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CONSTRUCTING CLASSROOM MEANING WITH THE INTEGRATION OF COMPUTER TECHNOLOGY INTO TEACHING

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A thesis submitted for the degree of Doctor of Philosophy at the University of Otago, Dunedin, New Zealand

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Abstract

This thesis was a study of how teachers construct classroom meaