative nature. The documents were analysed and coded several times as new ideas (nodes) are identified and the theory develops. With that recoding came changes in the theoretical structures connecting the nodes. These are described in the text accompanying Figure 57.



The Search Results node set contains documents that collate all the references relating to particular node searches or node-node coincidences.

Later developments of the node structure included under algorithm: instructions, pseudocode, code and dfd (data flow diagrams). Flow diagram is reported as flowchart in the thesis; most text books use flowchart.

Literal teaching is identified as including that relating to virtual, physical and conceptual aspects of the computing curriculum and approaches that included scenarios, devices and verbal descriptions.

Narrative codes originally applied to verbal descriptions of a metaphoric nature. Narrative now relates to any metaphoric approach including verbal, visual, devices and actions. Iterative recoding of the previous documents was carried out.

The resources node (like some curriculum topics) has ceased to have any value because the focus of the pedagogy lies within the cognitive constructs that the teacher creates rather than the presentation of the curriculum.

The PCK nodes relate solely to the scrutiny of journals and academic literature relating to pedagogic content knowledge and are not used in the coding of interview transcripts.

The curriculum node set includes the nodes for each curriculum area (difficult-to-teach topics).

Figure 57 nodes and node sets

The final set of nodes (Figure 57 above) is used to re-code all documents with the motivations for using metaphoric approaches. They come into play in the later stages of analysis.

There is a direct connection between the interview transcripts and the coding process. Each interview is treated as a separate document. Each document is coded and re-coded and eventually resembles the example in Figure 58. In the example the coding comprises of both the manually identified nodes and the automatically generated nodes resulting from keyword and Boolean searches of the data.

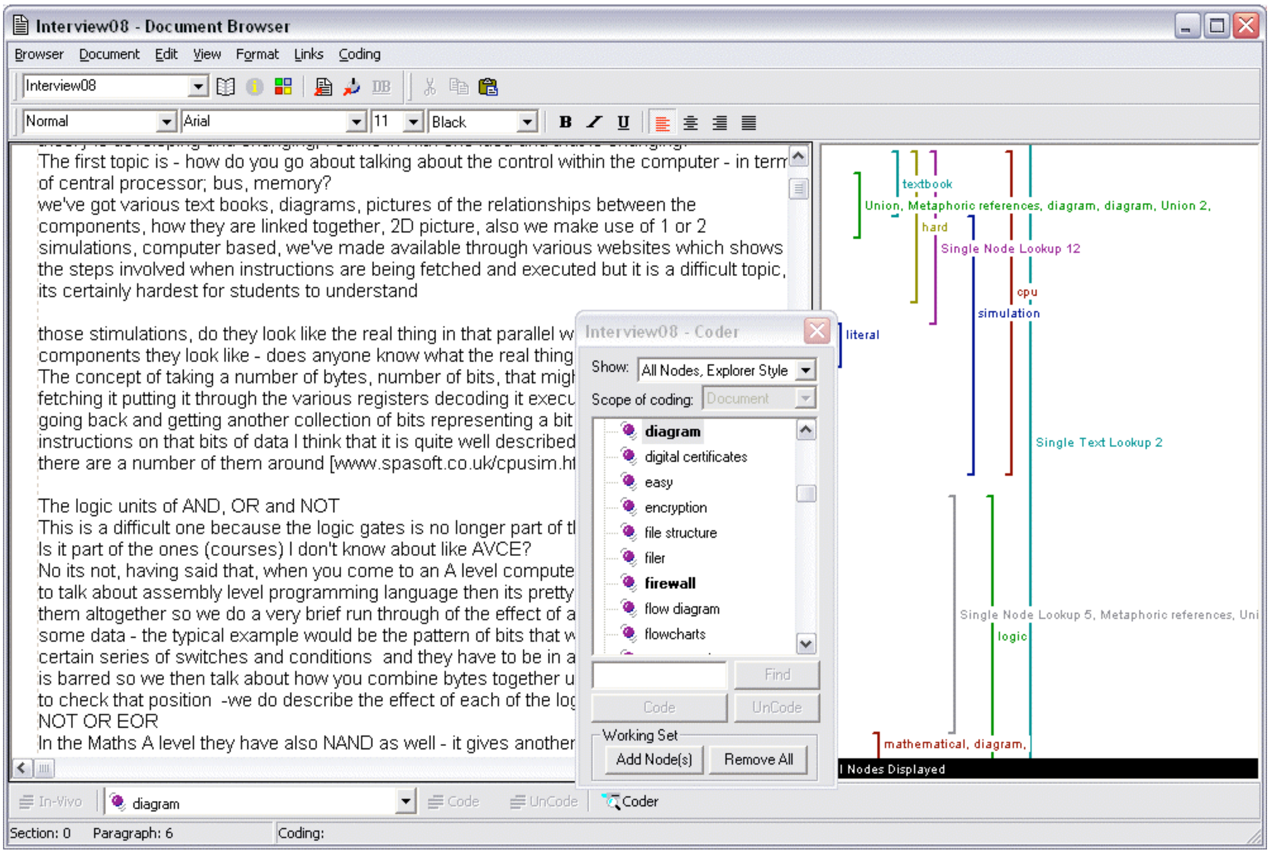


Figure 58 example coding of an interview segment

visualisation of the node relationships

The next stage of coding is the visualisation of the relationships between the concepts (nodes). A classic representation is the pyramid or hierarchy of tree nodes. The first visualisation of the overall model of pedagogic content knowledge within computing is represented as an NVivo model of interrelating nodes (Figure 59.) This is later represented in a pyramid structure using Microsoft Word. The figure below compares the two.

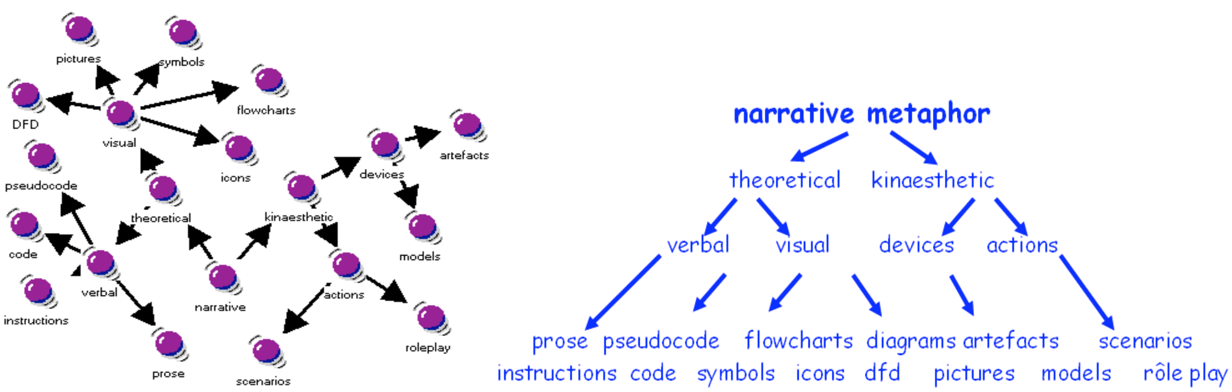


Figure 59 early and later representations of the developing taxonomy of PCK

Coding documents is the process of highlighting sections and assigning to them a label, for example, “difficult”. Any piece of text that indicates that the respondent thinks that the concept is “difficult” to teach is given this label. Documents are searched for particular nodes. The results of a search process include the document names, paragraph numbers, word-counts, and attribute data. The search for “bad metaphors” results in a long screen of attributed paragraphs. The text below (Figure 60.) is simply the relevant responses without the origin. In this form it is possible to create the construct bad metaphor.

we discussed the bus queue; I have a concern about the bus queue - what happens when the bus comes and only 5 people can get on?
that is the point - you are using a model - the bus queue and that is where a limitation occurs, like if I use the Russian doll I know that there is a significant limitation, there is an implication that the first structure is a smaller bit of code than the second, than the next time and the next time
queues and stacks; queuing for dinner (incorrect understanding - by teacher?), dinner plates in a cupboard, here there was a good analogy:
binary tree; talked about the family-tree but on return admitted that it is not analogous, also mentioned directory tree this is not analogous
go to a page on the web; go to a web site it takes them to that place I don't know, I haven't thought, they should know that it is being taken to their computer
just like a queue at the cinema or supermarket checkout; like plates on a pile in a cafeteria
As the name suggests, the disks are read-only. When the master disk is created, a laser beam burns tiny holes in the surface of the disk, which (unlike a magnetic disk) has a single spiral track divided into sectors. To read data from the disk, a laser beam is reflected off the surface of the disk, detecting the presence or absence of pits which represent binary digits”

Figure 60 raw text results of the “bad metaphor” node search (04/01/04)

The initial coding identifies an aspect of pedagogy such as diagram, use of video, kinaesthetic work, easy, flowcharts etc. The recoding of the documents reveals the prevalence of the idea and sometimes a theme emerges. In this case, the theme emerging relates to the inappropriate use of metaphor. It is then from the collated raw data that the first hypotheses regarding the nature of “bad metaphor use” can be gleaned.

In a similar way 5 reasons why teachers use metaphoric approaches are identified. They emerge as a theme from the iterative coding of the interview transcripts.

The total and final list of nodes include: algorithm; anti-metaphor; bad examples; binary tree; bread crumbs; burning a CD; code; compression; concept; cpu; cut paste; DFD; diagram; digital certificates; easy; encryption; file structure; filer; firewall; flow diagram; go to a web page; hard; icon; instructions; internet; kinaesthetic; literal; logic; looseness of language; mathematical; misconception; narrative; normalisation; novel; personification; physical~realism; Pringles; pss; pupil awareness; queues; real life; recursion; recycle; recycle bin; resources; searching; sequential~random; simulation; sort; stack; surfing; textbook; traditional; video; visual; walled garden; www. In excess of 50 search nodes were generated that revealed connections between nodes and connections between documents.

The next chapter of the thesis reflects the results of the data manipulation, representation of ideas and naming of concepts.

Chapter 7 Towards a taxonomy of pedagogic approaches

This chapter describes the formulation of a classification of pedagogic approaches. That formulation is based upon the prior reading outlined in Chapters 2, 3 and 4, and the analysis of the results of the interviews. The structures have developed over a period of some 3 years, as both theoretical ponderings and practical experiences competed to mould the shape of this taxonomy. The first division, caused by the focus of the study, makes delineation between literal approaches to teaching compared with the non-literal, metaphoric approaches. It is not the intention of the research to illuminate literal teaching in terms of its rôle and affordances. However, the nature of literal teaching needs to be defined so as to better define the complementary non-literal approaches.

The term "pedagogic metaphor" is introduced and described in terms of approaches to teaching and a taxonomy based upon theoretical/kinaesthetic and novel/traditional examples is established. The particular rôle of algorithmic teaching approaches is described and illustrated through examples drawn from the research data. The problems associated with metaphor are again considered. Finally the rationale for why teachers choose metaphor is considered.

Chapter contents:

7.1 Defining the terms of metaphoric and non-metaphoric teaching

The non-metaphoric approaches are those representing literal teaching. The metaphoric is all other teaching on the pragmatism that anything that is not real (or literally true) must be non-real or metaphoric. The metaphoric approaches include approaches based upon diagrammatic representation, narrative forms (kinaesthetic and theoretical), algorithmic structures and models. Literal teaching is also analysed and divided into three types: teaching based upon scenario or socio/technical systems; teaching based upon artefacts or physical devices and teaching based upon verbal description. The analysis establishes that the metaphoric approaches are mutually exclusive and exhaustive of all pedagogic approaches and fall into that aspect of teaching called pedagogic content knowledge.

definition of metaphor

The definition of metaphor, established in Chapter 2, is used to contextualise the data collected in the language of linguists and cognitivists. Metaphor is any description or utterance that is not the literal truth and are sets of **alternative labels** or **reorganisations** including diagram, model and algorithm. Metaphor is described in terms of a **model-product** structure of **metaphor theme** with associated **tensions**. The categorisation is based upon an embodied physiological model described as **image schemas** such as: container, surface, source-path-goal, link, part-whole, near-far, centre-periphery, up-down, front-back, linear etc. They are illustrated in Figure61.

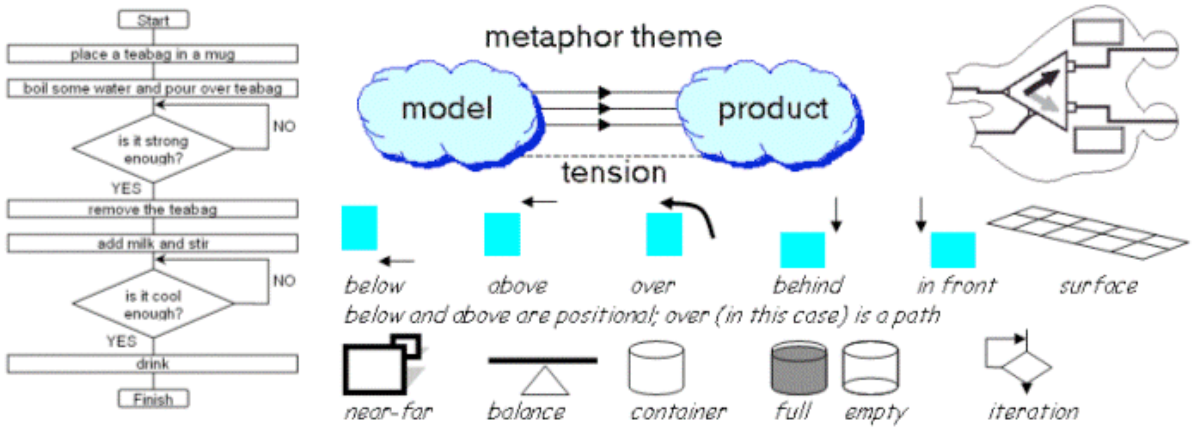


Figure 61 a collage of the diagrammatic, metaphor theme and exemplar image schema

The word metaphor on its own can therefore have several meanings. The following terms are now being used.

- Those metaphors that are being used as an approach within pedagogic content knowledge are called (by the author) **pedagogic metaphors** (see page 103).
- Those metaphors that are of cognition and physiology are called **image schema** (Gibbs, 1996; Johnson, 1987; Lakoff, 1987; Lakoff and Johnson, 1999; Richardson, 2001).
- When metaphors are used in rhetoric and literature it is called **metaphoric language** (Martin, 1992: 1).

the research methodology

The research methodology is based upon gathering information by interviewing experienced and successful teachers and using the grounded theory method to establish a better understanding of the teaching processes. The result of this study is a theory about the different approaches adopted by teachers when teaching difficult topics in computing; these are represented in the form of taxonomy. Before carrying out the writing task, the processes of the grounded theory approach are:

- data-collection (interviewing teachers, scrutiny of textbooks and literature review);
- note taking (verbatim transcripts of interviews, scanned images and OCR text);
- coding (using curriculum, PCK, metaphoric/literal approach nodes);
- memoing (amending, appending and annotating the text documents); and
- sorting (using Boolean, keyword, node/document searches).

These stages (Figure62.) are evidenced by direct reference to the documents, nodes and the results of searches in the following text. Interviews are referenced directly and relate to the interviewee list (appendix 5) whilst searches are described in terms of the keywords used.

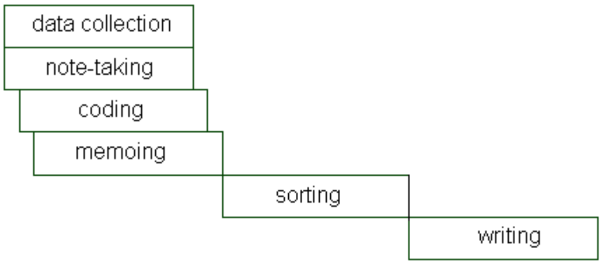


Figure 62 the staged aspects of grounded theory method (ALARPM, 2003)

definition of terms

The following terms (alphabetical) are used without further explanation in this description of teaching:

- agent - a device, virtual or real, that behaves in a predictable away in its interactions with other devices, the environment or people, for example a router, a robot arm or a macro;
- approach - a means of tackling an issue or teaching situation, of transforming knowledge into other forms (Turner-Bisset, 2001: 69) for example, representing a Von Neumann computer diagrammatically or using scenario to illustrate packet switched system operation;
- artefact, device, object - used synonymously for anything physical, visible and touchable (the term artefact will be developed further as part of the analysis of pedagogic metaphor);
- virtual artefact, device, object - anything that has no physical presence but has the other properties of an object such as representable, changeable, describable, for example, a macro, a stack or a spreadsheet file;
- kinaesthetic - involving physical movement or handling of physical objects;
- recursion (see recursion);
- sequence - a list of items in which the order is important, for example, ”how to make a cup of tea”;
- strategy - a generic organisational device for ensuring pupils interest, classroom management and/or discipline and not directly impacting upon pedagogic content knowledge, for example, voice, voice animation, use of space, planning, surprise;
- system - either a virtual, cognitive, technical or sociological structure with many functions/concepts/objects/people relating with each other or impacting upon each other.

The following terms are briefly defined here but will be the focus of further analysis in this chapter and discussed in the next chapter:

- application - generic software enabling description of a system or concept;
- artefact - any physical object;
- code - instructions for a computer in a programming language;

- diagrams - a visual representation that is predominantly symbolic;
- flowcharts - a standard form representing input, processing and output of a system;
- icons - small pixel-based image representing an action or concept;
- instructions - a clear sequential list;
- novel - a pedagogic metaphor created by the teacher (see traditional);
- pictures - life-like images;
- prose - any written account in standard English or note form (including bullets);
- pseudocode - notation resembling a programming language;
- rôle play - a system acted out by learners as people of that system;
- scenario - a described system usually involving learners acting out the actions of virtual or real agents or objects;
- simulation - a special-purpose computer program that emulates a situation;
- symbols - simple/mathematical images that represent concepts;
- traditional - a pedagogic metaphor found in the literature, text books or common usage.

It is an important aspect of this work that the definitions become more rigorous as the data is collected and the iterative process of the grounded theory method enabled the ideas to develop.

the pedagogic metaphor

The term "pedagogic metaphor" is introduced at this point to establish the clear difference between metaphor in everyday language and rhetoric, metaphor in the cognitive sciences (image schema) and metaphor in pedagogic content knowledge. The term "pedagogic metaphor" is used to describe a literally untrue description of a concept or body of knowledge. It is the central conclusion of this work that pedagogic content knowledge is primarily based upon putting the material to be learnt into another form, using another organisation or another set of labels, to enable learning to more easily take place. Pedagogic content knowledge is seen to be primarily metaphoric in nature. Pedagogic metaphor is used to distinguish it from rhetorical metaphor and image schema, although they are closely related. The term has not been used widely in the academic literature before. The only reference revealed by a search of BIDS and the internet (Google, 2004b) relates to its use in a single report from the Policy Observatory for Lifelong Learning and Employability (Cullen, 2002). There, pedagogic metaphors include simulations and other virtual learning environments.

Pedagogic metaphor is, within this thesis, described as *"a representation of the curriculum content which is not literally true"*. The pedagogic metaphor is a description, in the form of words, actions, images or diagrams, of an element of teaching.

defining taxonomy

Taxonomy is the science, laws, or principles of classification (systematics) and representation of a body of knowledge. Taxonomy partitions and defines the relationships among the parts (IEEE,1986) or categories. The following characteristics underpin decisions about the design:

- categories do not overlap (mutually exclusive);
- categories include all possibilities (comprehensive);
- clear and precise description (unambiguous);
- without clashes with other established taxonomy (acceptable);
- repeated classification of the same data gives the same results (reliable);
- gives an insight into the knowledge (useful).

This checklist is used in the coding and categorisation process to ensure appropriate identification of nodes.

7.2 Do teachers use metaphor?

This research focuses upon the question:

what do teachers do to turn content knowledge into pedagogic content knowledge with special emphasis upon the use of metaphor and analogy within computing and the use of computers?

The teachers' responses to the suggested use of metaphor are summarised diagrammatically below. In the following analysis no numerical values are used. The sample size would not enable legitimate claims to percentages to be made. However, the qualitative statements can form the basis of future investigation and analysis.

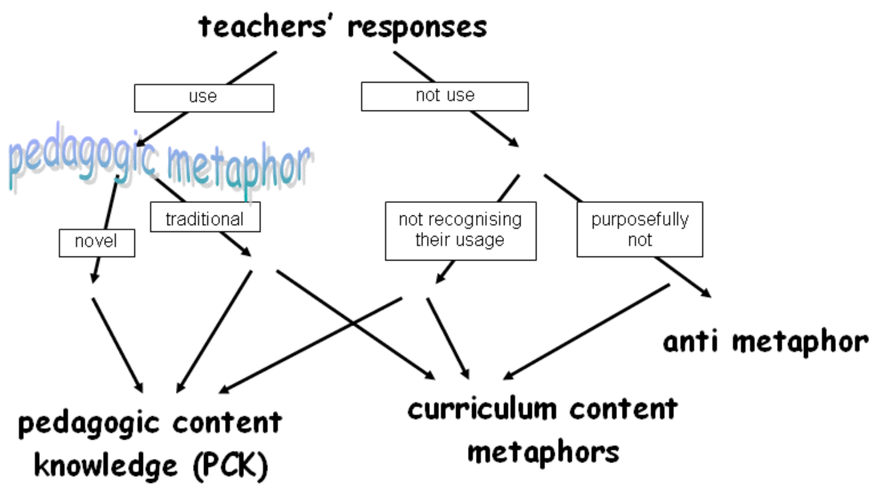


Figure 63 do teachers use metaphor?

Some teachers immediately acknowledge that they use metaphor (the left hand branch of the figure above). Of those, some show recognition that the computing curriculum is rich in metaphor whilst others recognise their use of metaphor as being a deliberate act of preparing the teaching materials. Here metaphors are part of pedagogic content knowledge. This is a very important aspect of this study. Some teachers openly and knowingly use traditional metaphors presented in textbooks and teaching materials. Some teachers take steps to create their own metaphors. These novel metaphors are of great interest because they are most likely to be meeting the needs of the curriculum and the learner and to also utilise the skills of the teacher.

Some teachers deny their use of metaphor (the right hand branch of the figure above). Some of these teachers do use metaphor but do not recognise the fact. They may be using traditional curriculum content metaphors like the Russian doll or plate stack metaphors. Some actually unknowingly develop those metaphors as part of their pedagogic content knowledge.

Some teachers adamantly state that the use of metaphor is wrong. "*Do not use metaphors, do not tell lies, tell the truth*" was one retort. Those teachers believe that the use of metaphor is not a legitimate approach in the classroom - they are expressing "being against metaphor". The analysis of the issues of anti-metaphor is an important aspect of determining the value of metaphor in pedagogic content knowledge.

There are some teachers who say they do not use metaphor in their work. This is patently not true because most rhetoric is based upon metaphor. It is contested, and evidenced, by George Lakoff and Mark Johnson that metaphoric language is secondary to the fundamental conceptual nature of metaphor (Lakoff and Johnson, 2003: 272) and that all language is underpinned by the metaphoric nature of cognition. More accurately the teachers, when they say they do not use metaphor, mean they do not use "pedagogic metaphor"; they do not use metaphor as part of their pedagogic content knowledge teaching approaches. However, all teachers responded with some form of algorithm, diagram and pseudocode approach to teaching. The teachers' denials of the use of metaphor are based upon the difference of their understanding of metaphor and the use of the term in this work.

Towards the end of the chapter the issue of whether teachers admit to or condone the use of metaphor in teaching is revisited. "Being against metaphor" is a recurring theme throughout this thesis. The main focus of this chapter is the analysis of the use of metaphoric approaches in teaching. However, before considering the use of metaphor, an analysis of literal teaching employed by respondents is described. This analysis of teaching was not an expected outcome of the research but arose out of the interpretation (coding, memoing and sorting) of the collected data.

7.3 Literal teaching

The clear division between literal approaches and the non-literal was established at an early stage of the research. At the time, non-literal (metaphoric) teaching approaches were still being investigated. Consequently, this early model (Figure 64.) misrepresents the metaphoric side; metaphoric teaching is more appropriately portrayed in later diagrams. This section of the chapter focuses upon the literal aspects.

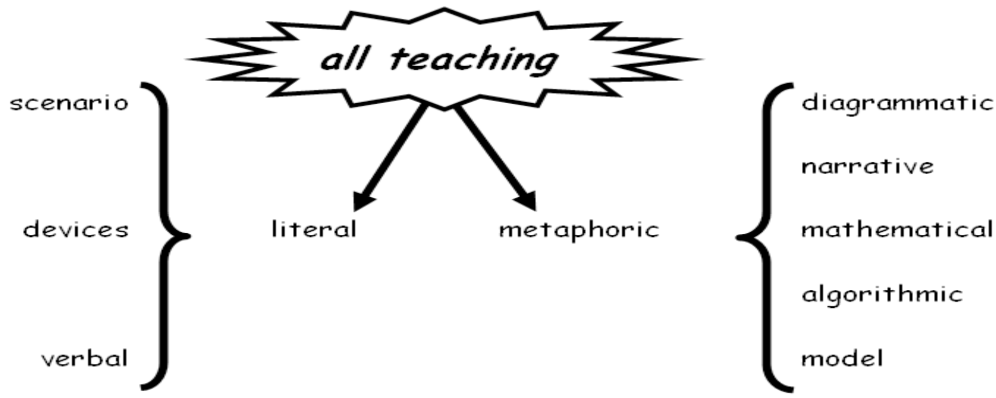


Figure 64 teaching: literal and metaphoric

This thesis proposes that metaphor is “anything that is not literal”. This definition subsumes under metaphor many diverse approaches used in teaching such as algorithm, model, sarcasm, fiction and myth, notation, icon… Literal teaching is that which is based upon a factual description of the actual. This “actual” may be a virtual phenomenon, a physical reality or a conceptual idea.

Virtual phenomena are those things that, although having no physical instantiation, behave like physical devices and, like physical devices, can be visualised and placed in a category hierarchy (Lakoff, 1999: 27). Virtual phenomena also include virtual doing which is discussed in Chapter 4.

The **physical** reality is any object that has a physical state, for example, the motherboard of a computer, the network server. It is also any physical activity or skill that can be carried out by the teacher of learner.

The **conceptual** aspects are those related to understanding. They are processes or structures that do not have a physical instantiation. For example, normalisation is a conceptual process and star network structure is a conceptual organisation.

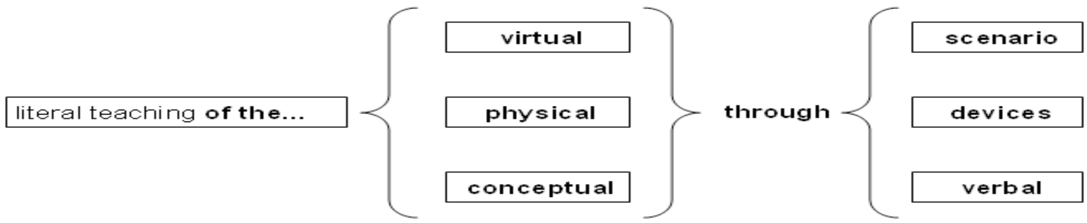


Figure 65 aspect of literal teaching and the approaches taken

The analysis of the empirical data of this research (30 direct references) indicates that there are three ways in which literal teaching takes place: scenario, devices and verbal description (Figure 65.)

teaching of the physical

The teaching of physical devices is exemplified by considering input-output facilities of computers in Hardware Devices (AQA, 2002: section 11.4). This form of teaching, describing the physical by means of the actual device does not appear to present pedagogic difficulties and, indeed, does not appear in the analysis of difficult things to teach. As a consequence, respondents are not directly asked about the teaching of any physical device. The table below (Figure 66.) identifies the difficult to teach topics and categorises them as virtual or conceptual.

virtual:	physical	conceptual:
the Internet and WWW; queue; program structure; memory structure; stack; file structure; PSS	no examples in the "hard to teach" topics	control; logic; tree traversals; recursion; sort; encryption; compression; normalisation

Figure 66 virtual and conceptual hard-to-teach topics

An example of a physical activity is the skill of cut and paste. One teacher described her need to place her hand over the hand of the learner and physically move it and the mouse to shape the learning of the skill (interview 14).

teaching of the virtual

There are many virtual phenomena, by virtue of the nature of the computer, in the teaching of computing. When asked "How do you go about teaching the clipboard and the facilities that it has?" one response begins,

"I always start by doing some copying and pasting just to make sure they know what I'm talking about. I do it from the web because that is useful for their other work - click and drag text and right button menu copy. Or, I right button menu over an image and copy and then paste into Word. I then define the words: cut and copy and what the action paste is…" (interview 23)

The respondent describes carrying out literal teaching, in this case, of skills and a set of facts. There is no hint of analogy or reference to the human computer interface metaphor (the desktop). The description is literally true. The knowledge is of the facility of the computer to temporarily store a single item and the process of using that facility. The teaching is through a verbal description of the situation.

An example of literal teaching which is based upon the description of another virtual phenomenon is this passage from a teaching resource.

"A digital certificate is a certificate for electronic use and attests to the truth that you are who you say you are, and that you own the particular public key specified in the certificate. A digital certificate or digital ID is provided by a Certification Authority and is made up of two types of key - public and private. They often also include an expiry date." (teaching resource 1)

These factual statements describe a virtual device - the digital certificate - using the verbal approach.

teaching of the conceptual

An example of literal teaching of a concept is this description of normalisation.

"A functional dependency is a 1-n relation of a set of attributes within a relation to another set of attributes in the same relation. Full functional dependency A of B is a functional dependency on B of A, so that B is not dependant on a part of A" (teaching resource 5).

Frequently, literal teaching is associated with inexperienced teachers. The following statements were used in a presentation by a trainee teacher when introducing the same topic to a novice group

"A rigorous process for converting complex data structures into sets of simple stable structures… Remove non-primary data that exhibits partial functional dependency with the key to another table… Steps in Normalisation: First normal form - removal of repeating data Second normal form - nonkey attributes require whole key for identification Third normal form - nonkey attributes do not depend on other nonkey data" (teaching resource 8).

The accompanying verbal commentary did nothing more than to emphasise the pronunciation. The statements are truthful and reflect accurately the curriculum content but do not reflect any element of pedagogic content knowledge. Teaching through a literal approach can be weak and ineffective.

Literal teaching is associated with a fixed body of knowledge - for example, the Data Protection Act. The teaching strategy is to present the facts, reinforce the facts through a knowledge/analysis/synthesis activity and review the facts in a plenary (interview 19). Another example of this strategy is the teaching of the internal control of the computer. "*For the CPU to function efficiently it needs a place to store data and instructions. Main memory consists of a sequence of locations. These locations are numbered, and the sequence number of a location is called its address. An address provides a way of picking out one particular piece of information from among the millions stored in memory. There are two types of main memory, RAM and ROM*" (teaching resource 7).

A justification for this strategy is given "*I present the pupils with the raw facts, as they will need to know them to answer the exam questions. I go through what they have to know*" (interview 9).

through verbal, devices and scenario based approaches

and

virtual, physical and conceptual curriculum topics

This table (Figure67.) identifies the three approaches to literal teaching: saying it as it is (verbal), using the real thing or object (devices) and using "the real system" (scenario).

Teaching	of the… virtual	physical	conceptual
through scenario system	using the school networking provision to describe networking architecture without generalisation (interview 10)	using the school bank as an example of the social/ monetary interactions without generalisation (interview 12)	teaching normalisation by setting up situations/databases that fail
devices object	using a computer motherboard to explain the purpose of bus technology (interview 20)	using a computer motherboard to describe the computer architecture (interview 7, 12)	teaching normalisation through examples of database applications (interviews 12, 16)
verbal process	describing the Internet in terms of user, protocol, hardware, ISP, IAP…	teaching novice learners to start a computer	dictionary definition of encryption (Illingworth and Pyle, 1996)

Figure 67 different approaches to literal teaching

The examples in the table above typify literal teaching. The analysis of the recorded accounts also reveals the thinking by some teachers that teaching should be based in “real life” scenarios. It is justified that with older students they have a good understanding of the real life situations and therefore the “understanding of concepts” can be through “generalisation from the particular”. It can be based on their prior experience - “*it is the case, because we have mature students that we relate things to real-life situations and they tend to grasp that quite quickly - applying the theory to it*” (interview 21). This aspect of literal teaching has positive aspects including: utilising the learners’ current knowledge and understanding (particularly with mature computing students); raising motivation and engagement through making the subject of the learning more relevant (particularly with more reluctant or less able students) and situating learning in the context of the curriculum.

An example of literal teaching of the virtual through the physical device (artefact) is described “*the pupils do have difficulties with that* [understanding the location of filer windows] *on a practical basis as much as anything else, you know I still have students, pupils who don't know where they save their work, and I tend to approach it from a sort of practical point of view you know each time you save a piece of work describing where to save it and you know I've actually brought kids into this room to show them the server and to try and give them the idea you know this idea of different locations and savings work in different directories or folders*” (interview 10). In this case the concept of a “virtual device” is taught through the physical device. An important concept in the computing curriculum is “logical device” in which devices are names logically (A, B, C…) and not by their physical name (FOLDOC, 2004).

In a similar way a physical system is used to teach a physical system - using the school bank as an example of the social/monetary interactions (without generalisation). “*The main concept that I find hard to get the pupils to understand, is about companies and how companies use ICT, and even when we are talking about backups, anything, disaster recovery, they cannot see the overall concept of that in an organisational view - I use the idea of the College bank and we see how much money will pass through by multiplying up what one student might do*” (interview 12). The teacher is teaching the literal truth about the School Bank. There is a suspicion (or likelihood) that she may then draw an analogy between it and the other organisations but here she states a description of literal teaching.

An aspect of literal teaching is the use of the actual object or artefact to teach about the physical device. Two examples relate to the control and components of the computer. The first suggests opening up a computer and showing the devices and parallel tracks/circuits to explain buses “*I'd show them a motherboard*” (interview 7). “*it* [computer hardware] *is taught at AS level and therefore quite simplistic, they need to know what the CPU does, ROM etc we use quite a visual style, we try to have a machine that we take apart - that is relatively recent, I don't see how it will help but they [the learners] love it - seeing the whole thing seeing how it works*” (interview 12). An explanation is given - “*obviously when you take the computer apart you have a motherboard and I'm saying that this is this, this is that and it, to them, they have very, call it anything, they would agree - I guess it must clarify in their mind when they can see where it is*” (interview 12).

Literal approaches have a place in teaching by experienced and successful teachers. They are justified in three different ways in terms of:

the most effective approach “*they tend to grasp that quite quickly*”;

difficulty to teach "*I find hard to get the pupils to understand* "; and

learners' needs "*I guess it must clarify in their mind*".

Two respondents justified literal approaches because they thought that the learners would not find metaphoric approaches acceptable "*Also, they are adults in nature - we do not feel comfortable using stories to explain real situations*" (interview 21) and "*the pupils do not take the 'game playing' well. They prefer to discuss difficult issues and use the lab time for their project work*" (interview 22). These two observations come from two contrasting establishments. One could be described as an academic 6th form college whereas the other is a college providing mostly vocational courses for a less academic, often older learner group. Also, the language register of some presentations usually dictates that a literal approach is more appropriate. For example, encryption is the "*conversion of plain text to a secure coded form by means of a cipher system; data encryption standard (DES) standard for a block data cipher system so that the encrypted text can be sent along ordinary telephone lines, and no one will be able to understand it*" is taken from a dictionary presentation (Collin, 1998: 125) and is distinctly different to an explanation, either oral or written, made by a teacher engaged in pedagogic content knowledge.

Another aspect of literal teaching emerged. Although the difficult to teach topic appeared on the syllabus, the demands were such that the teachers did not feel the concept was difficult to teach at the level required to pass the examination. "*An important question is how much they need to know to get through the examination*" (interview 12). Talking about normalisation, "*we give them the example and point them… to read about it; and give them past questions… that is sufficient*" (interview 21) indicates that literal teaching is appropriate when the learners do not have to understand. Talking about recursion another teacher responded "*I really don't see the point - we do it at a trivial level and it has no application; often I do the recursion bit and they just get lost - so I do the factorial as an example and it gets them through the examination*" (interview 16).

frequency of literal teaching

The difference in frequency of literal from metaphoric teaching would be an interesting value to ascertain. It is hypothesised, based upon the author's experience that inexperienced teachers frequently resort to literal approaches. For example, they make statements of facts and use unexplained formula. They list keywords and use them without a context. The sample group of respondents are successful and experienced teachers and there would be a tendency for little of such teaching thus suppressing the amount of literal teaching recorded.

The curriculum topics under discussion are difficult. They require more interpretation and explanation than most teaching. Therefore the frequency of alternative teaching approaches would be higher and therefore the amount of non-literal teaching I propose would be higher. Literal teaching of the topics is more likely to be unsuccessful and therefore not used by these teachers because they are successful teachers.

An analysis of the documents reveals 131 references to metaphoric approaches (algorithm, diagram, flowchart, icon, narrative, prose) whilst only 18 references to literal teaching over the same document scope. This suggests that metaphoric approaches dominate the teaching styles of the experienced and successful teachers in this study.

summary of literal teaching

In summary, literal teaching has two sides to its character. The first, most beneficial, is the situating of learning in the real or concrete. This is what Jean Lave called the process of "legitimate peripheral participation" (Lave and Wenger, 1990) or situated learning. It is the strength of some teaching that it is authentic and relevant and thus motivating to the learners. What is taught is literally true. It is also felt, by respondents, to be an effective way of teaching - in particular when there is a well defined body of knowledge. Preparation for examination is also cited as a reason for using literal approaches.

The other characteristic of literal teaching is associated with poor practice. It is exposition that lacks interpretation to enable the learners to better grasp the concepts. Literal teaching is the statement of facts, rules and relationships and, in essence, not representing the body of knowledge in a new form to enable better learning. It is characteristic of some inexperienced teachers.

7.4 The pedagogic metaphor

The metaphoric approach to pedagogic content knowledge is placing the subject of the learning into a different form. This can be sets of **alternative labels** or **reorganisations** (Goodman, 1976: 72-74) including diagram, model and algorithm. Metaphoric teaching occurs when the literal truth is not used but the truth is represented in another format, the pedagogic metaphor, to give a clearer understanding of the fact, concept, system or function being learnt about. It is proposed (Figure 68.) that there are two sorts of pedagogic metaphor - those based upon a **kinaesthetic** approach (doing, being, moving or making) and those based upon a **theoretical** approach (thinking, writing, describing or imagining).

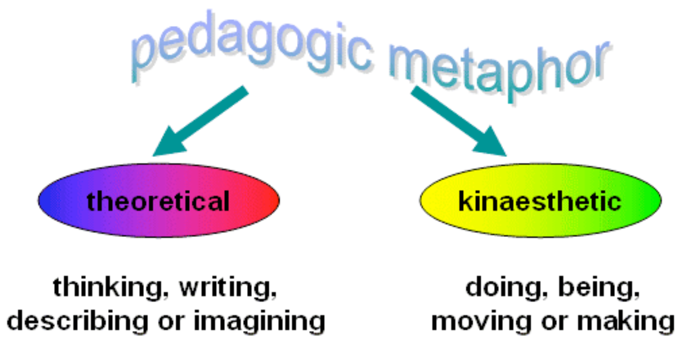
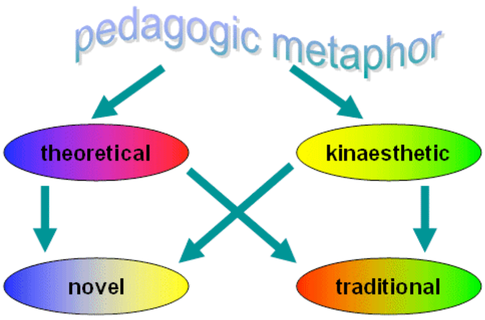


Figure 68 the pedagogic metaphor: theoretical or kinaesthetic

Also, pedagogic metaphors, for the purposes of reporting this research, can be differently divided into two groups - the novel and the traditional. Traditional pedagogic metaphors are those found in text books or in the legend of the computer world; they are commonly known about. Novel metaphors are those used (and usually made up) by individual teachers. The **novel metaphors** are of important interest because it is those that have gone through a recent pedagogic justification by the teacher. He or she has a vested interest in establishing an effective and efficient metaphor. The metaphor will not be dated but of current value. The **traditional metaphors** may have stood the test of time but equally, they may now be less appropriate to new learners, new teachers or the changing curriculum. These are illustrated in Figure 69. The following definitions of the different pedagogic metaphors have arisen from a consideration of the collated and analysed data:

- novel - being new to the author (not existing in other interviews, literature or text books examined) and being claimed to be made up by the teacher respondent;
- traditional - being identified by the respondent or the researcher as existing in the literature or text books;
- theoretical - being described verbally or visually;
- kinaesthetic - being described as a physical activity including gross and fine motor skills

(Kinaesthetic activities typically involve moving about the classroom and interacting with others, using the mouse to manipulate objects on the desktop or using small artefacts including pens and writing.)



Metaphor approaches to pedagogic content knowledge can be considered to be theoretical or kinaesthetic and can be traditional or novel.

Figure 69 the pedagogic metaphor: novel or traditional

Some of the more interesting examples of the different sorts of pedagogic metaphors discovered in this research are listed below (Figure 70.) The following section describes some of these pedagogic metaphors to exemplify the different aspects of theoretical/kinaesthetic and novel/traditional.

	theoretical	kinaesthetic
Novel	absolute $ sticky references spiral turning recursion website is a house Andrea, Oreo and Notty logic busy teenager stacks office cleaner firewall - fly screen compression – pipe width (Brett)	secret notes encryption stacks of Pringles networks of skipping ropes fly door for firewall scrabble codes Packet Switched System parcel tape – sequential files paper chain compression wash basket stack
	theoretical	kinaesthetic
Traditional	walled garden sorting champagne bubbles tree, root, branch, leaf star, bus, ring networks shop checkout queue	filing cabinet filer system front of class queue/bus queue Russian dolls recursion plate stack/paper spike spools of tape file structures Tower of Hanoi algorithm/recursion

Figure 70 the pedagogic metaphor exemplified

novel, theoretical pedagogic metaphor

Novel, theoretical pedagogic metaphors are those created by individual teachers to meet their learners' needs or their own teaching style. They are theoretical in the sense that they are not accompanied by a physical artefact or physical activity but are taught through thinking, writing, describing or imagining activities. They are usually based upon a concept which is familiar to the learners. Like all metaphors, they are not literally true but represent the concept under discussion.

This novel, theoretical pedagogic metaphor is illustrated by the following 8 examples:

- absolute and relative addressing in spreadsheets;
- recursion with a visual representation;
- recursion through formulaic prose (a song);
- recursion using code, pseudocode and a dry run table;
- queuing is shuffling up and queuing in a shop;
- website is a house;
- anthropomorphism of AND, OR and NOT;
- the busy teenager stack and the laundry basket stack.

Absolute and relative addressing within a spreadsheet application is identified by respondents as being a difficult issue to teach. "*I find relative and absolute addressing difficult to teach. I try to draw parallelisms between LOGO instructions, $names in Excel and absolute, indirect addressing in machine code programming*" (interview 9). The "$ sticky references" metaphor draws a mental association between the concept "absolute" (not changing position), sticky, the letter "S" and the string sign used in MicroSoft Excel "$". The teaching procedure is fully described $ sticky references (Cox, 2002). "*I am talking to year 9 kids, absolute addressing, I talk about the $ sign being the glue that glues it to the column and glues it to the row - I thought that was really obvious there are things like that… we just assume that they are known*" (interview 3).

This novel, theoretical pedagogic metaphor was created by an individual teacher to meet her learners' needs. It is theoretical because it is not accompanied by a physical artefact. It is based upon a concept which is familiar to the learners - stickiness. Like all metaphors, it is not literally true but represents the concept "absolute" when teaching absolute and relative addressing within a spreadsheet.

When copying formulae from one cell to another in a spreadsheet the cell references are copied as well. Normally they are adjusted to keep their "relative" reference correct. In image 1 the reference "= A1*1.175" is copied down the column and automatically changing the actual cell contents to reflect the row it is in. (See Figure 71.)

1.

	A	B	C	D
1	£46.00	= A1*1.175		
2	£52.00			
3	£45.00			
4	£58.00			

B1 contains the value A1 + VAT at 17.5%

2.

	A	B	C	D
1	£46.00	= A1*1.175		
2	£52.00	= B1*1.175		
3	£45.00	= C1*1.175		
4	£58.00	= D1*1.175		

B1 copied to B2 to B4

3.

	A	B	C	D
1	£55.00	= A1*$C$1	1.175	VAT
2	£77.00			
3	£46.00			
4	£99.00			

C1 contains the value for VAT (17.5%)

4.

	A	B	C	D
1	£55.00	= A1*$C$1	1.175	VAT
2	£77.00	= B1*$C$1		
3	£46.00	= C1*$C$1		
4	£99.00	= D1*$C$1		

B1 copied to B2 to B4

Figure 71 spreadsheet referencing: relative and absolute

In the second example (image 3) the first column contains similar prices and B1 contains the calculation of the price including VAT. When the formula in B1 is copied down it would conventionally (relatively) make the formula “= B2*C2”. However, the $ sticky makes the second half of the calculation stick at C1 (image 4).

This is an application of absolute addressing. The real-life application is illustrated by considering what would happen if the Chancellor of the Exchequer changed the rate of VAT. In the first example every entry in column B would have to be changed. In the second, only a single value (C1) needs to be changed.

A theoretical interpretation of this concept, using image schemas, is that there is a source-path-goal relationship between the absolute reference (the source) and the calculated answer (the goal). This can be represented by  (Woollard, 2004a). The image schema has a dual rôle to play: it is a directly understood structure and it is used metaphorically to represent other complex concepts (Lakoff, 1987: 283). This visual representation of the computing concept of absolute/relative cell referencing is embedded visually in spreadsheets. For example, in Microsoft Excel’s formula auditing, the trace precedents function represents the source-path-goal is a similar manner (Figure 72.)

	A	B	C	D
1	£46.00	£54.05	1.175	VAT
2	£52.00	£61.10		
3	£45.00	£52.88		
4	£58.00	£68.15		

Figure 72 trace precedents exemplifies the source-path-goal image schema (Lakoff, 1987: 33)

In this example of metaphoric stickiness, the $ sign being the glue that glues it to the column and glues it to the row, the teacher reflects "*I thought that was really obvious, there are things like that… we just assume that they are known, that it is common sense and it is sort of commonsense also at the point we are talking about it, we don't recall it [afterwards] - we only recall it at the point when we use it*" (interview 3). [metaphor is natural; subconscious]

The **concept of recursion** is very difficult to teach as testified, frequently in an emotive way, by most respondents. No respondent considers the process to be easy. Although there are many traditional and novel approaches, only one of those presented can be considered to be a theoretical pedagogic metaphor. In response to the prompt "recursion"

"Yes, hah, how do we go about that…? Or another metaphor along the same terms is a spiral, a spiral turning in on itself until we hit the condition that allows it to unwind and getting across the idea to the student that it's not until you reach that position and the things start to unwind that results start to drop out although you can have a result before the conditional test. We then try to apply recursion take a particular algorithm and try and apply it to things like tree traversal" (interview 8).

Figure 73 spiral metaphor - a centre-periphery image schema

This spiral is not a diagrammatic metaphor but symbolic. A diagrammatic metaphor is one where there is a relationship between the diagram and the focus of learning. It is a diagrammatic metaphor when the component parts of a concept, skill or body of knowledge have a one-to-one relationship with the components of the diagram. The concept of repeating (the rotation about a point) getting closer to an end point (the centre) and the idea of unwinding from the middle is conceptual imagery. The diagram above (Figure 73.) has no representation of the model (in this case the recursive programming code). George Lakoff considered that there is a limited number of primitive image schemas (Woollard, 2004a) including concepts of centre-periphery and cycle (Lakoff, 1999 p35). This description of recursion is a practical example of a primitive image schema in action.

The **mathematical approach to recursion** is very popular. "The essential feature of recursion is that the solution to a problem is described in terms of solutions to easier or smaller versions of the same problem. You will have realised that in the example above you were finding 6! = 6 x 5 x 4 x 3 >< 2 x 1. In the recursive method you did this by using 6! = 6 x 5! 5! = 5 x 4! and so on" (Parramore et al, 2001: 171)

Here is a non-mathematical example of recursion (interview 22).There were 10 in the bed and the little one said "roll over, roll over". They all rolled over and one fell out, there were nine in the bed and the little one said... And so on… This can be described as a prose pedagogic metaphor describing the bed and actions of the children. It is represented as pseudo-code as:

```
x = 10
{rolled over}
there were x in the bed and
if x = 0 then end remark they have all fallen out
the little one said roll over
they all {rolled over} and 1 fell out x = x - 1
end
```

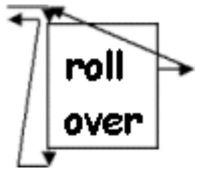


Figure 74 pseudocode representation of "there were 10 in the bed…"

Dry running this program produces the whole song. It can be represented diagrammatically as an icon (Figure 74.) above right.

Alternatively, it can be written as a structured program, in LOGO, called RollOver. The program refers to itself at the end of the third line.

```
TO RollOver
PRINT "There were x in the bed and the little one said rollover and they
all rolled over and one fell out" x = x - 1 IF x > 0 THEN RollOver
END
```

The song "there are 10 in the bed" can be considered to be a pedagogic metaphor used to explain the process of recursion.

A third example of teaching recursion through a novel, theoretical pedagogic metaphor again illustrates the difficulty felt by teachers in trying to explain this concept. "*Argh, I hate recursion; I always teach it with a fragment of program; and we plod through it, so we do, a table of the moving values and we recurse through it, so I will teach it by literally moving through a series of instructions showing at the point in which I have to go back - again, very much on the whiteboard; I want to show them how this is moving and You say you would record the values, how would they be recording that I would have a table of the incrementing values* [dry run table] *and I would have a piece of code* [code]*, usually I have a piece of code on the overhead and we would walk though the piece of code recursing and then I usually use the data projector to show a piece of recursive code -how do you do that? show it working [on the computer], show the value incrementing, and then slow it down, to slow it down I use CPU Crippler"* (interview 5) This description of teaching practice reflects a number of metaphoric approaches being integrated to form an effective teaching strategy for teaching recursion. The approaches are firmly theoretical being using code and pseudocode to define the process, using a dry run table to illustrate the product of recursion.

In response to the prompt "how do you teach queues and stacks" one teacher described the process as **shuffling to the top**. "*queues and stacks; oh, shuffle up to the top - as I say - I teach non-numerically the students understand that it is the first one in, first one out - like a proper queue"* (interview 5) The description "shuffle" is metaphoric. It conjures up the image of small movements of the contents as items leave the front of the queue leaving space at the back for more. This is another example of George Lakoff's primitive image schema - the emphasis being upon forced motion. An example of a text book illustration of queuing is the cartoon (Figure75.)

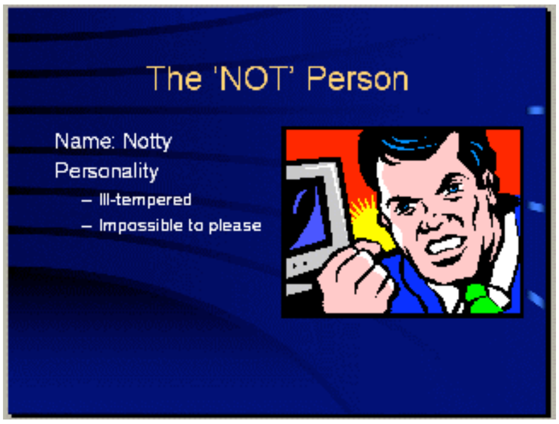
Figure 75 queuing in a shop to represent a computer queue (Watteville, 1997: 278)

Another novel theoretical metaphor is explicitly described by one respondent (interview 9) and strongly supported by another (interview 20). It is the "**website is a house**" metaphor (Banks, 2003). It is a classical container schema metaphor. Container schema metaphors are not physical containers, but rather conceptualisations that we impose upon space. The characteristics of containers are:

- given a container and an entity, the entity is either inside or outside and not both at once;
- if Container A is inside Container B, and Entity C is inside Container A, then Entity C is inside Container B.
- if Container A is inside Container B and Entity C is outside Container B, then Entity C is outside Container A (Lakoff, 1999: 380)

The website is a container. It holds web pages and the resources that are used when those pages are rendered in a browser. It contains containers within containers and this is reflected in terms of tree-like filer structures. The filer structure is a representation of the container-within-container category of metaphor. This example of representing a website as a house exploits the parallels between filer folders inside folders (rooms within the house and rooms accessed from within other rooms). The outer container has an entrance (index.htm page and front door). All objects within a room are considered to be within the house. All images within a page are considered to be within the website.

A further example of a novel, theoretical pedagogic metaphor is the teaching of the logical units of: AND, OR and NOT through **anthropomorphism** - giving human characteristics to inanimate objects. In this example, the literal meaning is presented simultaneously with the metaphoric (Rudge, 2003) illustrated below (Figure 76.). An example of the personification of virtual objects is in the video Warriors of the Net (Elam et al, 2002). Stars of the video include TCP Packet and the Router. At one point the Router is heard to mutter "pick this up… put this here… whoops, sorry… here it is…"



Remember: the NOT instruction operates on a single binary value:

The value 1 changes to 0

The value 0 changes to 1

The 'NOT' Person

Name: Notty

Personality: ill-tempered; impossible to please

Remember: the AND instruction operates on pair of binary values:

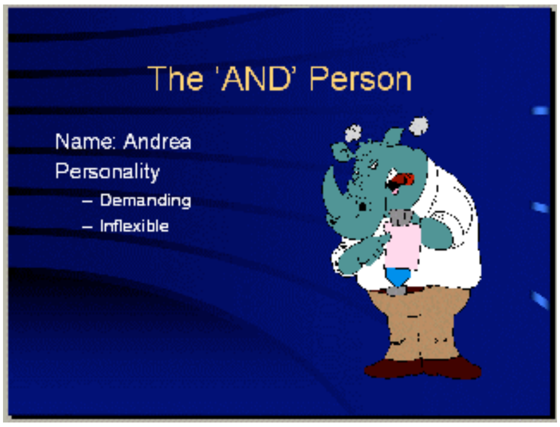
It produces a 1 if both the bits are 1

It produces a 0 in every other case

The 'AND' Person

Name: Andrea

Personality: demanding; inflexible



Remember: the OR instruction operates on pair of binary values:

It produces a 1 if either the bits are 1

It only produces a 0 if both bits are 0

The 'OR' Person

Name: Oreo

Personality: very easy-going; very flexible

"Now tell us some things that Notty, Andrea and Oreo will do"

Figure 76 anthropomorphism of logic units http://www.pgce.soton.ac.uk/it/logic

Interestingly, some respondents do not consider logic to be a difficult subject. Those teachers are ones with an electronics background and, perhaps, a well developed understanding of the principles of logic. One respondent noted "*enjoyable to teach, pupils enjoy the activities*" and another, "*I use a drawn presentation, works ok, I guess they find it easy, I use your idea of blue and red, boy and girl*" (interview 15) quoting an ICT resource used in teacher training (Woollard, 2000b). In this approach the logic concepts are exemplified by presentation of a range of pictures.

The next theoretical pedagogic metaphor, which explains the memory structure stack, is based upon the concept "busy" - teenagers are busy; computers are busy. Computers carry out many millions of processes every second. They are multitasking - they are carrying out several jobs at the same time but cannot do more than one thing at a time. There is a system of interrupts where a waiting job demands the attention of the computer. This narrative leads naturally onto the computer function of “interrupt”. The narrative begins “*student sitting at home in bedroom doing their homework, parent calls them for tea, whilst eating someone knocks at the door and whilst having a conversation their mobile rings, they answer it but it is a wrong number - what do they do next?*” (interview 6)

The story is explained through a diagram of the stack (Figure 77.) As each activity is interrupted a reminder is placed on the stack. When any activity is finished they go to the stack to see what to do next.

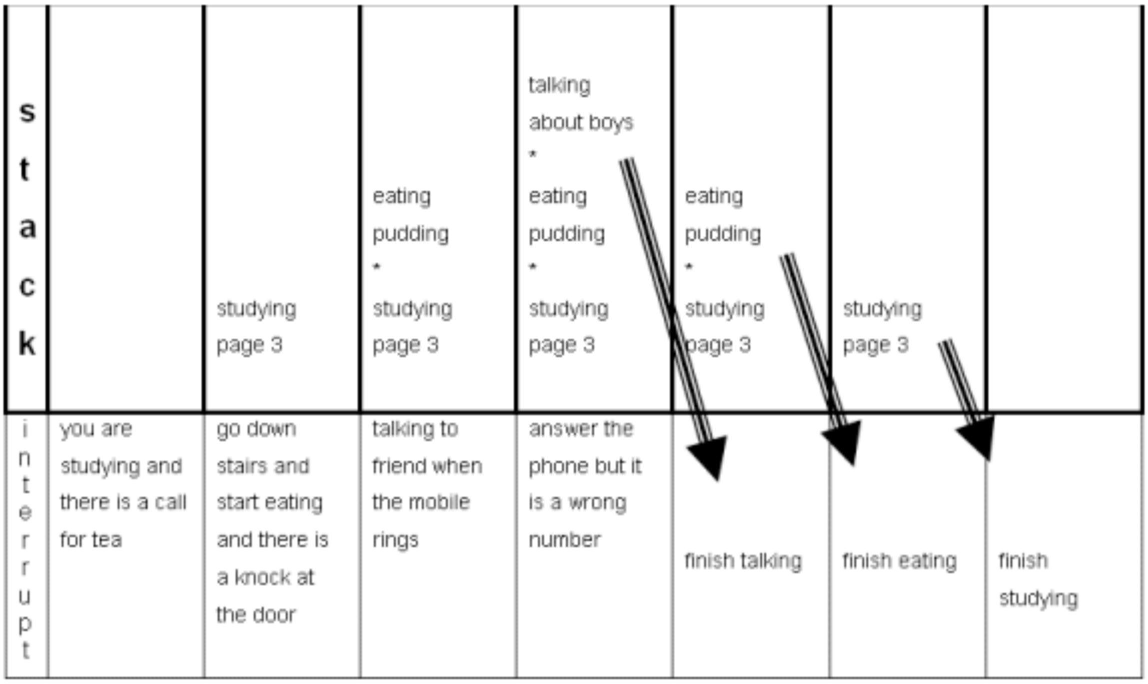


Figure 77 the busy teenager stack

Another theoretical explanation is the laundry basket. “*Imagine your laundry basket and wash day - you put your washing in during the week one item at a time. On wash day they are picked out one at a time, in the opposite order, LIFO”* (interview 11). LIFO is last in, first out.

novel, kinaesthetic pedagogic metaphor

Novel, kinaesthetic pedagogic metaphors are those created by individual teachers to meet their learners’ needs or their own teaching style. They are kinaesthetic in the sense that they are accompanied by a physical artefact familiar to the learners, and more especially, manipulated by the learners. Like all metaphors, they are not literally true but represent the concept under discussion.

Kinaesthetic approaches identified below include: simulations, applications, artefacts, models, scenarios and rôle play.

For example, the teaching of stacks is associated with a number of traditional metaphors including restaurant plate stacks (interview 18) and paper spikes. Interviewee 8 states “*going back to stacks, of course for any student who is working a restaurant in a kitchen the old plate holder, the plates with a spring in the heated cabinet is quite a nice metaphor to use*”. The stack is “*often compared with a pile of plates in a canteen. After washing up the plates, the last plate will be placed on to the top of the* *stack. The next plate to be used will be taken from the top of the stack, i.e. a LIFO stack*" (Bradley, 1999: 501). This text book example remains theoretical but, because this is frequently outside the experience of learners, teachers devise their own. Examples drawn from respondents include sitting on laps, stacking chairs and the "Pringles" pot. These are kinaesthetic stacks because they are associated with physical activity.

"*I always teach it using Pringles, we have two boxes Paprika flavoured where they are reddish and salt and vinegar, one is reddish and the other white, and we interleave them (pt some of one sort and then the other) and you can always tell where they are when you lift them out - because hotel plates are useless with the kids - they don't see hotel plates stacker which is the example given in the book. What I'm trying to get in is the push-pull and they get the idea… but if you publish it* [this novel, kinaesthetic pedagogic metaphor] *I will expect to get the credit - I came up with the idea - copyright*" (interview 5).

The sorting algorithms are also presented kinaesthetically. Traditionally, in UK schools, the more detailed teaching of sorting algorithms occurs in the mathematics curriculum. Textbooks frequently rely upon literal descriptions and a diagrammatic representation. For example, the bubble sort algorithm is described:

"The bubble sort is so named because numbers which are below their correct positions tend to move up to their proper places, like bubbles in a glass of champagne. On the first pass, the first number in the list is compared with the second and whichever is smaller assumes the first position. The second number is then compared with the third and the smaller is placed in the second position, and so on through the list. At the end of the first pass the largest number will have been left behind in the bottom position.

For the second pass the process is repeated but excluding the last number, and on the third pass the last two numbers are excluded. The list is repeatedly processed in this way until no swaps take place in a pass. The list is then sorted." (Compton et al, 2000: 17)

"The name bubble sort comes from the metaphor that, in FINDFIRST, the lightest item seems to float upwards toward the top like a bubble in water" (Seidman, 2003)

The kinaesthetic approach requires physical activity.

"bubble sort; I have done this by getting them all out [of their seats]; they are mostly boys, I don't have any girls, they are mostly active kinaesthetic learners; I have them out running around, and I've done it again very interactively" (interview 5)

"bubble sort; I normally do it by having students standing up at the front and have them moving up and down" (interview 11).

In the following example more technical learning, rather than procedural learning, is supported by kinaesthetic methods.

"central processor; bus, memory; brain, central part - always involved with all actions, students rôle-play different I/O activities, sense of where control lies - it gets the students thinking harder about the relationships" (interview 6). This idea of a Von Neumann computer being a person is common in

many texts. An example (Figure 78.) taken from Noel Kalicharan (1988: 14) is illustrated below. "*The way we describe it using brain and eyes and stuff helps them visualise it*" (interview 6).

Figure 78 Von Neumann anthropomorphism (Kalicharan, 1988: 14)

"queues and stacks; again on the board and a PowerPoint presentation that we bought in which takes us through queues and stacks and its got things pushed on and popped off. We ask the students what they do next, it is an interactive thing which we do (Heathcote resource)" (interview 11)

In the following example (Figure 79.) the interviewee describes physical classroom activities such as queuing up at the print buffer.

Queuing at the printer buffer

"*Place four chairs by the side of the printer. Imagine sending your work to the printer.*

A - go up and wait at the printer; B - go up; A - the printer is ready - it prints - A walks away (see photo) What happens now?"

The printer queue illustration shows the position after 2 pieces of work have arrived but only one has been processed. The data does not "shuffle up".

Figure 79 a printer queue

"A common answer is that B shuffles up to the start. "NO" a queue does not work like that. B sits still until called to the printer.

C - go up and wait at the printer; D - go up; B - the printer is ready - it prints - B walks away

E - go up and wait at the printer; What happens now? E has to sit in the first chair

The printer is ready - who should go to the printer?

This process, people going up to the printer queue, waiting their turn and then leaving, is the emulation of a circular queue" (interview 22).

An effective simulation of this situation was presented by one respondent based upon Microsoft Excel. Here the learners physically engaged in the queuing action by predicting the movement in the queue (teaching resource 9).

Two further examples of the novel kinaesthetic approach using an artefact are described:

"*How do you teach central processor; bus, memory? I open up a computer and show the devices and parallel tracks/circuits. I show them a motherboard*" (interview 7). The teacher went on to describe the one-to-one relationship established between the devices and the computer actions. This is not literal teaching because the reality of control and processing is not as simplistic as the rhetoric suggests. Also, some aspects are literally not true. The teacher is simply putting into the minds of the learner the separation of the processing tasks by suggesting their physical separation on the motherboard.

"*How do you teach about the central processor, bus and memory? I teach it at AS level therefore quite simplistic, they need to know what the CPU does, ROM etc we use quite a visual style, we try to have a machine that we take apart - that is relatively recent, I don't see how it will help but they love it. seeing the whole thing seeing how it works*" Here, the teacher is even doubting the efficacy of the process of using the motherboard in this way but acknowledges that the stimulation of the artefact appears to make the approach more effective. The interviewer queried further. "*I'm interested in why you don't think that would help. Obviously when you take the computer apart you have a motherboard and I'm saying that this is this, this is that and it, to them, they have very, call it anything, they would agree - I guess it must clarify in their mind when they can see where it is*" (interview 12).

Another example of the kinaesthetic novel pedagogic metaphor is the scenario method (described at http://www.pgce.soton.ac.uk/it/pss) for teaching the processes of Packet Switch Systems for sending information (particularly web pages) around the Internet. Here, the teacher and pupils take on the rôle of routers and pass fragments of a letter which, when the scenario ends, can be assembled into a complete page (web page).

traditional, theoretical pedagogic metaphor

The traditional, theoretical pedagogic metaphors reported by the teachers are here illustrated with reference to commonly used text books or the specific text book cited by the teacher. They are illustrated by describing the three: Von Neumann diagram (Figure 80.), plate stack and the Russian doll.

These three examples show the use of diagrammatic pedagogic metaphors. "*How do you teach the central processor; bus, memory? I use the human brain analogy, also Von Neumann structure (diagrammatic) with a video showing the transfer of the data*" (interview 5).

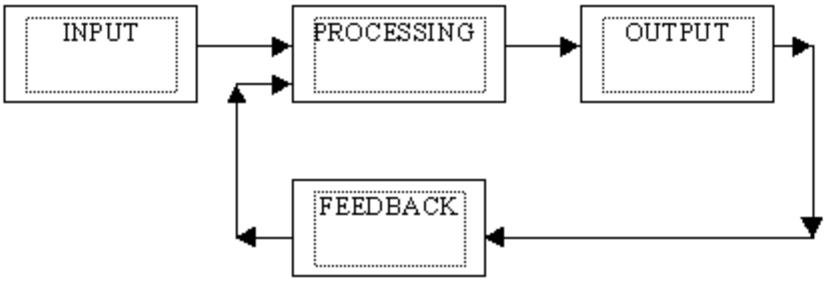
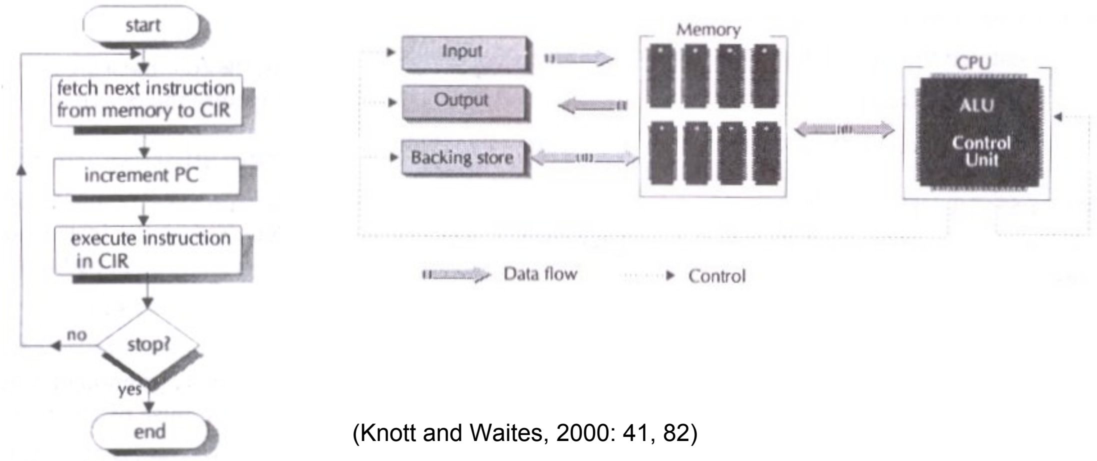


Figure 80 simple input-process-output model

"*I use diagrams, a simple box diagram but I make the direct connections with the fde cycle because I see no point in just learning the diagram - they have to be doing something - I make them trace the actions around the diagram*" (interview 16). This teacher described the algorithm that accompanied Figure 81. (Knott and Waites, 2000: 41, 82).



(Knott and Waites, 2000: 41, 82)

Figure 81 CPU structure and process using algorithm

"*I teach CPU through the use of diagrams and a short animation sequence which emphasises the use flow of data along the lines of the buses*" (interview 18).

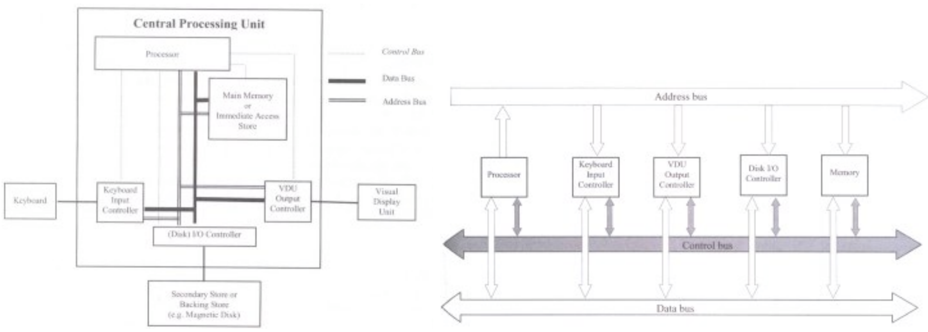


Figure 82 representations of the CPU and buses (Heathcote, 2000: 79, 81)

"*We've got various text books, diagrams, pictures of the relationships between the components, how they are linked together, 2D picture, also we make use of 1 or 2 simulations, computer based, we've made available through various websites which shows the steps involved when instructions are being fetched and executed but it is a difficult topic, its certainly hardest for students to understand*" (interview 8).

These examples (including Figure 82.) illustrate the common diagrammatic approach to teaching the processes of the CPU and the control at the heart of the computer.

The second example of a traditional, theoretical approach is the **plate stack pedagogic metaphor** representation of the computer data structure called a stack (Figure 83.) "*The dinner plates in a cupboard - there was a good analogy*" (interview 6). A text book reference states, "it [stack] is often compared with a pile of plates in a canteen. After washing up the plates, the last plate will be placed on to the top of the stack. The next plate to be used will be taken from the top of the stack, i.e. a LIFO stack" (Bradley, 1999: 501).

Figure 83 dinner plate stack pedagogic metaphor

A Head of Computing recalled, "*going back to stacks, of course for any student who is working a restaurant in a kitchen the old plate holder, the plates with a spring in the heated cabinet is quite a nice metaphor to use*". She went on to say, "*one person [teacher] said me 'I hate that one because the kids had never seen it - well, some of them have - working out in a New Forest restaurant*" (interview 8). This illustrates a caution when using any pedagogic metaphor that they only work when the learner is fully aware of the model on which the metaphor theme is based.

An alternative representation of the stack is the tabular form (Figure 84.).

1	Southampton	5	
2	Barcelona	6	Head Pointer
3	Athens	2	4
4	Alexandria	3	
5	Tunis	0 - terminator	
6	Lisbon	1	

Figure 84 tabular form of stack (AQA, 2002: 6)

Although this is not a popular description of the concept stack, it is the form that is more commonly adopted by text books.

The **Russian doll pedagogic metaphor** is very popular (Figure 85.) Over 40 references to its use can be found on the Internet. (Google 23/02/04 Searched the web for "Russian doll" recursion. Results 1 - 48 of about 61. Search took 0.28 seconds.) Five teachers made direct reference to its existence but only two related using it. "*I use the Russian Doll because they just don't* *get that the sequence goes down inside itself*'.

Figure 85 the Russian doll metaphor

Although there are a number of detractors against the Russian doll metaphor some teachers persist in its use and they suggest modifications. "*My explanation of [recursion] the Russian doll metaphor putting a piece of paper inside each doll with the values*" (interview 5). However, there are other approaches similar in structure.

"*The big one, recursion. Yes, argh, how do we go about that, this is one where your metaphors sort of come through. For some people, I'm sharing with you the results of the research in a sense; some people sit there are they describe it using a metaphor. I've tried this by various methods, over the years and you that at least the most able students will pick up what it is happening - you try to get over the concept of a subroutine procedure that calls itself and one of the methods I've used that is drawn out on the board as a kind of box - we're running this process at the moment we start within that box of the process and then the process calls itself means we draw another box inside it, but there is going to be a slight difference between the process, what is the slight difference? well it often is that we apply the same procedure to a different piece of data - a modified piece or adapted - so we kind of draw up this series of boxes - concentric boxes, stepping into a box within a box within a box, what's going to bring this to an end? what terminating condition is going to be triggered meaning that we will have to step back out of these boxes until we get back to the starting point. Sometimes I'm conscious that after the context of some kind of computer game where they go into a room within a room within a room they've to find a condition or solve a problem whatever allows you to back track and as you backtrack you pick up or note various pieces of information of the terms of recursion and why does it recur. That is very close; this room within a room, to the Russian doll approach the idea of Russian dolls and layers going down. A recursive function will keep on calling itself, so make sure there is a condition where the function will not call itself anymore*" (interview 8).

Two styles of supporting diagrams were discussed in this interview including those that reflect the object-within-an-object image schema and the source-path-goal schema (Lakoff and Johnson, 1999: 31, 32). These are formally represented in Figure 86.

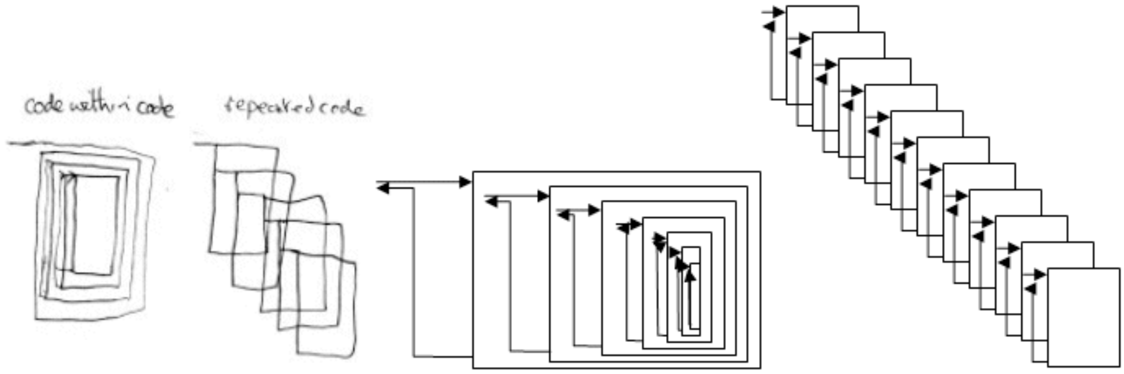


Figure 86 field notes and diagrams of Russian doll and cascading representation

This description is considered to be explanatory by one teacher: "*A Russian doll is a sequence of similar (except for the size) dolls inside each other that can be opened. Each time you open a doll, a smaller version of the doll will be inside, until a certain level where you will find a candy. A recursive function is a Russian doll where even the size does not differ. It will keep on calling itself several times like opening the doll. But since there is a condition to avoid an endless loop, at a certain point there will be no recursive call anymore. That is the point where you close the smallest doll and finish the parent function (second smallest doll). You keep on doing this until the function you started with is executed, just as an iterative function*" (interview 19). This is from the Pico website (D'Hondt and De Meuter, 2002).

The walled garden (Figure 87.) is a theoretical metaphor originally devised by British Telecom to describe a commercial facility for limited internet access by pupils (Campus World, 1995)

http://www.campus.bt.com

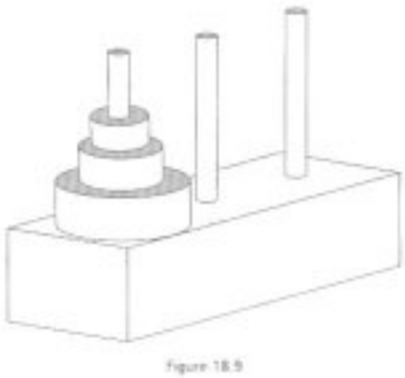
Figure 87 walled garden metaphor to explain limited (protected) access to the Internet

The system [Campus World] was password protected and the content, and access to the Internet, were limited to approved, "suitable", material in a "walled garden" environment (House of Lords, 1996).

"*walled garden, firewall - yes, we mention and we give them an idea of what it is - what is their perception of what it is? why is it called a firewall? (laughing) I really haven't a clue as to what they think firewall means. It could be something to do with the Fire of London*" (interview 21).

traditional, kinaesthetic pedagogic metaphor

An example of kinaesthetic teaching is recursion through a physical device. Figure 88. is a text book description of the activity based upon the Tower of Hanoi.



The rules of the problem are:

• Only one disc can be moved at any time.

• After each move, all discs must be on the poles (you can't hide one in your pocket!)

• No disc maybe placed on top of another disc, which is smaller than itself

(Bradley, 1999: 387)

Figure 88 recursion: Tower of Hanoi

A further example is the introduction of this kinaesthetic activity through a PowerPoint presentation. The learners here have to replicate the Tower using pens/pencils/paper on their desks. The strategy remains kinaesthetic; the learners are physically moving objects in an attempt to learn the conceptual structure of recursion (Green, 2003). A virtual kinaesthetic approach is to use a computer program that emulates the physical activity. One such animated resource "plays" the game repeatedly.

Andrea Lawrence reported on two studies of the teaching of algorithms that considered software animations and the effects on people's ability to comprehend and work with previously existing programs (Lawrence et al, 1994). The results were that animations were shown to help the participants with program comprehension if the participants were actively involved. Of two presentations used by a respondent (interview 22), the first showed the progress of the Tower of Hanoi moves with no user participation, the second required the learner to identify the piece to be moved next thus requiring active participation. The respondent reported that the former presentation was useful in enabling students to learn the sequence and played an important rôle in understanding the important repetitive character of recursion. The evidence cited by Andrea Lawrence and others emphasised the importance of participation.

Another traditional approach is to embed the concept into code or pseudocode. When presented as a simulation with learner participation by clicking their predictions it becomes a kinaesthetic activity (teaching resource 2). The Tower of Hanoi has been treated in a similar way (teaching resource 1) and forces the learner into predicting correctly. Errors of prediction are highlighted and progress is not made until the correct disc is identified. There are strong behaviourist principles being exploited in this simulation.

Mark Brown attests, based upon a literature review of the techniques for algorithm animation, that although systems for animating algorithms are becoming more powerful and easier for programmers to use, not enough attention has been given to the techniques that an algorithm animator needs to create effective visualizations (Brown and Hershberger, 1991). They describe new techniques that they have developed for using colour and, to a lesser extent, sound. Their paper also presents six algorithm animations that illustrate the colour and sound in algorithm presentations. There are strong parallelisms between their work and the examples discovered during the teacher interviews of this research. For example, the Microsoft PowerPoint presentation “Tower of Hanoi in COLOUR” (Figure 89.) uses two techniques for engaging learners in the subject matter of algorithm and recursion (Howell, 2003).

Figure 89 pedagogic metaphor: Tower of Hanoi in COLOUR

A further consideration of this example of a kinaesthetic pedagogic metaphor includes the concept of “end game”. “*This* [simulation of the Tower of Hanoi] *helps the learner understand algorithm and recursion*” (interview 22). The end game is an understanding that the process can be broken down into a series of exactly the same moves and by working backwards from the end point reach the start point.

Finally, in this section on traditional, kinaesthetic metaphors, the concept of encryption is considered. Traditional theoretical explanations are provided in the text books. For example,

“*before transmission from the client computer, the message is encrypted using a randomly generated encryption key. Then, using the public key received from the Web server, the key is itself encrypted, effectively placing it inside a “digital envelope”. The digital envelope can only be ‘opened’ with the server’s private key, known only to the server. Upon receipt, the server opens the digital envelope and uses the enclosed key to decrypt the message.*

This authenticates both parties with a distinct public/private key pair to create a “digital signature”. This digital signature Authentication is further strengthened by the use of certificates issued by a trusted third party Certificate Authority (CA)” (Knott, 2000: 263).

Traditional kinaesthetic approaches to teaching the concept include asking the pupils to “*write out a short message and then apply their* [encryption] *rule to it. They pass the message on to see if it can be decoded. After a while they pass on the decoding instructions*” (interview 21). “*I then introduce the idea of key by saying that everyone uses the same rule but it is encrypted with a key provided by the recipient. They get the idea that no one can crack the message except the person it is destined for. We can they talk about public and private keys. I have to do it practically else they just don’t get it*” (interview 21).

the pedagogic metaphor: theoretical verbal or visual; kinaesthetic devices or actions

The pedagogic metaphor has been described by dividing into those that are kinaesthetic (doing, being, moving or making) in nature and those that are theoretical (thinking, writing, describing or imagining). Illustrated in Figure 90.

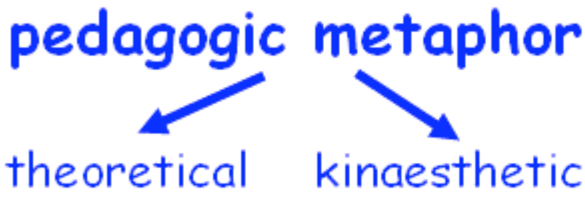


Figure 90 pedagogic metaphors: theoretical or kinaesthetic

As a result of further consideration of the examples illustrated above, it is proposed that theoretical metaphors can be further divided into two groups - those based upon a verbal (written or spoken) exposition and those based upon the visual (diagrammatic, pictorial or iconic) representation. The kinaesthetic pedagogic metaphor is likewise divided into two groups - those based on actions and those based upon a device. It is at this level that the teachers' approaches can be categorised. Illustrated in Figure 91.

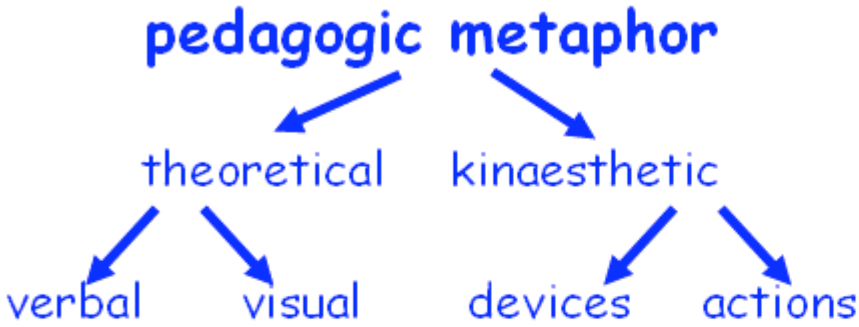


Figure 91 pedagogic metaphors: verbal, visual, devices or actions

The range of metaphoric approaches used by teachers has been drawn up from the interview analysis and also from the author's experience of teaching, training, inspecting and examining in computer education. It will be proposed that they (Figure 92.) represent the full repertoire of approaches teachers use when teaching computing. However, the analysis of the data continues with determining the connections between the findings and the theoretical concepts of metaphor and image schema.

prose - pseudocode - flowcharts - diagrams - simulations - artefacts - scenarios
instructions - code - table - symbols - icons - pictures - applications - models - rôle play

Figure 92 PCK approaches used in computing teaching

The pertinent research questions at this point are: what is the nature of teaching methodology? how do teachers/trainers/tutors teach computing? and what is a metaphor?

The earlier literature review identified the importance of the work by George Lakoff and Mark Johnson and their development of theory based upon image schema. The following tables (Figure 93.) show a representative list of pedagogic metaphors and the equivalent image schema.

Novel kinaesthetic pedagogic metaphor	Underpinning image schema
secret notes encryption	container
stacks of Pringles	container
networks of skipping ropes	surface
fly door for firewall	process
scrabble codes	process
Packet Switched System	process over a surface with blockage
parcel tape – sequential files	merging containers with internal links
paper chain compression	process of matching within a container
wash basket stack	container
Novel theoretical pedagogic metaphor	**Underpinning image schema**
absolute $ sticky references	process with a clear link
spiral turning recursion	cycle process
website is a house	container
Andrea, Oreo and Notty logic	anthropomorphism
busy teenager stacks	process stored in a container
office cleaner	process on a surface
firewall - fly screen	process
compression – pipe width (Brett)	process and restraint

Traditional kinaesthetic pedagogic metaphor	Underpinning image schema
filing cabinet filer system	container within container
front of class queue/bus queue	process
Russian dolls recursion	container within a container iteration
plate stack/paper spike	container/process
spools of tape file structures	linked process
Tower of Hanoi algorithm/recursion	process iteration
Traditional theoretical pedagogic metaphor	**Underpinning image schema**
walled garden	container
sorting champagne bubbles	process
tree, root, branch, leaf	links on surface
star, bus, ring networks	surface
shop checkout queue	process within a container

Figure 93 representative pedagogic metaphors and their corresponding image schema

A developing theme in the analysis of the reported teaching approaches is the idea of algorithm as a means of presenting ideas. Further re-coding of the interview transcripts then revealed another category - algorithm. It is therefore pertinent to consider the rôle of algorithm in the processes of teaching, and in particular, in the teaching of computing.

7.5 Algorithmic teaching

Algorithm is within the discipline of computing. Algorithm is also within the curriculum of computing. It is therefore to be expected that the pedagogic content knowledge of computing involves the use of algorithm. The next section discusses the features of algorithm and identifies those approaches used by computing teachers that are algorithmic in nature.

algorithm within the discipline of computing

An algorithm can be described as a "detailed sequence of actions to perform to accomplish some task" named after an Iranian mathematician Al-Khawarizmi (FOLDOC, 2003). Technically, a refined algorithm must reach a result after a finite number of steps, thus ruling out brute force methods for certain problems, though some might claim that brute force was also a valid (generic) algorithm. The term is also used loosely for any sequence of actions which may or may not terminate (Black, 2003). Algorithms include common functions, such as Ackermann's function of recursion. Problems include travelling salesman (Figure 94.) where a route is found enabling the salesman to visit each and every customer once and to return to base covering the shortest total distance. In computer terms, the algorithm finds a path through a weighted graph which starts and ends at the same vertex, includes every other vertex exactly once, and minimizes the total cost of edges (Bond, 2004: 9).

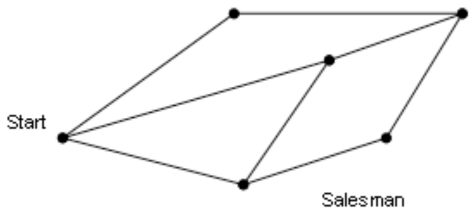


Figure 94 travelling salesmen algorithm

Another type of algorithm is the solution for the Byzantine General. That is, suppose two separated generals will win if both attack at the same time and lose if either attacks alone, but messengers may be captured; if one decides to attack, how can that general be sure that the message has reached the other general and the other general will attack, too? Problem solving like these examples forms the basis of many computing world problems, for example, replacing generals with internet servers and salesman with network routing software. Algorithm is therefore within the discipline of computing.

algorithm within the curriculum of computing

The curriculum of computing in the United Kingdom is defined by statute through the Qualifications and Curriculum Authority. It is operationalised by a range of examination providers such as OCR, AQA and Edexcel. Algorithm is part of that curriculum.

The following extracts illustrate the inclusion of algorithm within the curriculum:

"A level specifications should also require an additional understanding of systematic methods such as the use of algorithms";

"AS and A level specifications should require students to develop skills in… Design: specify and document, using appropriate systematic methods: the algorithms"; and

“candidates should be able to analyse a problem and identify the parts which are appropriate for a computer-based solution; select, justify and apply appropriate techniques and principles to develop data structures and algorithms for the solution of problems” (AQA, 2002).

Algorithm is part of the curriculum. It is therefore expected that some approaches of pedagogic content knowledge will relate to algorithm. Flowcharts and pseudocode are both of the curriculum and of teaching of the curriculum. They exemplify disciplinary authenticity (Shaffer and Resnick, 1999: 199).

In this study algorithm refers to the following instantiations:

- pseudocode - a program-like text that can be read by a human, easily translated into a high level computer language but cannot be coded directly;
- code - a program that will run on a computer using on-board compilers and/or interpreters;
- instruction set - usually numbered, statements/instructions presented as a list in human-readable form;
- prose - instructions presented in grammatically correct English prose (for example, if you want to make a cup of tea then boil some water and pour onto a teabag in a mug; when it is strong enough remove the teabag, add some milk and stir and then, when cool enough, drink);
- scenario - the learners act out a system by taking on the rôle of devices and behaving according to a set of rules (algorithm);
- flowchart - a visual representation of any one of the above using a specific symbol set.

These are illustrated by the “making a cup of tea” example (Woollard, 2003c).

algorithm as prose, instruction, pseudocode, code and diagram

When pupils are first introduced to programming at whatever level, a popular example is “making a cup of tea”. It is an activity associated with combining components in a specific order, over a period of time and ends when a condition is set. A metaphor is an apparatus of organisation that takes over a new territory. Making a cup of tea is a system of inter-related objects and functions. We can describe the making of a cup of tea as an algorithm – a sequence of instructions with a precise structure. In prose: if you want to make a cup of tea then boil some water and pour onto a teabag in a mug; when it is strong enough remove the teabag, add some milk and stir and then, when cool enough, drink. (Figure 95.)

```
1       place a teabag in a mug;
2       boil some water;
3       pour over teabag;
4       wait until strong enough;
5       remove the teabag;
6       add some milk and stir;
7       drink when cool enough.
```

Figure 95 “cup of tea” set of instructions

The pseudocode is not a formal programming language; it is a set of instructions laid out in a way that could be directly coded in any imperative computer language. (Figure 96.)

```
procedure maketea
objects: mug, teabag, water, milk;
actions: pour, put, boil, stir, drink;
conditions: strong, cool;
begin
boil water;
put (teabag, mug);
pour (water, mug);
repeat [ ] until strong = TRUE
put (teabag, NOT mug);
pour (milk, mug);
stir (mug);
repeat [ ] until cool = TRUE
end
end procedure
```

Figure 96 pseudocode description of a "cup of tea"

The algorithm can be represented diagrammatically as a flowchart. (Figure 97.)

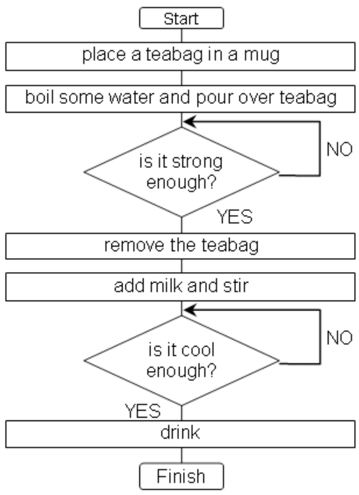


Figure 97 flowchart of a "cup of tea"

A set of instructions or prose is as much a metaphor as any use of oral/written language as it is the representation of thought, knowledge or understanding in another form. The instruction set has a structure that implies sequence and time. The format of instruction could be considered to be "a whole set of alternative labels, a whole apparatus of organisation that takes over new territory" (Goodman, 1976: 72-74).

The format of flowcharts is even more highly organised with rules specifying the linkages, labelling, shapes of objects and layout on the page. Consider the mental concept of "making a cup of tea" and the representation as a flowchart – it is truly metaphoric. Pseudocode has a similar level of organisation; the labels, consistency of punctuation and the linear layout. True programming has an organisation, syntax, grammar, logic and regulation to an even higher degree of specificity.

As seen through this "making a cup of tea" example, the flowchart, pseudocode and programming script can be metaphoric representations of a concept, system, object or function.

Teachers' preferred teaching style can be based upon algorithm. The analysis of responses indicates that there are typical approaches associated with particular items of the curriculum. This is to be expected. However, it is noted that some teachers prefer an algorithmic approach and choose that approach rather than the more typical. The analysis is summarised in Figure 98.

Topic	**Typical approach**	**Algorithmic approach**
recursion	narrative/ diagrammatic	Visual Basic code giving fractal
sequential files	diagram/literal	flowchart approach
queues	narrative	pseudocode
stacks	narrative	code to reverse 4 numbers
compression	literal	algorithm
sorting	literal	code
tree traversals	diagrammatic/ kinaesthetic	pseudocode

Figure 98 typical approaches to teaching computing topics

From the interviews that reflected a high level of algorithmic teaching (interview 7, interview 8 and interview 15), a number of commonalities can be identified. More importantly, the motivations for adopting algorithm can also be gleaned.

The following examples typify algorithmic approaches adopted by some teachers of computing. The first three illustrate the "dry run" approach where the learner acts as the computer in following the logic of the steps and keeping a record of variables and position pointers.

"I always teach it [recursion] *with a fragment of program; and we plod through it, so we do, a table of the moving values and we recurse through it, so I will teach it by literally moving through a series of instructions showing at the point in which I have to go back - again, very much on the whiteboard; I want to show them how this is moving and…"* (interview 5).

"I would have a table of the incrementing values and I would have a piece of code, usually I have a piece of code on the overhead and we would walk though the piece of code recursing and then I usually use the data projector to show a piece of recursive code…" (interview 5).

The algorithm is a metaphor for the "real" concept of recursion - recursion being an activity that, as it proceeds, calls itself.

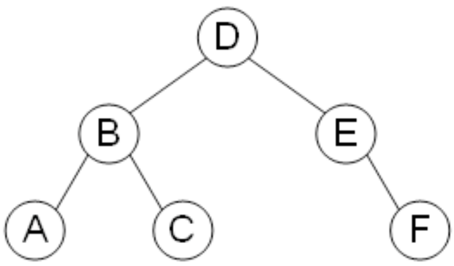


Figure 99 binary tree diagram with node symbols

"I do the dry run of a recursive program - a copy of the Heathcote exercise but I do it in front of the whole class and write it up on the white board. it takes a lot of concentration on my part so that I do

not make a mistake! The kids do make mistakes - I think it is hard because they have to be accurate and because they don't picture what recursion is..." (interview 18). In this example the teacher refers to the traversing of a binary tree in Figure 99. The computing process is to take an unordered list and order it through a recursive algorithm (recursion); the binary tree never exists as a physical or electronic artefact. Recursion is represented as "walking through" a diagram which has almost kinaesthetic qualities.

"that they have to go through [the hashing algorithm] *to find the next available address at which to store that information - we do it by example, example of index numbers we go through and create what the hashing algorithm would be and we always make sure there are some that are got the same address "What do I do now?" they put their hand up. You open it up to discussion, what should be done now? and they nearly always come up with that solution - it should be stored at the next available space"* (interview 11).

This response (interview 11) shows a different use of algorithm. Here the learners are constructing (synthesising) the algorithm rather than following the algorithm. This particular teacher also makes the clear connection between code and prose. *"It* [teaching of algorithms] *usually comes after they have done check digits and yet we usually make up an algorithm - not a pseudo code - nor VB code - set out on the board in English prose"* (interview 11).

"[teaching] *compression; diagram on the board (how do they think…)* [they consider] *picture of the sky they think of it as an algorithm, it is reversible, it is not lossy"* (interview 7).

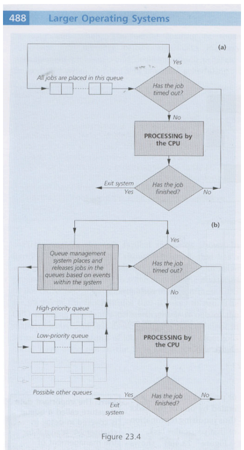


Figure 100 flowchart showing the queue management algorithm

"queues and stacks; Figure 23.4(a) shows how a queue is managed in diagrammatic form; it is an algorithm expressed in the form of a flowchart" (Bradley, 1999: 488) and is illustrated in Figure 100. A flowchart is a form of visual control-flow specification employing arrows and "speech balloons" of various shapes (FOLDOC, 2003).

Considering the responses and the characteristics of interviewees 7, 8 and 15 the following common characteristics can be established. They all teach in an academic environment - two are in 11-18 schools with an emphasis upon A level study whilst the third teaches at a 6th Form college with a high capacity for computing education. All three have a programming background and teach Visual Basic, Pascal and/or C++ languages. It appears that their teaching approach is being influenced by their own knowledge and skills. This may be the principal factor influencing the choice of pedagogic approach.

A further example is the technique called bubble sort. The common approach is a description of the process. However, there are a number of algorithmic approaches adopted. One text book answer is to present a full computer program to demonstrate the sort algorithm. (Figure 101.)

```
FOR i = 1 TO n – 1
swapflag = 0
FOR j = 1 TO n – i
IF L(j) > L(j + 1) THEN
temp = L(j)
L(j) = L(j + 1)
L(j + 1) = temp
swapflag = 1
NEXT j
IF swapflag = 0 THEN i = n – 1
NEXT i
```

The input will be the same for both:

```
READ n
DIM L(n)
FOR i = 1 TO n : READ L(i) : NEXT i
DATA
```

where DATA is the value of *n* followed by the list of numbers to be sorted. Output can be achieved with:

```
FOR i = 1 TO n : PRINT L(i) : NEXT i
```

Figure 101 bubble sort in pseudocode (Compton et al, 2000 p19)

These examples illustrate that algorithm has a place in pedagogic content knowledge in helping the teaching of a range of difficult topics. Some teachers have a tendency to use algorithm in preference to other approaches - these being those with a programming (as compared with a systems) background. Algorithm can be considered as being a form of metaphor in what ever form it appears - pseudocode, code, prose, instruction or diagram. Algorithm is, in terms of Nelson Goodman’s whole set of alternative labels, a whole apparatus of organisation that takes over new territory (Goodman, 1976: 72-74). The algorithm is not the literal object, process or system but a representation of it.

7.6 Being against metaphor

As described earlier (section 7.3.6), the majority of teaching approaches reported were metaphoric in nature. However, not all teachers were in favour of using metaphor. The teachers’ reaction to the use of metaphor is summarised diagrammatically. (Figure 102.) Some say that they do not use metaphor and a few even decry the use of metaphor. These are against metaphor.

During the period of this research, both during the empirical data collection and the literature review, there were many suggestions that metaphor was wrong. The following examples illustrate the different reasons why being against metaphor might occur.

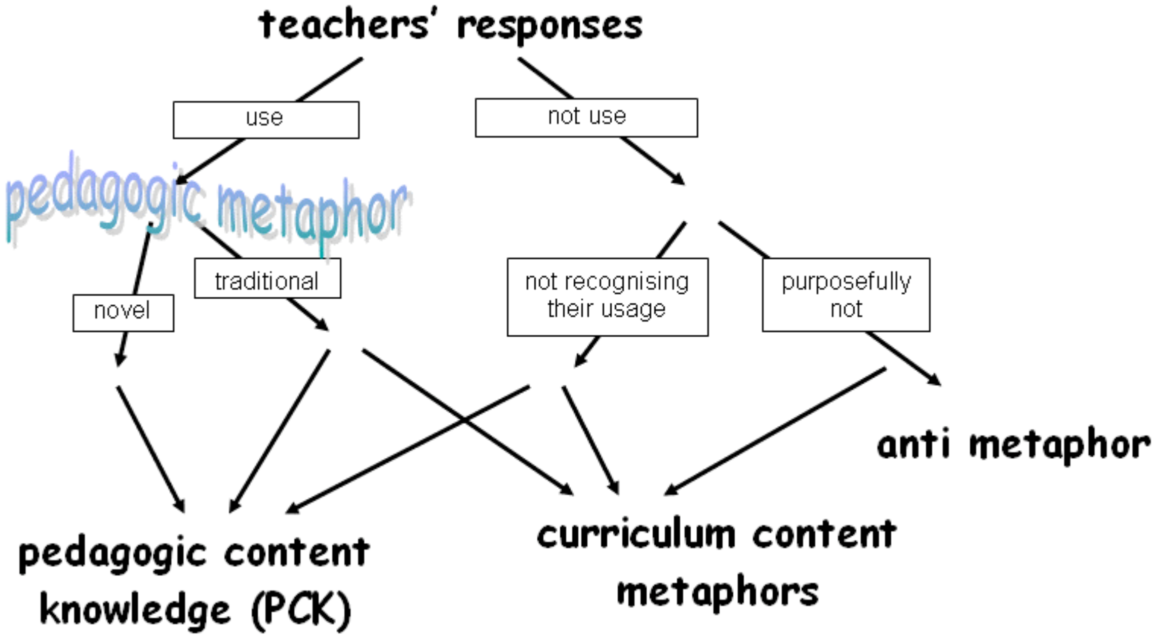


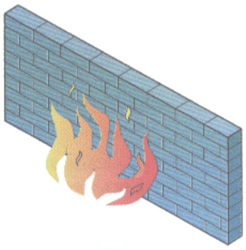
Figure 102 teachers purposefully not using metaphor

When discussing the memory structure queue the bus queue was cited. "*I have a concern about the bus queue - what happens when the bus comes and only 5 people can get on? The queue moves… (pause) only 5 people can get onto the bus (?) but the rest of the queue remains - so I don't understand what the problem is. Well, with a queue mechanism, when the queue gets full - oh I see - they start to fill in from the front*" (interview 5). This is an example of where, in the metaphor theme, there are a number of significant tensions. There are instances where the one-to-one relationship between the model (bus queue) and the product (computer queue) do not exist. The teacher identified that a printer queue does not shuffle up as items leave whereas passengers move up to the front of the queue. The metaphor model is incorrect.

"*That is the point - you are using a model* [metaphor] - *the bus queue and that is where a limitation occurs, like if I use the Russian doll I know that there is a significant limitation, there is an implication that the first structure is a smaller bit of code than the second, than the next time and the next time then it's what you hope and I hope that they understand, I don't know*" (interview 5). In this second example there is a conceptual difference. The image schema for a procedure is a container. The concept of recursion relates to the image schema "iteration" (Johnson, 1987: 126). Together they relate to containers within containers. It is the reason why the Russian doll metaphor is so popular. However, the metaphor implies that the second code called is smaller than the first and the third smaller still. Not only is this wrong but it is misleading and offers justification for some people to reject metaphor.

The third example is the firewall. Here there is a metaphoric implication drawn from the name. The illustrations below show the prevalence of this incorrect association. A firewall is not a wall of fire; it is not a wall and some fire. A firewall is a filter system that permits the passage of "good" data and prohibits "bad" data. The following illustrations (Figure 103.) reinforce misconceptions regarding firewalls.

O'Byrne (2001: 56)



Geschonneck (2003)

Conceptionet (2004)

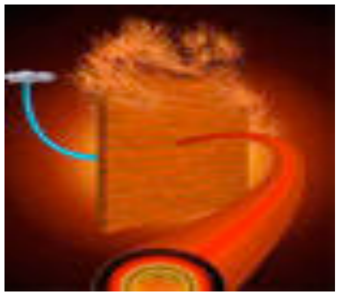


Figure 103 the firewall is not a wall of fire

The following diagram (Figure 104.) illustrates how even serious, technical illustrators (University of Connecticut, 2004) resort to misleading imagery.

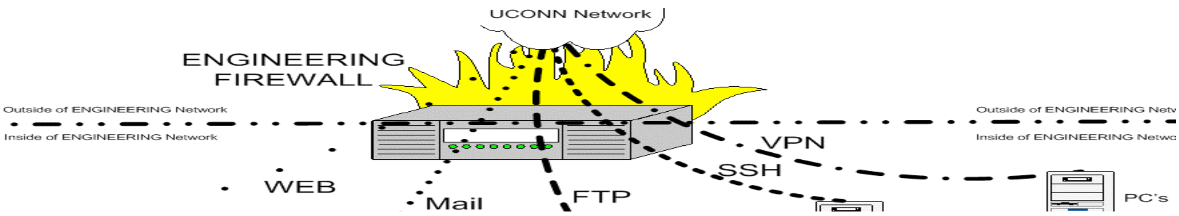


Figure 104 technical diagrams also use the fire imagery

This illustrates the failure of the metaphor to support understanding of the situation and, because of its prevalence, can create misunderstanding. When discussing this situation with trainee teachers the following incorrect interpretations were given: wall of fire, a fire break, a fire brake, a fire door, a fly screen. One teacher explained, "*firewall - yes, we mention and we give them an idea of what it is - what is their perception of what it is? why is it called a firewall? (laughing) I really haven't a clue as to what they think firewall means. It could be something to do with the Fire of London*" (interview 21). "*They don't seem to have a problem with understanding the functions of a firewall - the term itself, I have tried to do it in what I understand a firewall to be, a building into two parts, I talk about the party wall of two houses, nothing should be pass between*" (interview 8). Although this final observation is the most correct description of a firewall it is technically an incorrect description of an electronic firewall.

Metaphor is representation of understanding that is not literally true. A consequence of the learner taking the metaphor as being literally true is exacerbated in the examination situation. "*Yes, the trouble with that, the danger with that a stack is a pile of plates in a motorway service station, is because you will see them write this sort of nonsense down, you don't need to explain to the examiner what it is like. In other words, people are using it as a metaphor, they are using the plate stack, and they are saying that it is a plate stack. Yes, exactly, and what I am saying, for God's sake, we don't want that, we don't have to try and help the examiner understand the concept by saying that it is like a stack of plates, they know it, they want to know what your (the pupils') understanding is*" (interview 7).

Another teacher identified a problem with metaphor. She said that metaphoric talk was a "looseness of language". It was not in keeping with the academic nature of the text we expect from students. Phrases like "heart of the computer" do not add to the meaning or understanding of the situation and so metaphors are not appropriate. Even those convinced of their value caution of their use. For example, the “website is a house” originator states “a disadvantage of the metaphor is the potential over-restriction of the concept of structure - that the structure is limited to that of a house” (interview 9).

The final example is the use of the metaphor “walled garden”. It illustrates the problem that the model that the metaphor is based upon is outside the understanding of the learner. “*There are some metaphors that exist, like the Walled Garden, we use and hopefully the audience gradually pick up what that means - if they are not aware in a traditional sense then perhaps it does not help with their understanding*” (interview 7).

Being against metaphor has 5 distinct different aspects:

- when the metaphor is an incomplete model - product relationship ;
- when the metaphor is an incorrect model - product relationship (leading to error);
- when the model is reported (in examination) and not the product;
- when the rhetoric falls short of academic standards or suggests literal meaning; and
- when the model, as well as the product, are unknown to the learner.

Metaphoric approaches to pedagogic content knowledge have serious difficulties which should be considered when planning learning resources and environments if errors and misconceptions are to be avoided.

7.7 Why do teachers use metaphor?

This analysis of the collected data reveals an interesting list of reasons for metaphoric approaches used in the classroom. The motivations are identified as belonging to one of five broad areas:

- dealing with conceptual difficulties (concepts);
- few/no connections with other knowledge;
- overcome errors and misconceptions;
- as an alternative to algorithm;
- boring and literal teaching.

dealing with conceptual difficulties (concepts)

There are a number of concepts of computing that are difficult to teach and pedagogic metaphor is seen to be the natural approach to adopt to enable learning. This research could be considered to be a “self-fulfilling prophesy” with regard to this justification for using metaphor. The research method identified difficult-to-teach topics to ensure that the more powerful pedagogic approaches would be adopted.

few/no connections with other knowledge

A major difficulty is when the new idea to be taught has no natural connections with prior teaching and learning. This first example is taken from the context of students using web-based resources for the first time (in a post-16 college). “*They become a bit stuck when it comes to downloading… they* *don't understand why they haven't got it* [resource]*, it is still on the machine* [server] *wherever it is and that they have not downloaded to their own vicinity. That is incredibly hard to grasp - we tend to term it more as an electronic library. For the students sake we use the metaphor, the term search, then some students respond that they should use keywords and lists*". The teacher is describing the use of analogy to enable students to understand the electronic process.

Although some topics do have connections with earlier teaching or concepts, for example, logic, program structure and encryption, much of the computing curriculum identified as difficult-to-teach does not have natural prior learning. For example, stacks, queues, trees, recursion and normalisation have few elements of prior experience within computing upon which to base teaching. Analysis of the text books reveals that these topics are introduced with no a priori knowledge. The processes are explained "as is". Teachers resort to metaphor as a means of explaining the concept. For example, a text book exemplifies recursion by the execution of a program (Heathcote, 2000: 235) whereas a teacher uses a pedagogic metaphor solving the Tower of Hanoi (interview 22) or an image schema of a spiral (interview 8).

However, the metaphor is not always the answer because learners may not know the model on which the product is based. "*That's the snag with using an analogy - you are using a foreign language, when I started teaching, people were teaching all sorts of things by using the moment of a pendulum and stuff, there was a lot of implied* [assumed] *mathematics. Metaphors help when they can connect what the students know to what they have to learn*" (interview 5).

overcome errors and misconceptions

Several respondents observed that literal teaching frequently works in the appropriate place, for example, "*when teaching the Data Protection Act - I present the pupils with the raw facts, as they will need to know them to answer the exam questions*" (interview 9) and "*the teaching strategy is to present the facts, reinforce the facts through a knowledge/analysis/synthesis activity and review the facts in a plenary*" (interview 19). When it does not work the symptoms of failing to learn are "errors and misconceptions". Some teachers resort to metaphoric approaches to overcome those misconceptions. When explaining recursion one teacher observed "*I prefer using code because it shows it is not lots of copies of the same procedure but just one set of lines*" (interview 19). "*There are so many misconceptions with regard to recursion - I try to get as many models as possible*" (interview 19).

One interviewee described in detail his use of "a website is a house" metaphor. "*I teach web page design and construction and I use a strong metaphor*… the metaphor enables students to better construct their site map… there is a strong underpinning of the concept that a web page consists of the HTML page and a number of supporting resource files and that these files may be located within the folder of the web page or at some other place within the house (web site) or even outside the house (interview 9). The interviewee identified a major misconception that a web page is a single file and justified the elaborate theoretical metaphor because it clarifies the concept.

as an alternative to algorithm

Although algorithm is a natural approach used by some teachers, others find that learners have difficulties in algorithmic thought. As noted earlier, interviewees 7, 8 and 15 used algorithmic approaches readily and utilised the most technical aspects of the algorithm - the computer code itself. "*The algorithm I like is the factorial I get across the fact of what a factorial is. The mathematical students catch on to that so that is one strategy I use*" (interview 15). However, for other interviewees, other metaphoric approaches are used to overcome the learner difficulties.

A similar reason given is associated with mathematics. "*I know that they struggle with binary mathematics - it is very difficult area and my colleagues who teaches the first part of the technology unit covers that anything to do with maths they find difficult*" (interview 21).

boring and literal teaching

Some areas of the curriculum are considered by the teachers to be less stimulating; metaphors are used to raise the level of interest and motivation in the learning process. "*I think that this is difficult because it is boring; we just have to tell them what it is, the components and some kind of process that goes on - they have to learn it off by heart - do they understand it - I don't think so*" (interview 6). "*The way we describe it using brain and eyes and stuff helps them visualise it*". "*I tell them the stories, and I get them to do these activities to keep them interested. Sometimes it is difficult to introduce the new ideas without an interesting activity*" (interview 3). "*I like your idea of a pedagogic metaphor* [narrow use of the term pedagogic metaphor]*. I have to tell stories to keep their interest. The more bizarre the better. But I use lots of analogies from the books*" (interview 17). "*When I first started teaching I taught biology - one student said that it is like Noddy does biology with little people in cells and going around the blood, picking up oxygen and dropping it off. I guess that I haven't changed*" (interview 12). And, talking about the encryption and sorting algorithms "*I do that with scrabble letters - they get a word which is scrabbled up and they are told at the other end a way to how is can be undone at the other end, its works, well, they enjoy it*" (interview 12). "*bubble sort; I have done this by getting them all out [of their seats]; they are mostly boys, I don't have any girls, they are mostly active kinaesthetic learners; I have them out running around, and I've done it again very interactively*" (interview 5). These teachers are reflecting the usefulness and presumed effectiveness of "story telling" to raise the interest level of the substance of the learning. Anthropomorphism is again evidenced through the computer activities being exemplified through human activity. This is strong evidence that teachers resort to metaphoric approaches to overcome issues of interest and motivation.

The motivations for the use of metaphor in pedagogic content knowledge can be summarised as those areas presenting conceptual difficulties because there is no connection with the learner's current understanding or there are errors and misconceptions. Metaphor is used as an alternative to algorithm and to raise motivation and interest when teaching boring aspects of the curriculum.

7.8 Summary

This chapter describes a classification of pedagogic approaches based upon the analysis of teacher responses to how they teach difficult aspects of the computing curriculum. The presence, rôle and justification of literal teaching is revealed and then the pedagogic metaphor is defined and described. Literal teaching is divided into three types: teaching based upon scenario or socio/technical systems; teaching based upon artefacts or physical devices and teaching based upon verbal description. The term “pedagogic metaphor” is described in terms of approaches to teaching and a taxonomy based upon theoretical/kinaesthetic and novel/traditional examples is established. The particular rôle of algorithmic teaching approaches is described and illustrated through examples drawn from the research data.

The rôle and importance of metaphor in the teaching of computing is revealed through an analysis of the motivations of teachers. Some teachers immediately acknowledge that they use metaphor and show recognition that the computing curriculum is rich in metaphor whilst others recognise their use of metaphor as being a deliberate act of preparing the teaching materials. Some teachers openly and knowingly use traditional metaphors presented in textbooks and teaching materials whilst others take steps to create their own novel metaphors.

“Being against metaphor” is considered and examples of issues pertaining to the use of metaphor are described including the problems arising when the metaphor is an incomplete or incorrect model - product relationship, when the learners report the use of the model and not the product and when the rhetoric falls short of the expected academic standards. Finally, in this chapter, the teachers’ motivations for using metaphor are examined and analysed.

The following chapter describes the taxonomy of pedagogic content knowledge approaches derived from this analysis of data.

Chapter 8 A taxonomy of teaching

This chapter describes the precise nature of the taxonomy of pedagogic content knowledge derived from this study of the teaching of computing.

Teaching is divided into 4 aspects (Figure 105.): skills of classroom practice, knowledge of the learners, knowledge of the curriculum and pedagogic content knowledge.

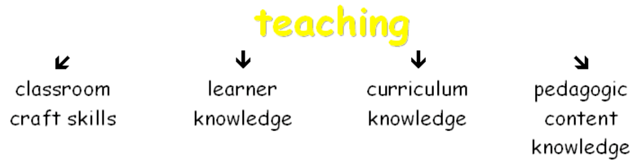


Figure 105 four aspects of teaching

This diagram is derived from a number of sources including PCK being the intersection between pedagogy and content (Enfield, 1999) and PCK being the pinnacle of the teaching process supported by knowledge of students and curriculum and the context which includes classroom management and other socio-cultural factors (Veal, 1999). It also identifies the importance of PCK as a major influence upon teaching practice which is based upon subject, pupil and pedagogic approaches (Askew, 1997). This study is concerned with pedagogic content knowledge.

The teaching approaches, the means of tackling an issue or teaching situation, of transforming knowledge into other forms (Turner-Bisset, 2001: 69) are divided into the literal and the metaphoric. The metaphoric are those that dress the subject content in the clothes of other things like the language and symbolism of algorithm and are pedagogic metaphors. The literal approaches are those that state the facts - that which is taught is literally true. It is an effective way of teaching when there is a well defined body of knowledge and reflects the positive nature of authentic teaching (Shaffer and Resnick, 1999: 198) situating learning in real life and aligned to what the learners have to do and want to do. Figure 106. shows the different aspects of literal teaching and the approaches used to convey information.

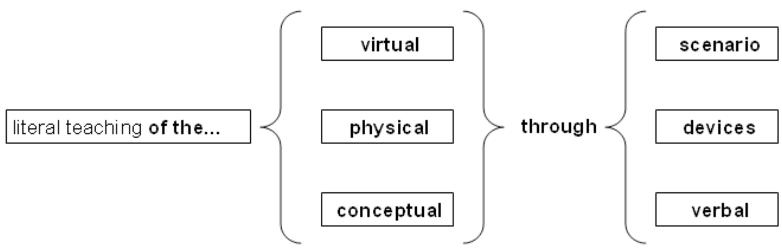


Figure 106 aspects of literal teaching and the approaches adopted

Other approaches are considered to be metaphoric because they do not state literal truth but present the knowledge and concepts by other means. These pedagogic metaphors are classified as being theoretical or kinaesthetic and further divided into verbal, visual, devices and actions. Many are exemplified within the research and form the base of the taxonomy. They are "*representations of the curriculum content*" (Shulman, 1987: 3) and summarised in the Figure 107.

8.1 Analysis of categories of pedagogic metaphor

Teaching that is considered being metaphoric if it is not literally true but a representation of the facts, concepts, systems or functions being learnt. The preceding analysis (Chapter 7) defines pedagogic metaphor as being theoretical (verbal or visual) or kinaesthetic (based on devices or actions). The analysis then identifies a range of types of pedagogic metaphor. These are the approaches used by teachers to represent the curriculum content. This thesis proposes that they include all the approaches described by the respondent teachers. They can be illustrated in a hierarchy (Figure 107.) However, there is not an exclusive matching of the bottom tier items to the verbal-visual-devices-actions layer. This is discussed below.

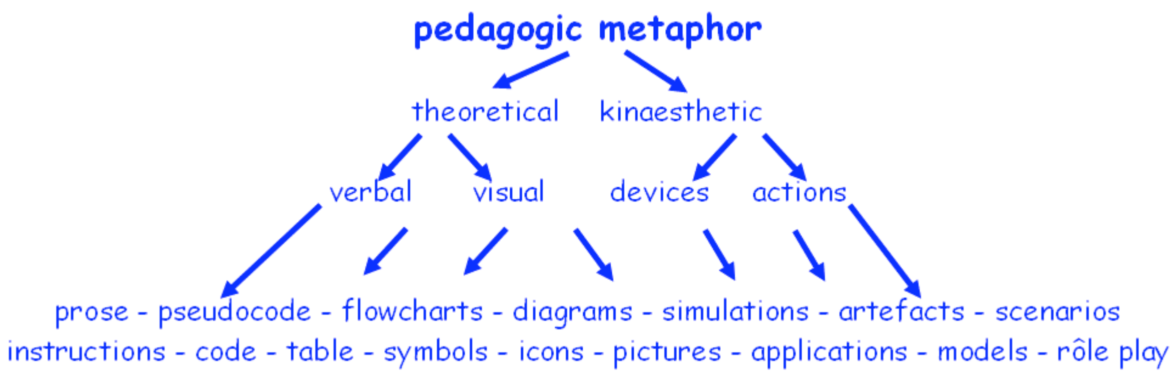


Figure 107 pedagogic metaphors used in teachers' PCK

The definition of taxonomy, presented in the previous chapter (Section 7.1), makes six conditions by which categories and the structure of taxonomy should be judged. They are:

- categories do not overlap (mutually exclusive);
- categories include all possibilities (comprehensive);
- clear and precise description (unambiguous);
- without clashes with other established taxonomy (acceptable);
- repeated classification of the same data gives the same results (reliable);
- gives an insight into the knowledge (useful).

The categories can be placed on a spectrum from the most concrete (kinaesthetic) to the most conceptual (most removed from the reality). The actual position of any single item on that spectrum and the relative position of any pair of items may be open to debate. However, the process of making a first guess and then comparing neighbouring items will identify where the first condition, mutual exclusivity, may be in danger of being broken (illustrated below).

mutual exclusivity

The juxtaposition of the following items needs justification of their exclusivity: scenario - rôle-play; application - simulation; simulation - model; icon - picture; icon - symbol; picture - diagram; diagram - table; diagram - flowchart; code - pseudocode and instructions - prose.

In a rôle play, individual learners adopt rôles either highly prescribed (e.g. a computer systems operator having to deal with conflicting demands of clients and service engineers) or less prescribed but responding as they felt they would under a prescribed situation. In a scenario, the learners take on the rôle of inanimate objects (e.g. the router in a packet switched system or the CPU of a Von Neumann computer) and act out a rôle determined by the functionality of the device they are imagining to be.

An application is an item of software used to carry out task related functions (e.g. a spreadsheet or a presentation package). A simulation is a computer program emulating another situation (e.g. a spreadsheet representation of a car park charging system). Simulations are applications dedicated to their single function. An application may be used but becomes a simulation when it loses its generic features and is dedicated to the single task.

Models are very similar to simulations but they have a technical difference. In simulations the user can change the variables to explore the virtual environment (microworld) whereas, in a model, the user can change both the variables and the formulae of the system. Simulations are associated with dedicated software applications and models with spreadsheet applications.

Pictures are visual representations that try to look like the real thing whereas icons are conceptual in nature. A picture has photographic qualities whereas the icon would be a generalised image. Both icons and symbols represent concepts (whereas a picture represents an object). The symbol is a conventional character of mathematics, Latin, Greek or other alphabet. Symbols cannot be generated on an ad hoc basis yet icons can be.

A diagram is not a real image of the object but stylised in appearance. A diagram represents objects and relationships between those objects. It necessarily has labels - without labels a diagram would become an icon. Three forms of diagram are binary tree, chart and graph.

A flowchart is differentiated from a diagram by virtue of the algorithm with a start and finish and a sequence of activities or instructions and is presented with an accepted set of shapes. A table is differentiated from a diagram because it is essentially text in meaning. The non-verbal elements (lines/cells) of a table have minor contribution to the meaning.

Code and pseudocode are representations of a computer program. Only the former can be entered into a computer and be actioned directly. There are different forms of code (high level, low level, scripting) but all are essentially the same in that the computer takes the characters and interprets them. Pseudocode cannot be directly interpreted by the computer and must be translated by a human into a computer readable form.

Prose is the presentation of ideas through written language made up of words, sentences and paragraphs. Although instruction also uses words, sentences and paragraphs it is essentially different because it contains an indication of sequence - usually by means of a numbered bullet point list.

comprehensive

Informal discussion with a number of colleagues and consideration of a number of texts does not reveal further categories of “representation of the curriculum content”. Further searching of the literature did raise some concerns regarding potential bias in the categorisation. On reflection of the work of Gráinne Conole and David Kennedy (Conole and Kennedy, 2004) the following question is asked: why are flowcharts included as a category and not maps (cartographic), mind maps, concept maps, semantic networks, charts, graphs? As a result, the definition of diagram and flowchart (proposed at the start of the research) requires revision.

Original definitions:

- diagram - a visual representation that is predominantly symbolic;
- flowchart - a standard form representing input, processing and output of a system.

Revised definitions:

- diagram - a visual representation of geometric shapes, symbols, icons and prose representing a concept, system, place or artefact;
- flowchart - a visual representation of geometric shapes, symbols, icons and prose representing a process with a specified start and finish.

A diagram can be explored in any order or with a range of strategies. A flowchart is not explored but followed - it is algorithmic in nature.

This revised definition places maps (cartographic), mind maps, concept maps, semantic networks, charts and graphs in the diagram category.

unambiguous

The categories occur because they are "ready-made" named sets with an already established definition for the title. The categories should therefore be unambiguous. Any ambiguity might arise from the closeness of traditional meaning of two names and that division should have been resolved in the "exclusivity" section above.

acceptable

An acceptable taxonomy would be one that does not clash with established taxonomy of a similar nature. The test of this aspect of the taxonomy would be to exhaustively measure it against all other established taxonomies. For example, it could be measured against the taxonomy of Jerome Bruner and Lee Shulman.

Jerome Bruner suggested that there are three ways to represent knowledge: enactive, iconic and symbolic; he postulates that these are developmental in nature (Bruner, 1970). When working with older learners it could be argued that all three come into play. The categories of the proposed taxonomy can be divided into the three Bruner groups:

symbolic: prose; instructions; pseudocode; code; table; symbols;
iconic: icons; flowcharts; diagrams; pictures;
enactive: applications; simulations; models; artefacts; scenarios; rôle play.

According to Lee Shulman pedagogical content knowledge "…embodies the aspects of content most germane to its teachability. Within the category of pedagogical content knowledge I include, for the most regularly taught topics in one's subject area, the most useful forms of representation of those ideas, the most powerful analogies, illustrations, examples, explanations, and demonstrations - in a word, the ways of representing and formulating the subject that make it comprehensible to others" (Shulman, 1986: 9). The quotation highlights "analogies, illustrations, examples, explanations, and demonstrations."

explanations: prose; instructions; table;
analogies: pseudocode; code; symbols;
illustrations: icons; flowcharts; diagrams; pictures;
examples: [literal teaching]
demonstrations: applications; simulations; models; artefacts; scenarios; rôle play.

This brief analysis suggests that the taxonomy does represent a construct that is acceptable.

reliable

A measure of reliability could be the way in which the taxonomy has developed under the iterations of the grounded theory method. As each new document has been coded, or as each old document has been re-coded, the taxonomy has matured. Several categories have disappeared (as evidenced in earlier sections) such as mathematical, narrative and algorithm. Some categories did not arise until much later than others such as symbol, application and table.

useful

The usefulness of the taxonomy will only be established when applied to a new situation. It currently brings an insight into the content pedagogic knowledge of computing but has yet to be applied to another curriculum area or reinforced by use of others within computing.

8.2 Further reflections

A further reflection is prompted by reconsideration of the questions raised in Chapter 4 regarding the Veal et al model where PCK is at the top of a pyramid supported by the other aspects of teaching:

Is knowledge of content filtered through the knowledge of learners and the consideration of the mechanics of teaching before impacting upon pedagogic content knowledge?

Does knowledge of the learner have any impact upon the processes of pedagogic content knowledge?

Do the mechanics of teaching have any bearing upon the process of making the subject content learnable?

A small number of comments suggested that knowledge of content was filtered through the knowledge of learners before impacting upon pedagogic content knowledge. Two teachers specifically suggested that the approaches adopted were matched to the learners' needs. This aspect of decision making was not part of the original "research questions" and so this evidence is inconclusive. There is also insufficient evidence to establish whether the mechanics of teaching have any bearing upon the process of making the subject content learnable.

Rosie Turner-Bisset proposes a classification within pedagogy called a pedagogical repertoire. To teach the facts, concepts, skills, processes, beliefs and attitudes of the curriculum there are 3 aspects (Turner-Bisset, 2001: 152) supported by the organisational strategies of whole-class, split-class, large group, small group and pair individual. Aspect 3 (acting skills) has little bearing upon this study as the items do not impact upon representation of the substance of the learning. The exception is rôle play. In her work “Expert Teaching”, Rosie Turner-Bisset is making reference to teacher actions whereas in the pedagogic metaphor rôle play is a representation of the subject. For example, teaching of the software development process through pupils taking on the rôles of client, consultant and developer. Aspect 1 and Aspect 2 of her model (Figure 108.) are less easy to delineate. The inclusion of “approaches” in Aspect 1 appears to suggest that Aspect 2 is a subset of Aspect 1. If that is accepted then clear parallels can be drawn between the pedagogic repertoire taxonomy of “Expert Teaching” and the pedagogic metaphor taxonomy of this thesis (Figure 108.)

A pedagogic repertoire (Turner-Bisset, 2001: 152)	Comparison with pedagogic metaphors in pedagogic content knowledge
Aspect 1 strategies	
approaches	approaches subsumes the list below
activities	activities includes the “physical activities” of rôle play and scenario
examples	examples have literal implications
analogies	pseudocode, code, symbols
illustrations	icons, flowcharts, diagrams, pictures
representations	this is a general term that could encompass all pedagogic metaphors

Figure 108 comparing pedagogical repertoire (strategies) with pedagogic metaphor taxonomy

Further, the Aspect 2 Approaches can also be matched, in the main, to the pedagogic metaphor structure. These are shown in Figure 109.

Aspect 2 Approaches	
storytelling	encompassed in prose
Socratic dialogue	encompassed in prose
drama	rôle-play
rôle-play	rôle-play
simulation	simulation
demonstration	a demonstration can be with anything from instructions to artefact
modelling	**
problem-solving	model and simulation have problem solving features
singing*	
playing games	rôle-play or scenario

continued…

knowledge transformation	this is a general term that could encompass all pedagogic metaphors
question-and-answer*	prose, instructions, pseudocode, scenario, rôle-play
instructing*	
explaining*	
giving feedback*	

* These aspects of “approaches” can be better described as teacher activities rather that representation of the substance of learning and therefore do not fit the pedagogic metaphor taxonomy

** The text does not define modelling. Modelling could describe the behaviourist approach of the teacher performing the skill, reciting the knowledge or utilising the understanding; the learner models (copies) the teacher. Modelling might refer to the use of a model (copy) of the substance of learning as in a computer model that simulates a real-life situation. In a generic sense a model might include a diagram with rules, a scenario or a flowchart.

Figure 109 comparing pedagogical repertoire (approaches) with pedagogic metaphor taxonomy

This direct matching of the elements of the Turner-Bisset model with the elements of pedagogic metaphor proposed as a result of this research reinforces the validity of the findings. The differing emphasises are likely to occur as a direct result of the differing contexts of the work.

8.3 The spectrum of categories of PCK approaches

Finally, in this chapter, the taxonomy of pedagogic metaphor is re-presented in a form that reflects the construct that lies between the kinaesthetic-concrete and the theoretical-symbolic aspects (Figure 110.) This is important because it draws together the ideas of pedagogic metaphor of being different approaches for teaching specific items of the curriculum in a way that enables a comparison with other models of cognitive (Jerome Bruner) and pedagogic (Lee Shulman) ideas.

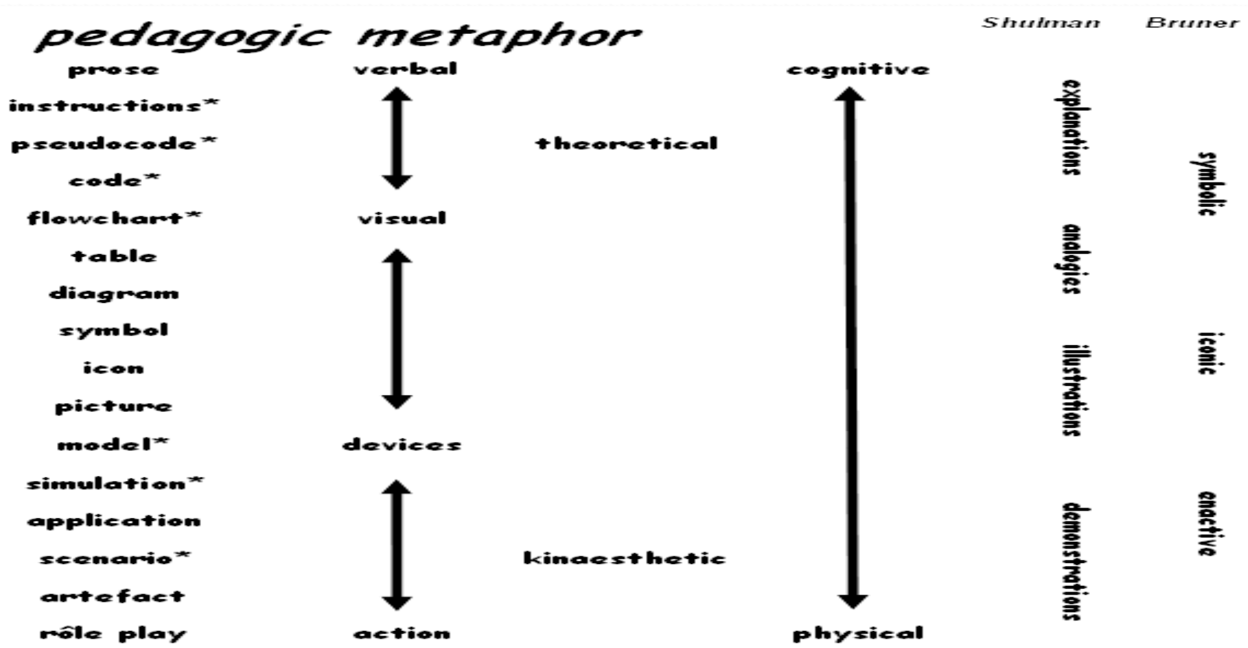


Figure 110 spectrum of categories of PCK approaches

The first column lists the different pedagogic metaphors that have been encountered during the interviews, the scrutiny of text books and my professional experience. The second and third columns reflect the analysis of the interview data and they show the division of pedagogic metaphors into those that are generally verbal or visual (theoretical) and those that are generally based upon a device or action (kinaesthetic). This implies a spectrum (column 4) ranging from cognitive approaches through to physical approaches. The final two columns place the keywords of Shulman's and Bruner's theories against the same spectrum.

It is not proposed that each pedagogic metaphor (prose, instruction, code…) takes a single place on the spectrum and that there is a predetermined order from prose through to rôle play. The order is not fixed. However, each pedagogic metaphor has a general position indicating its nature - whether it is verbal or visual, a device or an action. For example, a prose pedagogic metaphor will certainly be placed at the verbal, theoretical and cognitive end of the spectrum. A prose metaphor is bound to be explanatory, in Shuman's terms, and symbolic (as all written language is) in Bruner's terms.

Another example is the table pedagogic metaphor; say, the dry run representation of programming code. It has both verbal and visual properties. The information and understanding is derived from both the content of each cell of the table and from the overall shape of the data (which cells are complete and which are empty). Some tables will have more verbal content than others which might give more information through the shape (visual aspects) like a diagram does.

Near the other end of the spectrum lies the scenario pedagogic metaphor. For example, the explanation of the packet switched system, whereby pupils take on the rôle of routers passing messages around an internet-like network (see page 126) is an action (no device is used), it is kinaesthetic and physical in nature. In Shuman's terms it is demonstrating and in Bruner's terms it is enactive.

This analysis has highlighted two important aspects of the pedagogic metaphor taxonomy. Firstly, that it possesses sympathy with two other, very different, models that relate to pedagogy. Secondly, it shows the fluid nature of the descriptions. Although, as outlined in the previous section, the types of pedagogic metaphor show mutual exclusivity, they are not fixed ideas but encompass a range of approaches adopted by teachers to explain and promote learning.

Chapter 9 Overview, summary and conclusions

This overview, summary and conclusions chapter is supported by a diagram that reflects the various aspects of the literature review, empirical evidence gathering and theory development, undertaken as part of this research. It also includes a presentation of the taxonomy. The keywords of the diagram below are emboldened in the text.

Chapter contents:

9.1 Overview

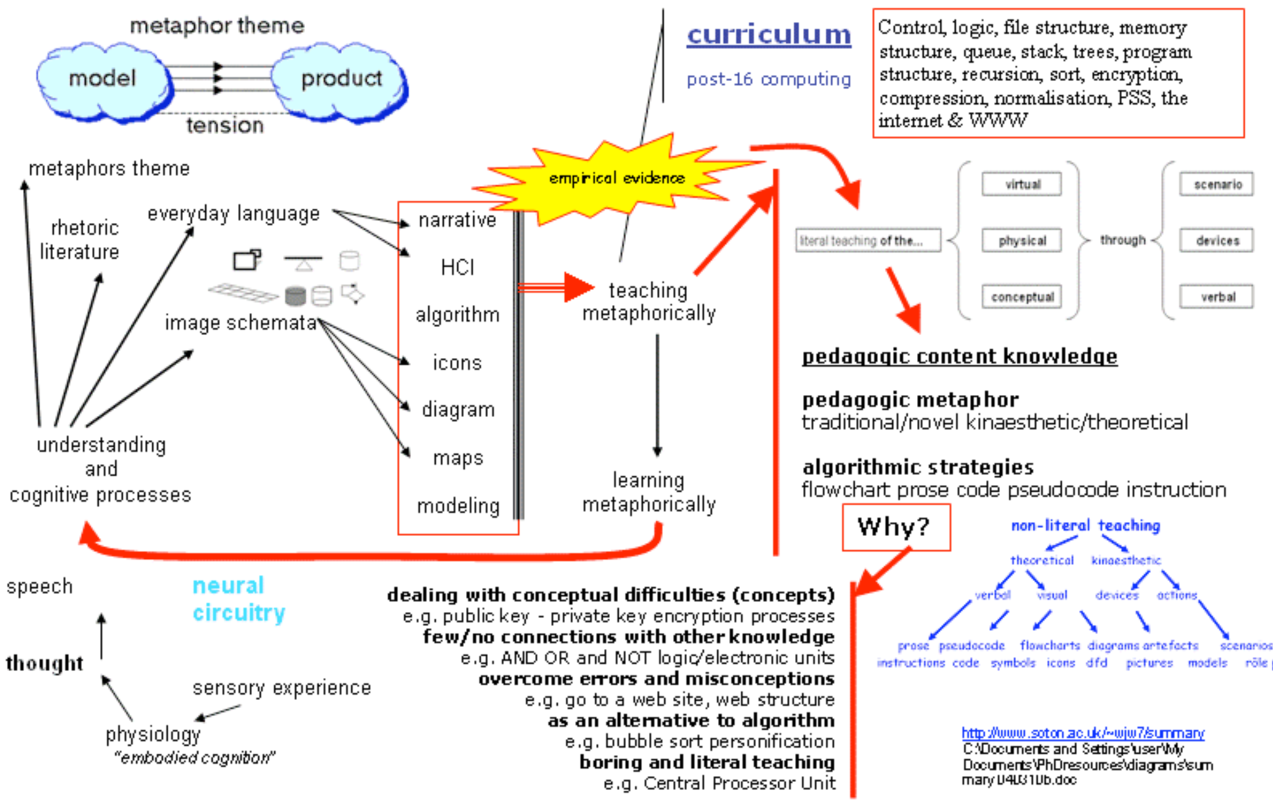


Figure 111 summary diagram

The diagram (Figure111.) reflects the cycle of thinking that has taken place. The literature review identified cognitive aspects of metaphor relating to language, thought and physiology (labelled **neural circuitry**). Arising from the language aspect are readings in **rhetoric**, **everyday language**, **image schema** and the **metaphor theme**. These then were considered in terms of metaphor within computing; literature on the metaphor-rich environment of human computer interface (**HCI**), **icons**, simulations, software design and **diagrammatic representation**. At that point **empirical evidence** was introduced, drawn from scrutiny of **curriculum** and policy documents, focus group work and teaching in the **post-16 environment**. This created and then used a set of **difficult-to-teach** computing topics and resulted in an analysis of **pedagogic content knowledge**. The final conclusions bear down upon the question of how and **why** those topics are taught and, combined back with the philosophies of metaphor relating to how we know, give an insight into how those topics are best taught. This is a major implication of the research findings.

9.2 Summary - physiology and embodiment

Metaphor exists in many fields of contemporary philosophical thought including language and communication, literature and rhetoric, cognitivism and physiology. The current premise within cognitive science is that understanding is an embodied feature of **physiology** or **neural circuitry** and that metaphor is a major structure of that embodiment. Most linguists contest that language is an expression of our understanding or our understanding is established through language. The metaphor is an important tool for explaining the relationship between language and learning. The literature review establishes the connection between **sensory experience, physiology, thought and the speech act**. Metaphor is related to **literature and rhetoric**. It is an artistic device to enable more colourful and stimulating writing and speech. It is a means of conveying meaning at a level not possible by the use of literal words. An implication of this research is that consideration has to be given to the situation where teachers deny their use of metaphor. Metaphor is also an aspect of the **everyday language** we use.

9.3 Summary - metaphor definition

This thesis takes as its definition a **model-product** structure of **metaphor theme** with associated **tensions**. Metaphor is any description or utterance that is not the literal truth and metaphors are sets of alternative labels or reorganisations including diagram, model and algorithm. A metaphor theme exists when the name of a familiar or primitive artefact, system or concept (model) is used in reference to a novel artefact, system or concept (product). Discontinuities between the model and product are tensions. This relationship between model and product with associated tensions has the icon  and a diagram (within the summary diagram above).

The other tropes of the English language associated with metaphor are described to more clearly sharpen our image of metaphor by describing that which is and which is not metaphor. They include: metonymy, synecdoche, simile and analogy. Myths and mixed metaphors have significance in this work.

The categorisation of metaphor is based upon an embodied physiological model. The description of computer-based metaphor focuses on the **image schemas** such as: container, surface, source-path-goal, link, part-whole, near-far, centre-periphery, up-down, front-back, linear as described by George Lakoff and how the understanding of concepts can be represented by the image schema. Some of these are represented in the summary diagram above and graphically in Figure 112.

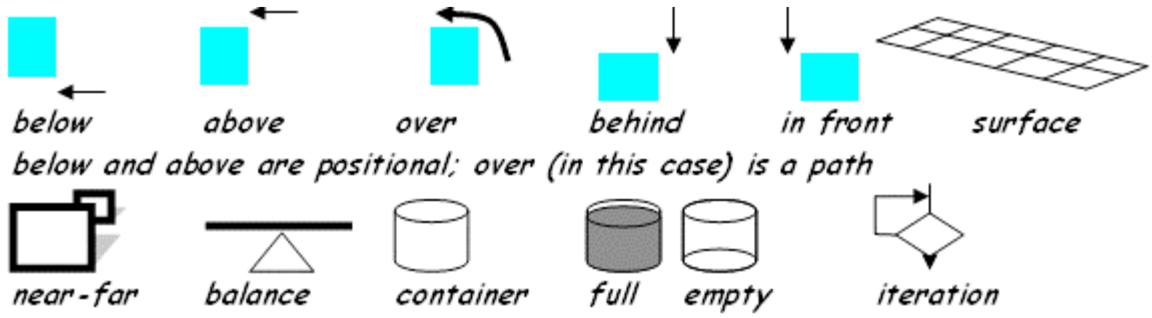


Figure 112 diagrammatic representation of some image schema

Appendix 7 relates the image schema to the pedagogic metaphors derived as a result of the research.

The literature review of metaphor in the world of computing and the computing curriculum reflects the key features of: categorisation, virtual activity, human computer interaction (**HCI**) and problematic metaphors. The review considers being, doing, naming and located metaphor and then the metaphoric aspects of the computer graphic user interface (GUI) including **icons** and software design. The computing curriculum is rich in metaphors of **maps, diagrams, modelling and algorithm**.

This research is about how teachers make the link between the curriculum and learners' understanding. It is also about the rôle of metaphor in that process. **Pedagogic content knowledge** is illustrated through reference to a range of authors whose work has a direct bearing upon the teaching of computing. That research is concerned with illustration, example, explanation, and demonstration. These are useful forms of representation of subject knowledge.

9.4 Research methodology

The study is carried out through using two research methods, the guided interview and the grounded theory method. The research style is second person and fourth generation with a therapeutic style of interviewing. The ethical aspects of the research are considered and the issues discussed. The grounded theory method is adopted and QSR-NVivo software employed to carry out the analysis of the data. Figure 113. reflects the data sources and the aspects of processing and the identification of the stakeholders in the research and the factors influencing the ethical conduct: professional conduct (1); pursuit of truth (2); informed consent (3); protection of anonymity (4); disclosure of public interest (5) and endorsement of research (6).

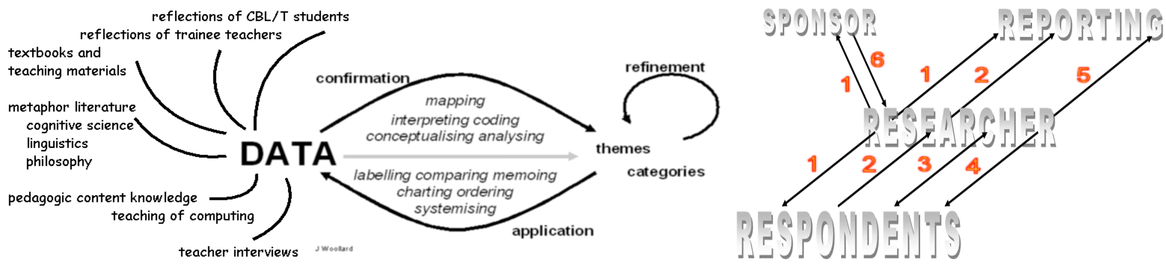


Figure 113 data sources of the grounded theory approach and the ethical dimension

The sample group is chosen through a process of purposeful sampling. The respondents are drawn from the small number of teachers with training responsibility in the University partnership schools. The selection is based upon the teacher's experience in teaching GCE level computing. The breakdown of the types of teacher interviewed shows a bias towards post-16 establishments rather than 11 to 18 schools. This is a direct consequence of the nature of LEA education structure in the immediate area of the University.

A premise of this study is that the most interesting and diverse strategies to support learning will take place when the most challenging topics are being taught. These topics are identified through the scrutiny of documents, experience of teaching and the use of a focus group study and form then the basis of the interview schedule. The results of this study are primarily based upon the statements of successful and experienced teachers of computing recorded as transcripts of structured interviews. In addition, a number of formal and less formal data gathering activities both supported and cross referenced the developing theories; they included observation of trainee teachers teaching the same topics; scrutiny of text books and examiner reports and discussions with colleagues.

This final section presents the conclusions to the thesis in three parts. It describes the answers to the original research questions (Figure 114.) A self-evaluation is conducted and reported on and the new perspectives revealed by the research are described. Finally, ideas for future research that build upon the conclusions are proposed.

9.5 Research questions answered

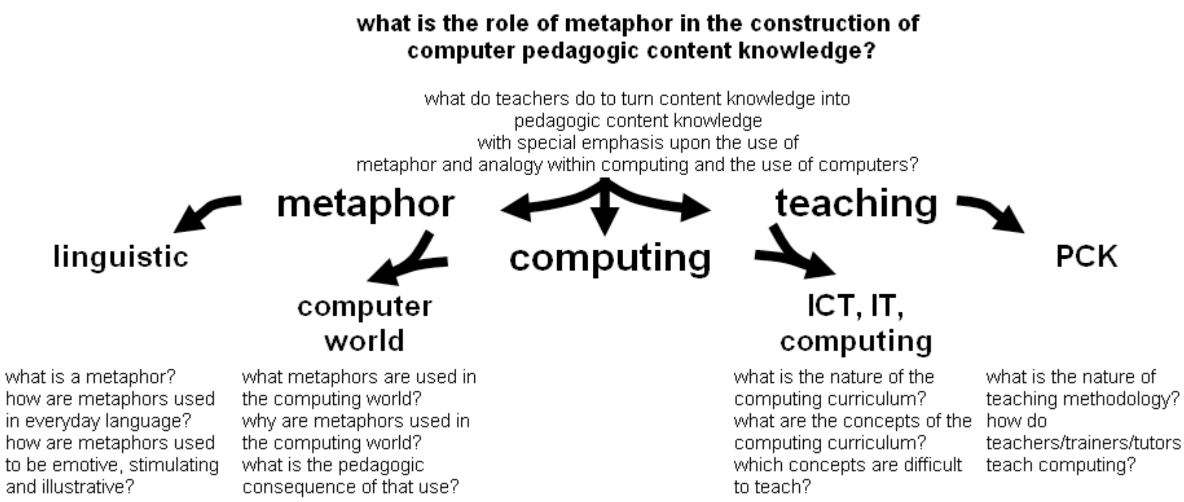


Figure 114 research questions

In this section, each of the research questions will be considered and an answer to the principle question "what is the role of metaphor in the construction of computer pedagogic content knowledge?" emerges.

- what is a metaphor?
- how are metaphors used in everyday language?
- how are metaphors used to be emotive, stimulating and illustrative?

The question "what is a metaphor" can be answered in many ways. Metaphor appears to be many things to many people. However, there emerged two very different concepts which appear to have a resonance with teaching and learning. The first interrelates ideas of physiology and the embodiment of knowledge and understanding with structures of image schema. They help interpret the diagrams, icons and other approaches used in pedagogic content knowledge. This gives justification or explanation of the teaching approaches. The second conception of metaphor is the metaphor theme - the wilful association between a known idea and a new idea enabling a better understanding of the new by generalisation from the old. This is the underlying principle of the pedagogic metaphor. It is also related to the design features of the graphic user interface and application software. The use of metaphor in everyday language reflects these both ideas: metaphor theme and image schema. The emotive, stimulating and illustrative aspects of metaphor appear to arise from the physiological and cognitive connections.

- what metaphors are used in the computing world?
- why are metaphors used in the computing world?
- what is the pedagogic consequence of that use?

The world of computing is rich with metaphor at every level of understanding metaphor. The language used, new words invented, systems developed and the curriculum approaches. The image schema interpretation has very strong implications. For example, the differences between the cognitive constructs of surface and container are illustrated by surfaces such as the desktop, Internet and hard drive. People say that they are going onto the Internet or saving onto their hard drive or floppy disc. In contrast, there are a number of containers. Files are placed into a folder and data is placed in documents. Other image schema include: attaching files to emails (object), absolute addressing of resources and/or references (path), comparing values of computers in terms of memory (mass-count) and repeated activity within programs (iteration). The metaphor theme is prevalent in the features of the graphic user interface/desktop environment. The use of iconic representation and virtual activity such as drag and drop are metaphoric in nature. Software designers, such as those for Macromedia Director, adopt novel metaphor themes as a way of making the processes more accessible by novice users. Traditional applications such as word processor, spreadsheet and desktop publisher retain the language and features of the historical processes such as upper/lower case, pasting and scrolling. Other operations have become iconised.

Those responsible for developments in computing are working in a fast changing world; they are working at the extremes of human knowledge and they are specialised in what they do. Communication is challenging because it needs to explain new functions and properties yet do so in an effective and efficient manner. Metaphor is a way of creating short-cuts to new language. Much of the naming of new devices, concepts and procedures are metaphoric in nature including recent developments as virus, worm, Trojan Horse, walled garden and firewall. The familiar words and concepts can be misconstrued when applied to the computer environment. A consequence is that both inexperienced teachers and learners make errors or have misconceptions.

- what is the nature of the computing curriculum?
- what are the concepts of the computing curriculum?
- which concepts are difficult to teach?

The computing curriculum is highly fragmented. Computing is represented by a range of examination specifications at different levels of academic/vocational/key skills levels of attainment and a wide range of subjects. In particular, the differences between ICT (as a curriculum subject) and computer studies and also ICT (as a key skill for implementation across the curriculum) lead to different understandings about the nature of the subject. The difficult-to-teach topics of this study were drawn, in the main, from the computing curriculum. The concepts of computing are those areas of the specifications that are not bodies of knowledge to be remembered but the systems and artefacts that require understanding to enable them to be applied to novel situations. The difficult areas of the curriculum were readily identified by teachers and, in the main, remained constant throughout the research processes of interview, reflection and cross checking with the literature. The difficult-to-teach topics are: control, logic, file structure, memory structure (queue, stack, and trees), program structure, recursion, sort, encryption, compression, normalisation, PSS, the internet and WWW.

- what is the nature of teaching methodology?
- how do teachers/trainers/tutors teach computing?

The nature of teaching in computing, as in many aspects of education, is variable across institutions, teachers and curriculum. The findings bring some order and a proposed structure to that variability with regard to how teachers tackle the difficult elements of the curriculum. The teaching methodology is seen to be both literal and metaphoric in nature. There is a defined list of approaches exemplified in the research data including: prose, pseudocode, flowcharts, diagrams, simulations, artefacts, scenarios, instructions, code, table, symbols, icons, pictures, applications, models and rôle play. There is a clear emphasis upon the algorithmic approaches (instructions, code, pseudocode, flowcharts and scenario), which is explained by considering the nature of the curriculum and the background of the teachers. The motivations for using metaphor in pedagogic content knowledge include overcoming conceptual difficulties because there is no connection with the learner’s current understanding or there are errors and misconceptions. Metaphor is used as an alternative to algorithm and to raise motivation and interest when teaching boring aspects of the curriculum.

Finally, in this research questions section, the challenge is set:

- what do teachers do to turn content knowledge into pedagogic content knowledge with special emphasis upon the use of metaphor and analogy within computing and the use of computers?

Teachers of computing use a wide range of approaches in their teaching. Many of those approaches are metaphoric in nature - they are those that are not literally true. They use forms of organisation to represent the artefact, system or concept being taught. There are also contrasting examples of literal teaching which enable “real life” and situated learning to occur. Although literal teaching is associated with inexperienced teachers and is simply verbal repetition of a textbook definition, there are positive justifications for literal teaching. There appears to be an emphasis upon the metaphoric approaches that are underpinned by algorithm - teachers use the practices of the computing discipline. Flowcharts and pseudocode are both of the curriculum and of teaching of the curriculum. They exemplify disciplinary authenticity, but as David Shaffer points out, “disciplinary authenticity assumes the existence of coherent, academic disciplines with rules of enquiry, and further assumes that students should learn to use these tools for thinking in the way academicians use them” (Shaffer and Resnick, 1999: 199). It was an aim of this thesis to bring a greater clarity to the discipline of teaching computing by identifying the activities of pedagogy; the developed taxonomy is a major aspect of that clarity.

9.6 Limitation in the thesis

This section identifies those areas of the study that either: led to concerns during the progress of the work or those that, upon reflection, could or should have been dealt with in a better way during the process. These fall under the headings of: literature review foci; sample group and method; theorising iterations; and timeliness.

The literature review grew and developed organically. It was directed by the research questions but the apparent balance between the sets of sub-questions does not properly reflect emphasises and importance of the different contributions of literature to the developing theories. On reflection, the works contributing a better understanding of tropes, rhetoric and physiology of metaphor are perhaps over-represented in their importance and contribution to the theory on the use of metaphor in the PCK. A greater emphasis might have been placed upon readings from pedagogy and pedagogic content knowledge. In part this was a result of the starting point which focussed upon metaphor.

The sampling was purposeful but the sample group is not fully representative of all teachers of computing. The sample is skewed towards those teachers that participate in initial teacher training through one higher educational institute. Although it may be representative of the computer teaching body as a whole there is little evidence to support the notion other than the fact that different styles of pedagogic approach were observed and they did represent aspects of pedagogy at either end of the proposed spectrum of approaches. The sample is also skewed to teachers working in institutions teaching only the 16-18 years age-range of pupils. A higher representation of 11-18 school teachers or teachers working in adult education teaching the same curriculum may have generated different emphasises. The sampling method was opportunistic; the selection was made on the basis of convenience and availability.

The grounded theory method was adopted as it best met the needs of the research aims. Although an ethnographic study of teachers and their teaching world would have been a satisfying and revealing approach, the time restrictions (on both the part of the researcher and the respondents) meant that it was not feasible. On the other hand, a survey approach would not have engaged the respondents and much of the idiosyncratic, individual data would have been lost and probably made this quest unsuccessful. The success and validation of the grounded theory method requires that the iterations of theorising reach saturation point. It is with confidence that the theory has not been contradicted by the data gathered and that it appears to be refined enough to be of value. However, when can researchers be sure that further data will not lead to amplification of the theory or, indeed, refutation of the theory? A limitation of the thesis is falsification (in the Karl Popper sense) cannot be proven; in the computing classrooms of the world "are there other approaches to pedagogic content knowledge that cannot be subsumed within the structure of this taxonomy?"

In the year 2000 there was a significant change to the teaching of post-16 examinations. The introduction of Advanced Subsidiary (AS) and Advanced (A2) examinations with 4 examination periods during the two years of study caused teachers of computing to focus their attentions on curriculum management and assessment criteria. There was less emphasis on developing subject knowledge and pedagogic content knowledge. The curriculum shrank; programming for many institutions was reduced to Visual Basic for Applications in Microsoft Excel and Access. Time pressures meant that exploration of the subject away from the specification became very limited and opportunities for tackling more interesting topics or the topics of the teacher's expertise within their teaching were reduced. This research was not of the time; it was not reflecting the current pressing issues of the teaching fraternity. However, it is of crucial importance in developing the pedagogy of computing.

This work had limitations that might have been avoided through design. Others were a consequence of the time and place of study. The most likely impacts of those limitations are that the conclusions fail to:

- report the full range of pedagogic content approaches available to computing teachers;
- assign the correct level of importance of algorithm in the pedagogic content approaches of computing teachers; and
- take into account the influence of the most recent changes to the curriculum and the new pressures on teachers.

However, it is unlikely that the connection between image schema and the metaphors of computing and computing pedagogic content knowledge is incorrect and it is unlikely the general conclusion, metaphoric approaches have a significant rôle, is incorrect.

The contribution this research makes to the body of knowledge associated with the teaching of computing is reflected in the next section.

9.7 The new perspectives

This thesis seeks originality through the synthesis of a structure. It is an interpretation of classroom teaching in the light of metaphor theory. As a result, the work will make explicit implications for the training of teachers and would-be teachers. The new perspectives that this study reveals are reported with the teacher training motivation in mind.

The primary finding is the identification of metaphor that occurs within pedagogic content knowledge. The findings of the study reinforce the idea that pedagogic content knowledge is at the interface between teachers' classroom craft skills and the curriculum content. It is an aspect of subject knowledge but is much more sophisticated that simple knowledge. The theory of pedagogic content knowledge is now different as a result of this study - there is taxonomy.

literal teaching

Literal teaching is described to enable a clearer definition of metaphoric teaching approaches. Literal teaching is divided into three types: teaching based upon scenario or socio/technical systems; teaching based upon artefacts or physical devices and teaching based upon verbal description.

pedagogic metaphor

The term "pedagogic metaphor" is introduced and described in terms of approaches to teaching and a taxonomy based upon theoretical/kinaesthetic and novel/traditional examples is established. Novel pedagogic metaphors are those created by individual teachers to meet their learners' needs or their own teaching style. They are based upon a concept which is familiar to the learners and one where the teacher is comfortable with making the connections.

taxonomy of approaches

The metaphoric approaches include those based upon diagrammatic representation, kinaesthetic metaphor form (doing, being, moving or making), theoretical metaphor form (thinking, writing, describing or imagining) and algorithmic structure.

metaphoric misgivings

The problems associated with metaphors are considered when analysing the teachers' interview responses. They are identified as being incomplete, inaccurate, inappropriate rhetoric, unknown model and inappropriate reporting (within examinations).

metaphoric motivations

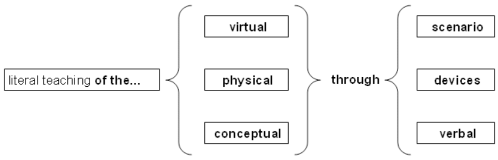
Different teachers choose metaphors for very different reasons. The vast majority of examples relate to ensuring a better understanding of difficult or unfamiliar topics. However, they are also used to raise the interest level of some topics and to ensure the learners engage in the learning process.

algorithm

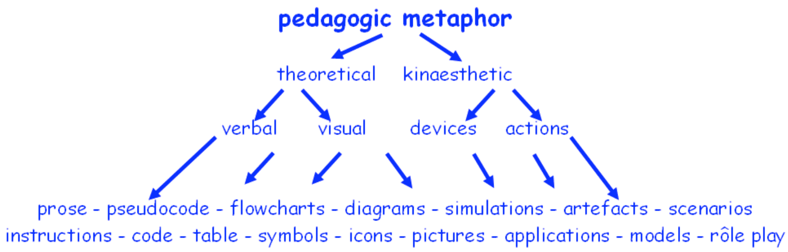
The metaphoric approaches to the teaching of computing are: prose, pseudocode, flowcharts, diagrams, simulations, artefacts, scenarios, instructions, code, table, symbols, icons, pictures, applications, models and rôle play. From these are identified those that are algorithmic in nature: instructions, pseudocode, code, flowchart, model, simulation and scenario.

representation

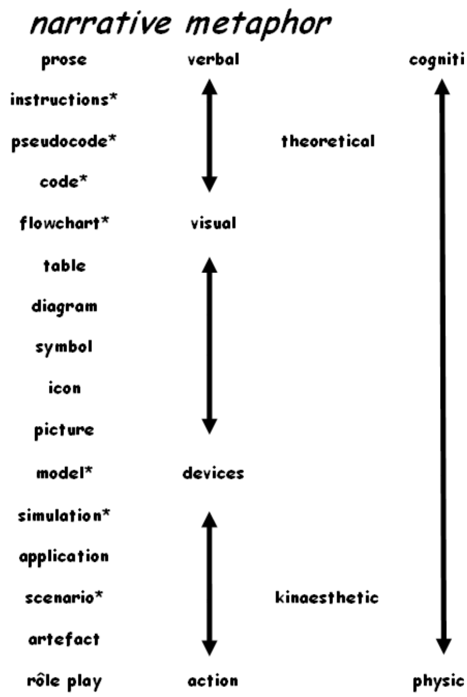
There are three significant representations relating to the findings of the study.



literal teaching of the virtual, physical and conceptual



pedagogic metaphors within the teaching of computing



pedagogic metaphor and theoretical constru

Figure 115 thumbnails: literal teaching and pedagogic metaphor taxonomy

The first describes literal teaching (Chapter 7 section 7.3). The other two represent pedagogic metaphor, the first as a hierarchy arising from the analysis of the data of the study (Chapter 8 section 8.1); the second relating the pedagogic metaphor to theoretical constructs (Chapter 8 section 8.3). Figure 115. represents them as thumbnails.

9.8 Key points arising

This research has both extended my understanding of the pedagogic processes and reinforced and supported many of the ideas I proffered in my previous teaching. It contributes to the discussion of pedagogic content knowledge not only taxonomy of teaching approaches but the underpinning rationale for placing teaching approaches within that structure. Most importantly, the research has given a foundation for those ideas and provided a structure onto which I can now build a model of pedagogic content knowledge that will support my teaching and my teacher training.

Metaphor is a many-headed beast that requires considerable taming if it is to be an unconditional benefit to the teaching process.

The key points arising from this work are:

Although teachers are not brain surgeons, the underpinning physiology and associated image schema, as outlined by Lakoff and Johnson, have implications for pedagogic content knowledge, for how we go about designing teaching materials and presenting the curriculum. The rôle of image schema in understanding and perception of ideas is an important consideration when we devise metaphor based pedagogic strategies.

The metaphor theme concept, with its important consideration of tensions, can ensure that the negative implications of metaphor use are avoided or minimised. Recognition that the tensions that exist between model and product are beneficial in raising cognitive engagement should be made. This has implications for the emotive and stimulating aspects of metaphor.

The rôle and derivation of computer based metaphors, including the human computer interface, software systems, icons and vocabulary, are more clearly identified and the implications for teaching are better understood.

The difficult areas of the curriculum are associated with understanding of procedures, artefacts and systems and that those difficult areas are taught in a range of different ways by different teachers. This research has identified teachers who prefer algorithm, those that prefer kinaesthetic pedagogic metaphors and those teachers who actively create their own metaphors. The focus of the work has been upon the pedagogy associated with difficult-to-teach topics. It has not illuminated the reasons why teachers tend to prefer or use specific methods. However, the identification of those teaching style preferences has important implications for initial teacher education.

The rôle and value of literal teaching has been identified and seen to be a valuable part of the teachers' arsenal in the fight to help learners meet the needs of the curriculum and education system.

Algorithm is important in both the curriculum and the pedagogy of computing. Algorithm and other metaphoric approaches contribute to disciplinary authenticity.

The pedagogic metaphor is a definable aspect of teaching and has taxonomy. That taxonomy enables educationalists to identify the salient features of approaches used by teachers. It meets the requirements of taxonomy in that the elements are: mutually exclusive; comprehensive; unambiguous; acceptable; reliable and gives an insight pedagogic content knowledge. This is where this research has contributed to understanding of the issues of teaching the computing curriculum.

9.9 Future research

This research has been a rewarding and satisfying experience, if only to establish a rationale for my own thinking and actions. More importantly, it sets the basis for future investigation. Five key research issues now appear to be important for me but first there will need to be a substantiation of the findings by exposing them to a more rigorous and widespread usage and criticism by colleagues in the teaching of computing field. The developing questions are:

can metaphor be engineered to help teach more areas of the computing curriculum?

The evidence from interview shows that some teachers positively create metaphor as part of their pedagogic content knowledge. Each topic is presented by someone's pedagogic metaphor. The key question is: can all other areas of the curriculum be effectively taught using pedagogic metaphor?

can elements of the curriculum be taught at a younger age as a result of using appropriate pedagogic metaphor?

An interesting observation is that some metaphors use would appeal to a younger audience. Some of the topics, such as recursion, are reserved in the UK to the curriculum of older students. The key question is: can the implementation of a new range of pedagogic metaphor enable the more difficult-to-teach topics to be taught at a younger age?

can motivation towards learning about computing be enhanced through the use of pedagogic metaphor?

The engagement of pupils and students in the computing curriculum appears, through the implication of reference to "boring", to be limited by interest and motivation. The key question is: can the implementation of a new range of pedagogic metaphor encourage the uptake of ICT and computing as a subject discipline and motivate pupils in their learning?

can the teaching of ICT capability by non-specialist teachers be enhanced through the use of pedagogic metaphor?

Computing, as represented by cross curricular ICT in Qualifying to Teach S3.3.10 (TTA, 2002: 13) and the new developments in ICT capability (CBfT, 2004) are taught, in the main, by non-specialist teachers. Both curricula have an emphasis upon skills and process and not capability and understanding. The key question is: can the introduction of appropriate pedagogic metaphor equip the non-specialist to be able to teach capability and understanding instead of being limited to skills and process?

how can pedagogic metaphor approaches be more rigorously promoted in initial teacher training?

The current emphasis of initial teacher training in the UK has a pre-disposition toward classroom management techniques, curriculum content and assessment. Pedagogic content knowledge in any form does not focus highly. The key question is: can the introduction of appropriate pedagogic metaphor take place to enhance trainees' ability to meet the training requirements (TTA, 2002: 12) with regard to teaching skills?

These questions will form the basis of my future research. They will help in the goal of bringing more rigorous computing into the curriculum of younger pupils and thus enable a larger number of pupils to reach post-16 education able and willing to take on the challenges presented by computing education and degree level computer science.

This study of metaphor has opened my eyes to the potential of a range of non-literal approaches to teaching and the necessity for explaining those approaches to teachers in their initial teacher training.

John Woollard

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Appendices

Appendix 1 A to Z of computer metaphors

Metaphors in teaching with and about computers

Absolute

absolute path, absolute zero, absolute reference

What is the computer meaning of the term and how does it relate to the English meaning?

Bookmarks

This is an old word applied to a new concept and giving an implied meaning. The vehicle is the **bookmark**, a piece of paper or card with your name on it or some picture or pattern that you can readily identify as your own, placed in a book, magazine or journal to physically locate text of interest or, more usually, the point reached in a reading session.

What is your understanding of the computer term bookmark?

In what ways is it similar to a traditional bookmark?

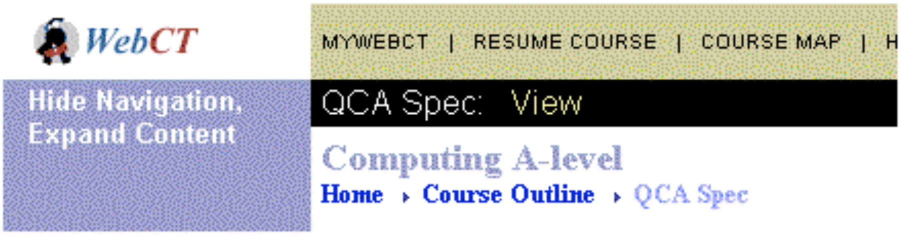
In what ways is it different from a traditional bookmark?

What errors and misconceptions do you think may occur in the learners you teach?

The meaning implied by the use of the word **bookmark** in an internet browser is that a marker is placed in the reading material (the worldwide web) at the point of interest. It is given a name equivalent to the picture, pattern or name that identifies the physical bookmark. The tension is great. The potential for error and misconception is high. One student quoted as saying 'I've been on the internet in the library and **bookmark-ed** lots of interesting sites; when I got home and looked on the internet the bookmarks were not there'. A characteristic of a bookmark is that it is physically located in the material. A worldwide web bookmark is not located on the worldwide web – it is located in the computer's software (the browser) being used. The name bookmark is misleading.

Breadcrumbs

The term breadcrumb relates to the tale of Hansel and Gretel from the Brothers Grimm, where they dropped little bread crumbs while they were entering the forest in order to find their way back. As websites have become deep dark forests of information, where the users can easily get lost, a need has arisen for help with navigation. The breadcrumb allows the user to see where they have come from and the route taken.



Home ► Course Outline ► QCA Spec is a breadcrumb trail.

In what ways are breadcrumbs similar to the Hansel and Gretel idea?

In what ways are they different from traditional breadcrumbs?

What errors and misconceptions do you think may occur in the learners you teach?

Click, beep and bug

Onomatopoeia – what other examples?

Cookies

A cookie is a piece of text that gets entered into the memory of a browser. It contains the domain, path, lifetime, and value of a variable that a website sets and can be read by websites when they are visited. To put it more plainly, a cookie is a mechanism that allows a web site to record your comings and goings, usually without your knowledge or consent. The name cookie derives from UNIX objects called magic cookies. These are tokens that are attached to a user or program and change depending on the areas entered by the user or program.

What parallels exist between the American biscuit and the web browser device?

A cookie is a handle, transaction ID, or other token of agreement between cooperating programs. "I give him a packet; he gives me back a cookie". The claim ticket you get from a dry-cleaning shop is an example of a cookie; the only thing it's useful for is to relate a later transaction to this one (so you get the same clothes back). Typically cookies are used to authenticate or identify a registered user of a web site without requiring them to sign in again every time they access that site. Other uses are, e.g. maintaining a "shopping basket" of goods you have selected to purchase during a session at a site, site personalisation (presenting different pages to different users), tracking a particular user's access to a site.

Cut, copy and paste

“cut and paste" refers to the paper, scissors and glue method of document production. It is a system supported by most document editing applications (e.g. text editors) and most operating systems that allows you to select a part of the document and then save it in a temporary buffer (known variously as the "clipboard", "cut buffer", "kill ring"). A "copy" leaves the document unchanged whereas a "cut" deletes the selected part. A "paste" inserts the data from the clipboard at the current position in the document (usually replacing any currently selected data). This may be done more than once, in more than one position and in different documents. (GNU Emacs uses the terms "kill" instead of "cut" and "yank" instead of "paste" and data is stored in the "kill ring".)

Without looking at the toolbar could you describe the three icons used to represent these actions?

Are these pedagogically grouped or do you teach highlight/mark, copy, paste and highlight/mark, cut, paste? What is the significance of the words to today’s learners?

Desktop

This is considered to be the ‘biggest’ metaphor used in contemporary computing as it encompasses the whole of the human computer interface. List aspects of ‘desktop’ that both apply to the computer screen and the traditional desktop:

Drag and drop

The user moves the pointer over an icon representing a file and presses a mouse button. He holds the button down while moving the pointer (dragging the file) to another place, usually a directory viewer or an icon for some application program, and then releases the button (dropping the file). Holding certain keys on the keyboard at the same time can often modify the meaning of this action. Some systems also use this technique for objects other than files, e.g. portions of text in a word processor.

The biggest problem with drag and drop is does it mean "copy" or "move"? The answer to this question is not intuitively evident, and there is no consensus for which is the right answer. The same vendor even makes it move in some cases and copy in others. Not being sure whether an operation is copy or move will cause you to check very often, perhaps every time if you need to be certain. Mistakes can be costly. People make mistakes all the time with drag and drop. Human computer interaction studies show a higher failure rate for such operations, but also a higher "forgiveness rate" (users think "silly me") than failures with commands (users think "stupid machine"). Overall, drag and drop took some 40 times longer to do than single-key commands.

Files and folders

Consider the terms: file, folder and directory and how they are used with your learners. How are they defined? Consider field, record and file. How are they defined and how do they relate to the first list. Which terms are used metaphorically? What misunderstandings may occur?

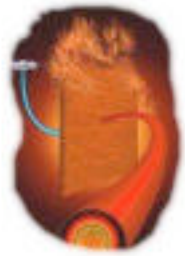
In a graphical file browser directories are traditionally depicted as folders (like small briefcases or card sleeves).

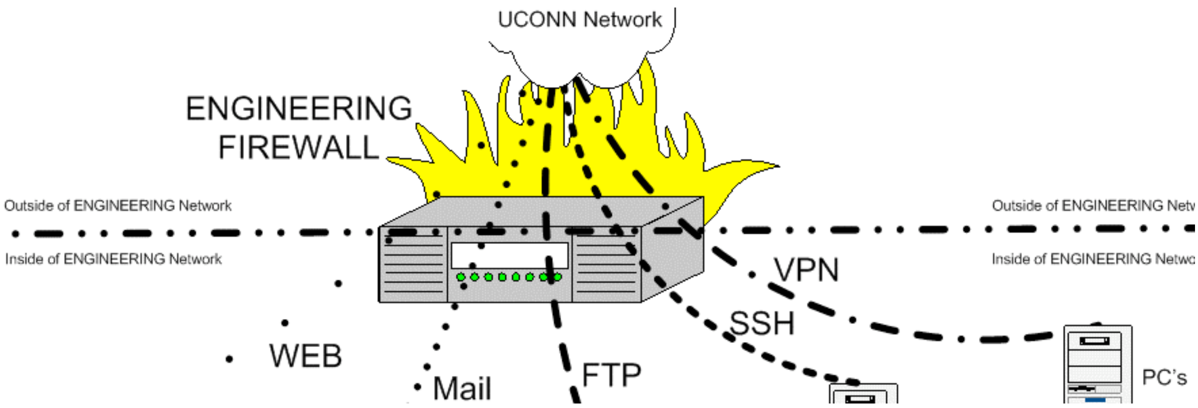
The features of a file are a single sequence of bytes, of finite length, stored in a non-volatile storage medium, with characteristics/properties, in a directory, with a name and a path.

Firewall

Description: a dedicated gateway machine with special security precautions on it, used to service outside network, especially Internet, connections and dial-in lines. The idea is to protect a cluster of more loosely administered machines (or of late, a single machine) hidden behind it from crackers/hackers. The typical firewall is an inexpensive microprocessor-based Unix machine with no critical data, with modems and public network ports on it, but just one carefully watched connection back to the rest of the cluster. The special precautions may include threat monitoring, call-back, and even a complete iron box keyable to particular incoming IDs or activity patterns. Firewalls often run proxy gateways.

The visual metaphor





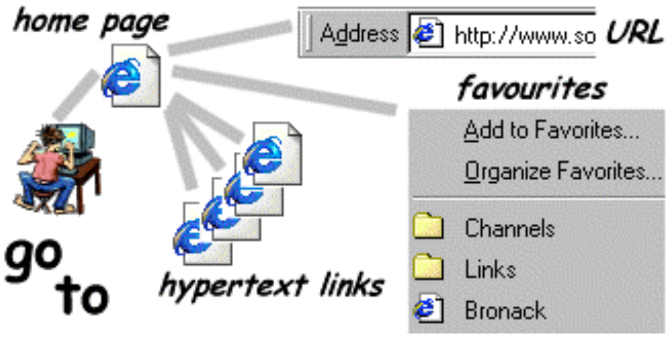
How is a firewall described to a novice?

Fragging

What is your understanding/use of fragging (coalesce files and free space on a file system)?

Further information: in contemporary file systems as space is used and files are deleted and created, the total free space becomes split into smaller non-contiguous blocks (composed of "clusters" or "sectors" or some other unit of allocation). Eventually new files being created, and old files being extended, cannot be stored each in a single contiguous block but become scattered across the file system. This degrades performance as multiple seek operations are required to access a single fragmented file. Defragmenting consolidates each existing file and the free space into a continuous group of sectors.

'go to' on the worldwide web



Do you use the phrase ‘go to’?

What is the learner’s understanding of the phrase ‘go to’?

Icons

;-) :-o

Also consider: micons, picons, earcons, indicons (symbols) and emoticons (Gayer, 1989).

What is the relationship between metaphor and the icon?

Memory

Computer memory is an abstract in the sense that only the tiniest minority of the people using the word has any knowledge of the actuality of ‘computer memory’. It is a ‘thing’ spoken about by most computer users. Like money it has the following properties: it can be represented as symbols (Mb, Gb and K); it has an intrinsic value; it can be used; it obeys the rules of mathematics and it is always present in computers. It is abstract in that it has no (readily available) physical appearance and one that we have little control. The linguistic metaphor is drawn through our use of language to describe the indescribable. We spend money; we use up the memory. We can talk about saving memory and saving time. ‘Running out of’, ‘wasting’ and ‘having’ are verbs associated with money and computer memory. How is computer memory described to your learners?

Metonymy

‘Netscape has made a new attack upon Microsoft today’

‘Internet access in my college is limited by keyboards’

Examples of metonymy in computing:

Recycle Bin

In what way is the computer feature represented by the icon  a recycle bin?

What other, more distinct functions does it possess?

What errors and misconceptions can occur?

Rubber band

Slideshow

Software metaphors: book, director, spreadsheet

http://www.cblt.soton.ac.uk/metaphor/example.exe or http://www.soton.ac.uk/~wjw7/a-z/example.exe (warning: large file)

Spamming

What does it mean? What is flaming?

Surfing, browsing and grazing

What are the meanings of these verbs?

Trashcan for delete

What is your opinion of closing a floppy disk using an Apple Macintosh computer?

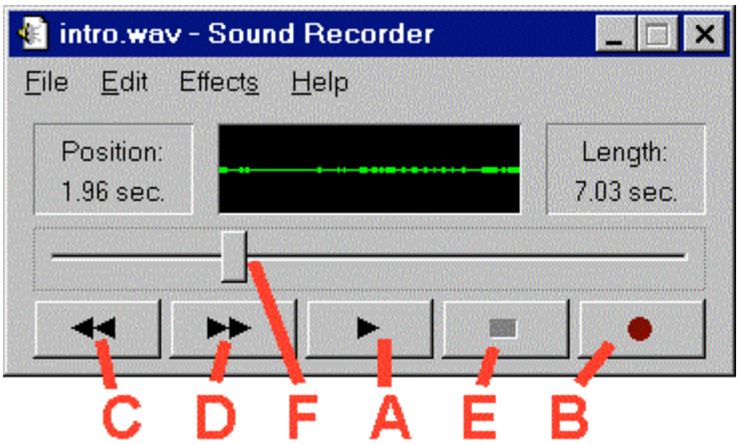
What is the difference between a trashcan and a recycle bin?

Trojan Horse

The term was coined (metaphor) by MIT-hacker-turned-NSA-spook Dan Edwards. It is a malicious, security-breaking program that is disguised as something benign, such as a directory lister, archiver, game, or (in one notorious 1990 case on the Mac) a program to find and destroy viruses! A Trojan horse is similar to a back door.

Describe the traditional Trojan Horse and the features you would therefore expect a computer Trojan Horse to possess.

Video controls



What assumptions do we make about a novice user's knowledge?

Virus

http://www.soton.ac.uk/~pgce\it\security\secure6.htm

Describe a virus:

Walled garden

How do you explain the concept of 'permit lists' in internet usage?

Worm

The phrase originates from the "Tapeworm" in John Brunner's novel "The Shockwave Rider" and describes a program that propagates itself over a network, reproducing itself as it goes. How would you delineate a worm from a virus?

Yahoo

Yet Another Hierarchical Officious/Obstreperous/Odiferous/Organized Oracle.

The extensive use of the term brings a new meaning to it – a good example of social cognitivism in action. Metonymic use of Yahoo encompasses all search engines. What is your learners understanding of the term Yahoo?

Zapping

Zapping is the lowest form of software programming known to mankind. It involves altering the assembly code in hex format after it has been output from a compiler or assembler. Done typically when there is a compiler bug, the proper data is not being generated or original source code has been lost. Origin: comes from the old IBM mainframe days of the 1960's where field units were updated in the exact manner.

Zip

What is the concept of compression?

Finally, consider:

When is analogy and simile established as metaphor?

When does the computer metaphor become literal?

Appendix 2 PCK literature review

PCK

of computing

in post-16 education

and initial teacher training

The definitive list of journals to be

consulted and articles identified for review

General teacher education articles with reference

to any computer OR PCK description and research

General teaching strategies	PCK in any subject teaching	PCK in computing teaching	Computing teaching strategies

Algorithmica: an intern journal to CS http://www.swetswise.com/link/access_db?issn=1432-0541

Computer journal http://www3.oup.co.uk/computer_journal/contents/

Computergram http://www.niss.ac.uk/news/computergram.html

Computers and education http://www.sciencedirect.com/science/journal/03601315

Computers In human behaviour http://www.sciencedirect.com/science/journal/07475632

Computing http://www.swetswise.com/link/access_db?issn=1436-5057

Interacting with computers http://www.sciencedirect.com/science/journal/09535438

Intern journal of human-computer studies http://www.sciencedirect.com/science/journal/10715819

Journal of computer assisted learning http://www.swetswise.com/link/access_db?issn=0266-4909

Theoretical computer science http://www.sciencedirect.com/science/journal/03043975

Teaching and teacher education http://www.sciencedirect.com/science/journal/0742051X

Teaching in higher education http://www.catchword.com/rpsv/cw/carfax/13562517/contp1.htm

Journal of information technology for teacher education http://www.triangle.co.uk/jit/index.htm

Journal of education for teaching: International research and pedagogy http://www.catchword.com/rpsv/cw/carfax/13600540/contp1.htm

Innovations in teaching and learning in ICS http://www.ics.ltsn.ac.uk/pub/italics/index.html

Universal access in the info society http://www.swetswise.com/link/access_db?issn=1615-5297

Journal of the American society for information science and technology http://www3.interscience.wiley.com/cgi-bin/jtoc?ID=76501873

Journal of the American Society for Information Science http://www3.interscience.wiley.com/cgi-bin/jtoc?ID=27981

Journal of information technology http://www.catchword.com/rpsv/cw/routledg/02683962/contp1.htm

Appendix 3 Research Seminar

Presentation slide text

The following text represents the PowerPoint–based presentation to the Research Seminar Tuesday March 14th 2001.

The organising device for the presentation is the metaphor that the presentation is "climbing a mountain" and each step of the arguments is related to that walk. The visual image implied that metaphor is one of an important set of strategies that are used to enable learning.

the metaphor acts as a tool the metaphor is a tool for thought the metaphor is a means of extending our cognitive capacity

Three aspects of metaphors Compactness Vividness Inexpressibility

the metaphor acts as a tool

the metaphor is a tool for thought

the metaphor is a means of extending our cognitive capacity

Metaphoric terms

The model

The product

The tension

I have taken these two words (model and product) to describe that aspect of the real or known world (the model) on which a new system or structure is to be based (the product). Other authors use different terms including: topic, tenor, vehicle and ground (Richards 1956b). Black 1962b developed the interaction theory of metaphors. It is one of the earliest attempts to define metaphors and distinguish between those functional metaphors existing to promote a greater understanding and those that exist simply as a literary instrument to make writing more interesting. (He interestingly compares metaphors with games and Wittgenstein's (1953) assertion that there is no such thing as a game. The metaphor (game) is as real as the system that it is based upon. Importantly, that metaphors are studied as pragmatics (acts and conditions) and not semantics (meanings) (Stalnaker 1972). In the educational use of metaphor we are concerned with cognition and here Black's treaty is strong and illuminating in identifying the metaphor as a cognitive instrument.

Linearity and the metaphor

The metaphor as a speech act

The constructivist would say…

The behaviourist would say…

Vividness and the metaphor

The metaphor brings alive the experience. It puts colour to the picture. The mountainside is a picture in everyone's mind. (The small girl of the 1970's saying that she prefers stories on the radio to stories on the television because on the radio they are more colourful and more real.) The metaphor uses that feature of the mind that inter-relates the topic in hand with previous experiences - adding colour, structure and emotion.

Like most science educators, I tell lies.

The best demonstration I've seen of the ‘phases of the moon’ took place in a darkened lecture theatre with 90 would-be teachers seeing a Heath Robinson driven globe, a football and a torch. The script goes '… and this [pointing to the torch] is the sun and this [pointing to the football] is the moon' and for the next minute in the minds of sane adults that truth is solid and the learning is secured. The house lights go up, the spell is broken - it's just a torch and an ordinary football but the phases of the moon are 'understood'.

Inexpressibility and the metaphor.

The inexpressibility of some concepts in mere nouns, verbs, adjectives and adverbs forces to use other cognitive devices.

The literary application of the metaphor enables writers to express feelings of love, hope, wonder and pain through the physical, practical and everyday experience. The metaphor means that when we are at a loss for words then the substitute can be used.

A poem…

The mountain sat upon the plain,
Hat so white and shoulders grey.
Her children sat about her feet,
In verdant green and golden ray.
Aged by time measured in aeons,
Mother of all she purveyed.
Wrinkled, creviced by worry and care,
Protector, creator and maid.

The metaphor is just a tool.

I would like to propose another tool that supports memory and learning.

The 'writing frame' as another tool for enhancing memory and learning. Like the metaphor, the writing frame creates a structure to the data; the structure enables the more efficient construction of the information

'I'm going to tell you a story'. Everyone expects a start and an end and looks out for the boundaries of setting the scene and summing up or the punch line.

'I'm going to tell you the story of how the computer learnt to control the lighthouse'; this story has a plot (an intellectual thread) with characters that are introduced; they come into and out of the plot and have a bearing upon the final outcome.

The writing frame structures our thinking about the linearly perceived/experienced story and places upon it a two or three or more dimensioned understanding.

However, I have now used a metaphor relating the writing frame to good teaching practice and have better described the good 'lesson' by saying it IS a story with all the facets of a story described by our understanding of a story drawn out through our use of writing frames. I therefore conclude that the metaphor is the 'supertool' of literature and learning.

The danger of the pragmatic metaphor.

By selecting a metaphor that is to be accepted by many it will be immediately scrutinised for weaknesses. We believe that the metaphor is only as strong as its weakest link. The existence of a single tension between the model and the product brings discredit to the metaphor. (This contrasts to the literature world where the tensions heighten contrast and make the metaphor more vivid.)

Metaphor characteristics

Based upon the work of Mayer (1989) the following characteristics are indicators of an effective metaphor: complete, coherent, concrete, conceptual, correct and considerate.

considerate - the metaphor should use appropriate vocabulary and representation

correct - where a tension exists this should be clarified

conceptual - the underlying concepts should be clear

concrete - the structures and actions of the metaphor should be obvious to the learner

complete - the totality of the product should be represented by elements in the model

coherent - the level of detail should be appropriate to the needs of the learners

The big one - 1990's computer metaphors - the desktop.

That metaphor is worthy of and has been treated to much analysis.

Desktop, Director and the walled garden

Macromedia

http://www.cblt.soton.ac.uk/metaphor/example.exe or
http://www.soton.ac.uk/~wjw7/a-z/example.exe (warning: large file)

The Walled Garden

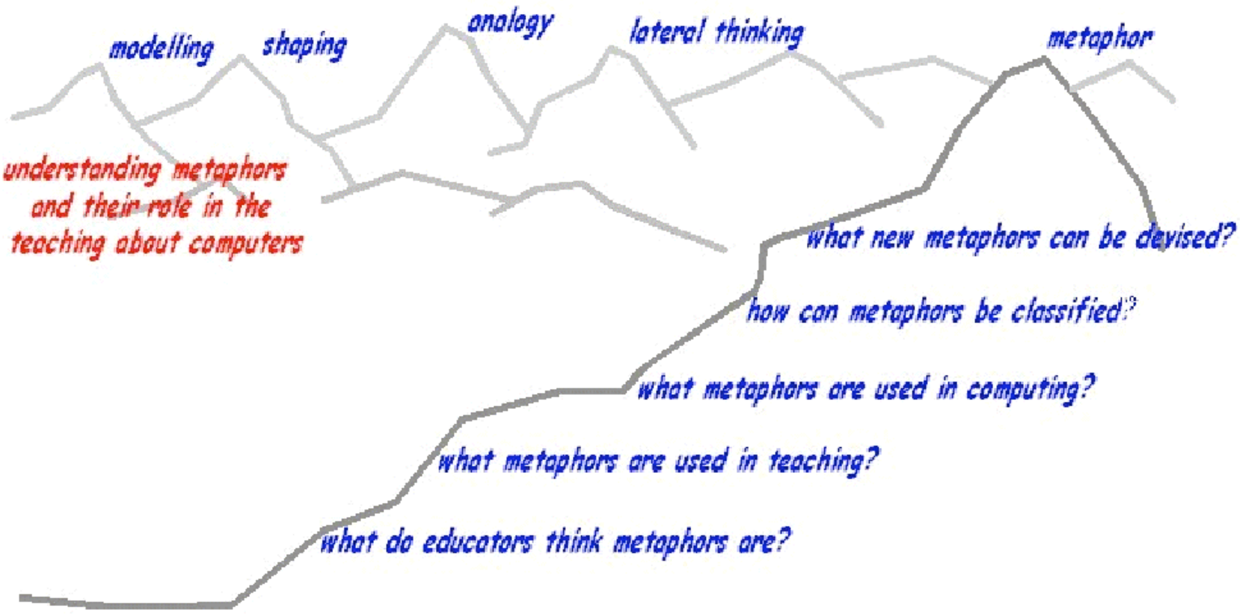
Close

The metaphor is a linguistic tool that has moved from linguistics to pragmatics

The ‘product’ based upon the ‘model’ enables better cognitive processing

Metaphors relate to compactness, vividness and inexpressibility

The metaphor is popular in the world of computing



John Woollard

Speaker's notes

This is a journey

The goal is a sharing of what a metaphor is

Ben Nevis of Snowdon

The metaphor tool: hammer, eye piece

Compactness

Vividness – girl radio

Inexpressibility

Model

Product

Tension

Speech act

Constructivist

Behaviourist

Evaluating software – the lesson is a story

Tension >>> colour

The Big One

Director

The Walled Garden

Appendix 4 Research Seminar 2

The following text represents the draft outline of the proposed presentation to the School of Education Departmental Seminar Series Tuesday October 21st 2003.

Preview

John Woollard is Lecturer in Information Technology Education researching teaching and learning in post-compulsory education – computer studies. He is a Curriculum Tutor on the PGCE Secondary programme for Information Technology and a tutor on the Graduate Training Programme. He is also a tutor on the MSc in computer based learning and training. John was a primary teacher and then a secondary school special needs teacher before working as an advisory teacher in special education and information technology and OFSTED inspector including ICT.

John's research is based upon asking computing teachers how they teach difficult areas of computing. He is using a grounded theory approach employing ethnographic analysis software (QSR NVivo).

The primary research question is 'what do teachers do to turn subject knowledge into pedagogic content knowledge (PCK) with special emphasis upon the use of metaphor and analogy within computing and the use of computers?' The evidence base is the witness statements of the teachers themselves and their own reflections upon practice. It is a grounded theory method and QSR NVivo is used to analyse the transcripts, textbooks and literature. The initial results indicate that metaphor is associated with 3 different strategies of PCK and teachers are suggesting 5 distinct and very different reasons for using metaphoric approaches in their work. An important outcome of the work is establishing strategies for training computing and ICT teachers in ITT and InSeT.

The research seminar will focus upon three areas: metaphor, knowledge and understanding; pedagogic content knowledge and a demonstration of the use of QSR NVivo to support grounded theory method.

physiology ¤ cognition ¤ linguistics ¤ literature & rhetoric ¤ everyday language ¤ systems & design ¤ curriculum ¤ pedagogy

Accompanying paper

The research seminar will focus upon three areas: metaphor, knowledge and understanding; pedagogic content knowledge and a demonstration of the use of QSR NVivo to support grounded theory method.

physiology ¤ cognition ¤ linguistics ¤ literature & rhetoric ¤ everyday language ¤ systems & design ¤ curriculum ¤ pedagogy

Metaphor is of our cognition, our understanding or our thinking. It is with metaphor that cognitive scientists explain how thinking is structured through categorisation of conceptual structure and image schema.

Metaphor is a most powerful trope of language and communication. Language is an expression of our understanding or, arguably, our understanding is established through language. The metaphor is an important tool for explaining the relationship between language and learning.

Metaphor is of literature and rhetoric. It is an artistic device to enable more colourful and stimulating writing and speech. It is a means of conveying meaning at a level not possible by the literal use of words.

Metaphor is of everyday life and language. It is a natural trope engaged in without conscious effort and interpreted without angst or difficulty. Metaphor is the vehicle for our conversational wanderings whether that is plodding through a description, stumbling through an interview or stepping through an argument. The world of computers is full of everyday metaphor, much of it flavoured by the technology. However, in addition, metaphor plays a different and important rôle.

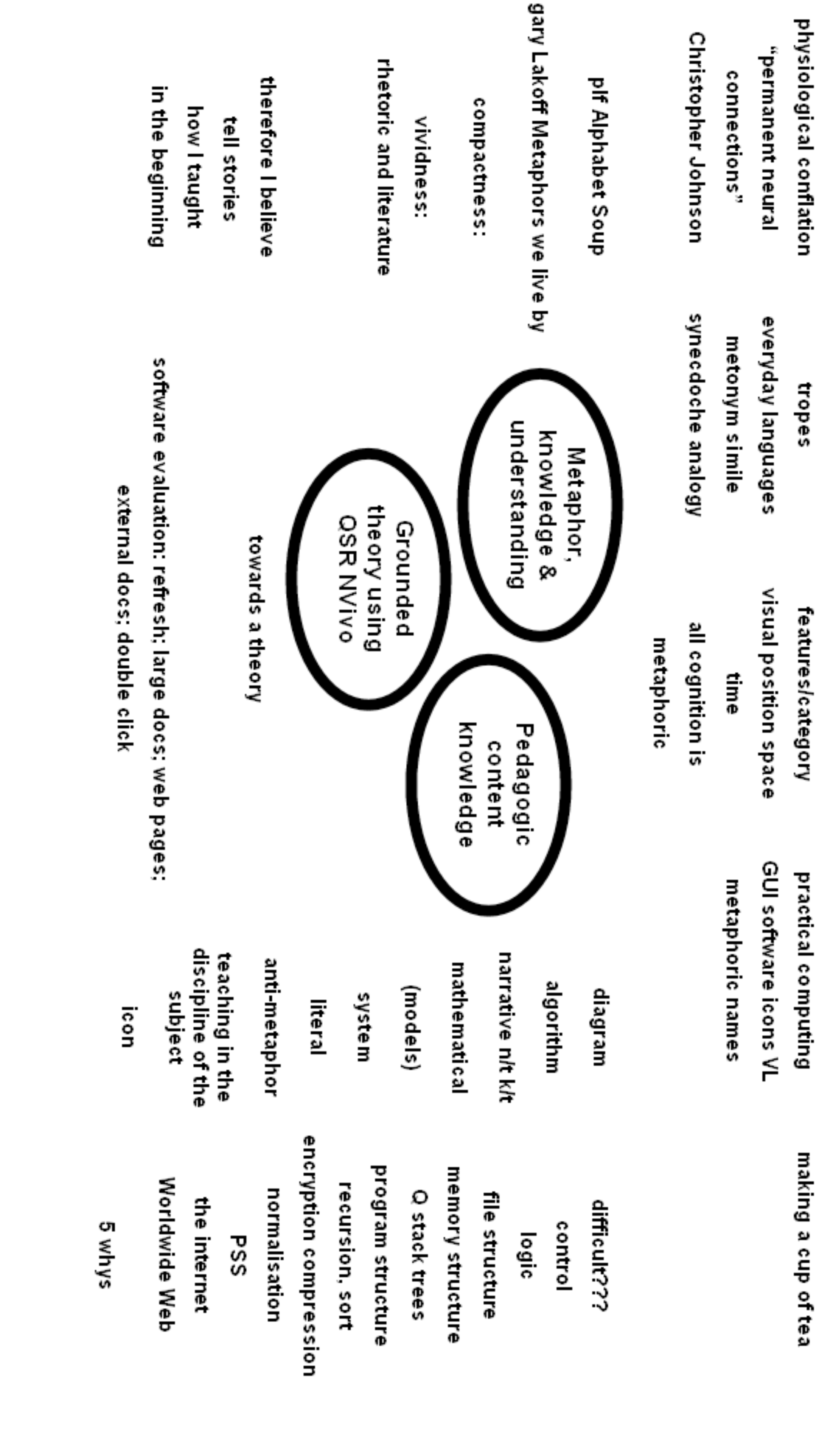
Metaphor is of the design of computer software and the human computer interface (HCI). The metaphor is exploited in a conscious and even artificial way to support the computer user when dealing with new facilities and new presentations of computer functionality. Metaphor is seen to be an important tool of the computer scientist.

It is the aim of this study to investigate and contextualise the role of metaphor is teaching about computers. That contextualisation includes these listed aspects of metaphor but it also includes those metaphor designed to aid the pedagogic process. It is those metaphors that will now take centre stage in the discussions. It is those metaphors that will be elucidated through the research methodology.

physiology ¤ cognition ¤ linguistics ¤ literature & rhetoric ¤ everyday language ¤ systems & design ¤ curriculum ¤ pedagogy

The raison d'etre of this study is the final step of the flash – pedagogy. Not only is it about how computing is taught but why computing is taught in that way.

Electronic prompt



Appendix 5 Interviews

	Location	Date	Inter-viewee	Environment	Length	Comment
1 int ttt				classroom	55	The first formal interview. The teacher showed an interest and willingness to support the research process and spent a lot of time reflecting upon whether it was the right answer. reflective, interpretive of books.
2 int ttt				classroom	48	Reflective, highly professional teacher with an enthusiasm for computing and the technical aspects of the computer science curriculum.
3 int ttt xx ☺		16.00 2/2/03		technician room	30	This interview had an informal nature – also interrupted. The respondent was well known to the researcher; she was apprehensive not to show a lack of knowledge – ex-trainee teacher with 3 years experience of post-16 teaching - enthusiastic (Taped interview with interruptions - verbatim summary statements)
4 int ttt				empty classroom	40	Reflective, very keen to support the research, she was not confident of her own teaching skills but showed a high degree of insight into PCK without stating that.
5 int ttt xx ☺		14.55 31/3/03		office	40	A formal interview. The teacher showed a great willingness to describe her teaching practice – on reflection, had no one asked her before? A number of teaching techniques that related to metaphor and analogy were described. reflective further coding necessary - done
6 int ttt xx ☺		14.00 8/4/03		office	35	This interview was characterised by the reticence and narrowness of answers. The subject appeared to be nervous and did not show a confidence in her own answers. However, there were a number of metaphors and analogies discussed including the computer brain, files with plastics wallets, dinner queues and plates in a cupboard. further coding necessary - done

7 int ttt xx ☺		09.15 11/4/03		office	45	This interview was characterised by an engagement by the respondent in the processes of the research and a professional approach to teaching. The teaching of the difficult concepts is carried out through the application of programming techniques and algorithms, for example, to teach recursion the teacher taught by example using programming code. He reflected that, at particular times, he had not considered what the student was thinking.
8 int ttt xx ☺		09.00 28/4/03		office (my)	45	The teacher showed a high level of expertise and experience in teaching GCE level computing (greater than 10 years and involvement in Foundation Degree level 1 teaching). The range of teaching resources used was diverse. Knowledge of metaphor and analogy; two identified without prompt. A pragmatic approach to teaching. algorithmic tendency further coding required done
9 int ttt xx ☺		12.00 1/5/03		empty classroom	40	The interviewee was a convert to computing from history and had a broad pedagogic experience as well as academic knowledge of metaphor in the computing world. Although less experienced at teaching computing, he is a very experienced teacher. He is knowledgeable of the research area.
10 int ttt xx ☺		11.00 14/5/03		network room	40	Professional transcription – a very experienced teacher; did not strike as being highly involved with PCK but reflected various strategies for teaching – pragmatic – “I do it this way because it is done this way”
11 int ttt xx ☺		11.00 5/6/03		empty workstation area	40	Highly motivated interviewee; considering the research aspects of the questions; very willing. Responsible for GCE Computing AS teaching/coordination
12 int ttt xx ☺		12.00 5/6/03		empty workstation area	45	Good interview – has a business/practical attitude to ICT delivery - aspects of literal/adult learners pedagogy andragogy - GCVE as well as GCE Computing responsibility
13 int ttt xx ☺		11.00 14/5/03		social area	60	University of Southampton trained teacher, MSc CBL/T experienced GCE Computing AS clear ideas regarding presenting the curriculum to students
14 int ttt xx ☺		7/6/03		tutor workbase	40	tape recorder failure!!! set to auto stop/start so disjointed transcription University of Southampton trained; textbook teaching

15 int ttt xx ☺		19/6/03		classroom with pupils	30	a thinking teacher – only 3 years experience but a dedicated 'computer science' teacher – some metaphor experience – University of Southampton trained. definitely into algorithm and programming - some use of metaphor
16 int ttt xx ☺		23/6/03		empty classroom	35	very experienced teacher of computing returning to ICT coordination in secondary education reflective on the teaching process but tends to be pupils orientated
17 int ttt xx ☺		30/6/03		office	40	strong interview but the clientele are below GCE Computing level – the value of metaphor is evidenced
18 int ttt xx ☺		8/7/03		tutor workbase	45	very strong interview with great insight; very experienced computing teacher - coordination responsibility MSc CBL/T no teacher training
19 int ttt xx ☺		8/7/03		teacher workbase	45	only 2 years experience but long industry training; University of Southampton GTP; AS only therefore limited curriculum thinking about the experience of the students - definitely a pupil centred teacher
20 int ttt xx ☺		10/7/03		office	45	experienced coordinator - a curriculum centred teacher - GCE AS and A2 - thorough understanding of curriculum content and had tried many strategies
21 int ttt xx ☺		10/7/03		office	40	very knowledgeable of metaphor and their rôle in computing and experienced GCE/GNVQ/Level 1 degree work in computer science, working with adults as well as students - very positive towards research and valued the opportunity to discuss andragogy
22 int ttt xx ☺		10/7/03		office	40	coordinator in a post-16 institution with a computing degree and commercial background as well as secondary school teaching (PGCE) a good range of strategies and very open to discussion of the issues

☺ coded; xx to be coded; ttt to be transcribed; int interview to be arranged

Appendix 6 Interview Schedules

There are two versions of the interview schedule that have been preserved although other versions existed as the changes were made between the first 5 interviews and the following interviews. The most significant change came about very early in the interview sequence. It became obvious that the research questions were not being fully answered because the focus of the interview talk was upon "metaphor". The respondents' reactions were to emphasise their knowledge of metaphors and try to reflect metaphors in all of the answers. As soon as the focus of the interview was changed to "difficult concepts of computing" the nature of the responses became more balanced between different strategies of teaching. As a consequence it was then possible to better analyse the relative value of metaphor.

The second very important change that took place was the tape recording procedure. For the first interviews tape recording (and minidisk recording) took place but the record of the interview was simply the contemporaneous notes made during the interview. The procedure was for the interviewer to place a T (for tape) on the schedule if the interviewee made an interesting response. It was then possible to refer back to the tape/disk to obtain clarification of what was said. For the majority of the interviews a different approach was made. It was planned that the recording would be transcribed and that the analysis would be carried out using that record only. This had a big impact upon the conduct of the interview. It freed the interviewer and enabled the questions to be more responsive to previous answers. It also changed the atmosphere of the interaction.

Much of the first schedule was probing the teachers' understanding and awareness of different metaphors in computing. This proved interesting but unnecessary to meet the needs of the research. This aspect was severely reduced in the revised interview schedule. The data collected from that part of the study may form the starting point for future research.

There are two documents:

Metaphor interview schedule – the original version

Interview schedule – the established schedule

Metaphor interview schedule

P means refer to picture during interview
T means refer to tape recording during analysis

I am carrying out research into the way in which we teach the different concepts of computing and how we understand how a computer works.

For example, we talk about the desktop of the computer. What do you understand by the term desktop?

What aspect of that description helps you teach/explain the working of the computer?

this is the desktop	know about [ ] have used [ ] future use [ ]	

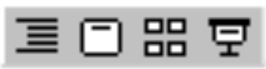
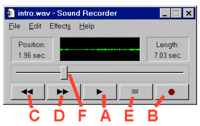
It really is not a desktop.

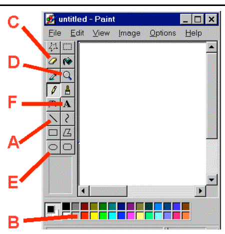
What other metaphors are you aware of?

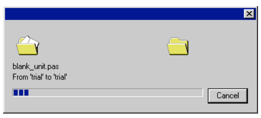
I have a list of metaphors that I would like to discuss over the next 20 minutes. Your comments will be strictly confidential in that they will not be associated with you or your school/college.

systems		
Walled garden	know about [ ] do you use[ ] future use [ ]	

Firewall	know about [ ] do you use[ ] future use [ ]	why is it called a firewall
Bread crumbs P	know about [ ] do you use[ ] future use [ ]	
actions		
click and drag	know about [ ] do you use[ ] future use [ ]	
drag and drop	know about [ ] do you use[ ] future use [ ]	
rubber band or rubber banding	know about [ ] do you use[ ] future use [ ]	
Surfing, browsing, grazing	know about [ ] do you use[ ] future use [ ]	

objects		
recycle bin	know about [ ] do you use[ ] future use [ ]	in what way is it recycling
trash can for delete	know about [ ] do you use[ ] future use [ ]	your opinion of closing a Mac floppy
slide show P 	know about [ ] do you use[ ] future use [ ]	presentation software
video controls P 	know about [ ] do you use[ ] future use [ ]	
computing terms		
information highway	know about [ ] do you use[ ] future use [ ]	
tree structure	know about [ ] do you use[ ] future use [ ]	
root directory	know about [ ] do you use[ ] future use [ ]	

phrases:		
‘go to a page on the web’	know about [ ] do you use[ ] future use [ ]	
‘burning a CD’	know about [ ] do you use[ ] future use [ ]	
images		
	know about [ ] do you use[ ] future use [ ]	
	know about [ ] do you use[ ] future use [ ]	
	know about [ ] do you use[ ] future use [ ]	
	know about [ ] do you use[ ] future use [ ]	
	know about [ ] do you use[ ] future use [ ]	

	know about [ ] do you use[ ] future use [ ]	
earcons, micons and picons		
earcons (1)  Chord.wav	recognise [ ] understand [ ] teach [ ]	
earcons (2)  Notify.wav	recognise [ ] understand [ ] teach [ ]	
earcons (3)  Logoff.wav	recognise [ ] understand [ ] teach [ ]	
earcons (4)  Reminder.wav	recognise [ ] understand [ ] teach [ ]	
earcons (5)  bbc.wav	recognise [ ] understand [ ] teach [ ]	
micons (1) 	recognise [ ] understand [ ] teach [ ]	

<table>
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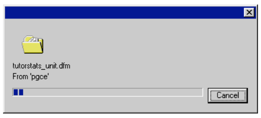

</td><td>recognise [ ]
understand [ ]
teach [ ]</td><td></td></tr>
<tr><td>micons (3)</td><td>recognise [ ]
understand [ ]
teach [ ]</td><td></td></tr>
</table>

computing concepts

how do you teach each of the following concepts/knowledge?

central processor; bus, memory;

recursion;

AND, OR, NOT as electronic units;

sequential files, random access files;

queues and stacks;

binary tree;

binary tree traversals;

encryption (weak and strong);

bubble sort;

normalisation;

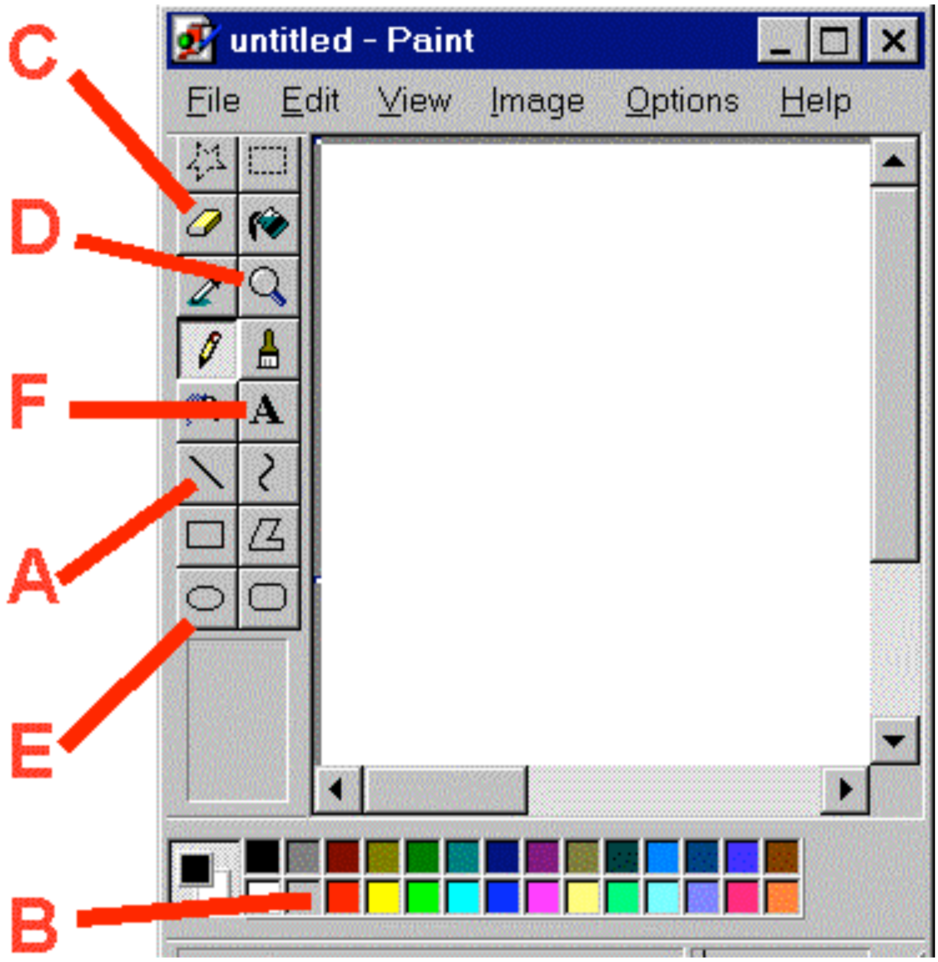
packet switching systems;

the internet infrastructure;

the Worldwide Web;

digital certificates;


intro.wav - Sound Recorder
File Edit Effects Help
Position:
1.96 sec.
Length:
7.03 sec.
C D F A E B


untitled - Paint
File Edit View Image Options Help
C
D
F
A
E
B

Interview Schedule [April 2003]

I am carrying out research into the way in which we teach the different concepts of computing and how we understand how a computer works. This involves all sorts of learners but focussing upon the curriculum relating to ICT and computing at GCE and University entrance level.

I have a list of concepts that I would like to discuss over the next 20 minutes. Your comments will be strictly confidential in that they will not be associated with you or your school/college.

How do you teach each of the following concepts/knowledge?

central processor; bus, memory;

AND, OR, NOT as electronic units;

sequential files, random access files;

queues and stacks;

recursion;

binary tree; binary tree traversals;

tree structure, root directory

encryption (weak and strong);

bubble sort;

compression;

normalisation;

packet switching systems;

digital certificates;

the internet infrastructure;

the Worldwide Web;

I would like to go back and discuss some of the concepts we have been discussing and identify the elements that are based upon metaphors.

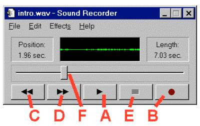
At this stage, I will be reflecting back and choosing those aspects of computing that the respondent has apparently used metaphoric methods. I will be teasing out two areas:

are they really using metaphor as I would define it?

are they conscious of the metaphor element of their method?

What other metaphors are you aware of?

systems		
Walled garden	know about [ ] do you use[ ]	
Firewall	know about [ ] do you use[ ]	why is it called a firewall?

Bread crumbs P	know about [ ] do you use[ ]	what do the pupils understand by?
Surfing, browsing, searching	know about [ ] do you use[ ]	what do the pupils understand by? surfing browsing searching
objects		
recycle bin	know about [ ] do you use[ ]	in what way is it recycling?
trash can for delete	know about [ ] do you use[ ]	your opinion of closing a Mac floppy
slide show P 	know about [ ] do you use[ ]	presentation software
video controls P 	know about [ ] do you use[ ]	
phrases:		
‘go to a page on the web’	use	what do the pupils understand by?
‘burning a CD’	use	what do the pupils understand by?

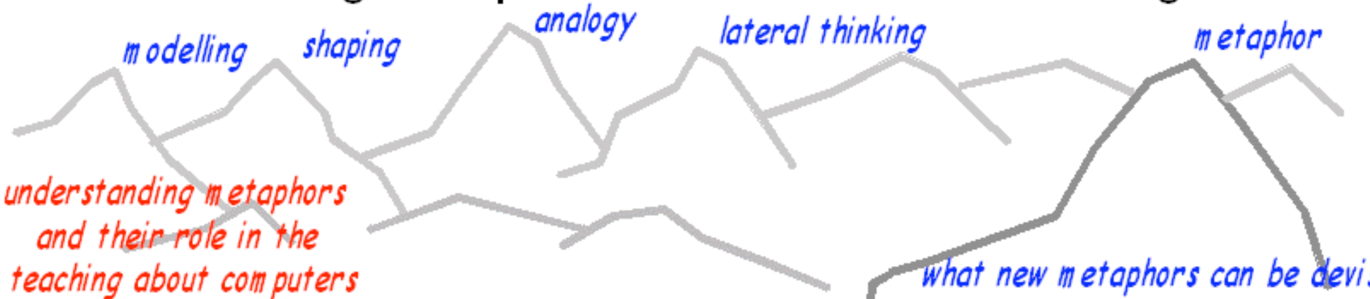
Any other comments over…

Appendix 7 Pedagogic metaphors and image schema

Novel kinaesthetic	
secret notes encryption	container
stacks of Pringles	container
networks of skipping ropes	surface
fly door for firewall	process
scrabble codes	process
Packet Switched System	process over a surface with blockage
parcel tape – sequential files	merging containers with internal links
paper chain compression	process of matching within a container
wash basket stack	container
Novel theoretical	
absolute $ sticky references	process with a clear link
spiral turning recursion	cycle process
website is a house	container
Andrea, Oreo and Notty logic	anthropomorphism
busy teenager stacks	process stored in a container
office cleaner	process on a surface
firewall - fly screen	process
compression – pipe width (Brett)	process and restraint

Traditional kinaesthetic	
filing cabinet filer system	container within container
front of class queue/bus queue	process
Russian dolls recursion	container within a container iteration
plate stack/paper spike	container/process
spools of tape file structures	linked process
Tower of Hanoi algorithm/recursion	process iteration
Traditional theoretical	
walled garden	container
sorting champagne bubbles	process
tree, root, branch, leaf	links on surface
star, bus, ring networks	surface
shop checkout queue	process within a container

Understanding metaphors and their role in teaching about computers



understanding metaphors and their role in the teaching about computers

what do educators think metaphors are?

what metaphors are used in teaching?

what metaphors are used in computing?

how can metaphors be classified?

what new metaphors can be devised?

Lesson observations. Trainee teachers will, as part of their normal work, make observations of the teaching of ICT. They will be briefed on the nature of metaphors and how they are used in teaching. They will record when concepts are being taught, the strategies that are being used to enable children's understanding and, if metaphors are being used, the exact nature of the concept. The observer effect and the 'risks' of third party data are considered. Denscombe, M (1998) *The Good Research Guide* OUP

Literature research. Metaphors in language study have a long history - as far back as Aristotle. More recently linguists differentiate between the linguistic metaphor and the pragmatic metaphor. It is the latter that seems to best meet the needs of teaching about computers. Ortony, A (1977) *Metaphor and Thought*. New York: Cambridge University Press Lakoff, G and Johnson, M (1980) *Metaphors We Live By* Chicago: University of Chicago Press.

Harmon, Joseph E. "The Uses of Metaphor in Citation Classics from the Scientific Literature." Technical Communication Quarterly, v. 3, pp. 179-194, 1994 The abstract reads: "To gain a better sense of the metaphorical nature of the scientific research paper, the author reviewed 89 journal articles taken from the top 400 most-cited documents in the Science Citation Index database for the period 1945-1988. Metaphorical constructions were found in a variety of forms: conceptual models, experimental designs, technical analogies, standard technical names, conventional figurative expressions, and even original figurative language normally associated with more-literary writing. Examples are given for each mode of metaphor."

Group discussions. Structured discussions of groups of ICT experienced teachers and trainers will be recorded. The agenda will include a presentation of ideas regarding metaphors and their role in learning. Some commonly used metaphors will be presented and discussed. Participants will be encouraged to present their own. metaphors. (Discussion group issues still to be considered.)

Internet research. An important aspect of the data collection will be the use of news groups, mail groups, targeted e-mail and 'advertised' web sites and forms to gather information and opinion. I expect to carry out a survey of ICT literate teachers. Important risk factors are identified in: Jones, S (1998) *Doing Internet Research*, Sage.

Teacher interviews. Teachers will interviewed regarding the use of metaphors in their work. The agenda will include:

what are the important concepts of ICT that need to be taught?
which are the hardest concepts to teach?
what strategies are used to help understanding?
are metaphors used?
which metaphors are used and how successful is their use?

Cohen, L & Manion, L (1989) Research Methods in Education, London, Routledge and Oppenheim, A N (1992) Questionnaire Design, Interviewing and Attitude Measurement, Pinter Publishers

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Appendix 9 Poster 2003

what is the role of metaphor in the construction of computer pedagogic content knowledge?

what do teachers do to turn content knowledge into pedagogic content knowledge with special emphasis upon the use of metaphor and analogy within computing and the use of computers?

metaphor — linguistic, computer world

computing — computer world, IT, ICT and computing

teaching — IT, ICT and computing, PCK

linguistic

what is a metaphor?
how are metaphors used in everyday language?
how are metaphors used to be emotive, stimulating and illustrative?

computer world

what metaphors are used in the computing world?
why are metaphors used in the computing world?
what is the pedagogic consequence of that use?

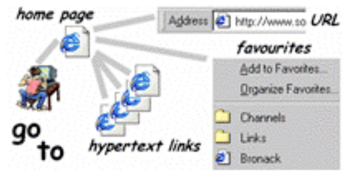
IT, ICT and computing

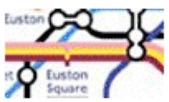
what is the nature of the computing curriculum?
what are the concepts of the computing curriculum?
which concepts are difficult to teach?

PCK

what is the nature of teaching methodology?
how do teachers/trainers/tutors teach computing?
how do teachers/trainers/tutors teach how to use a computer?

Do we go to web pages or do they come to us?

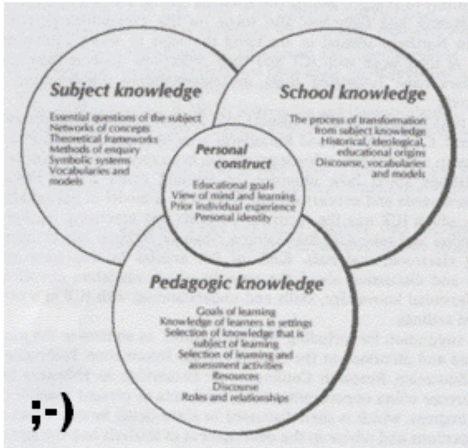




maps are metaphors

Subject knowledge
Essential questions of the subject Networks of concepts Theoretical frameworks Methods of enquiry Symbolic systems Vocabularies and models

Pedagogic knowledge
Goals of learning Knowledge of learners in settings Selection of knowledge that is subject learning Selection of learning and assessment activities Resources Discourse Roles and relationships



;-)

icons are metaphors

School knowledge
The process of transformation from subject knowledge Historical, ideological, educational origins Discourse, vocabularies and models

Personal construct
Educational goals View of mind and learning Prior individual experience Personal identity

from Leach, J. & Moon, B. (2000) *Pedagogy, Information and Communications Technology and Teachers' Professional Knowledge.* Paper presented at British Educational Research Association Conference, Cardiff.

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jw7@soton.ac.uk http://www.cblt.soton.ac.uk/metaphor/poste...

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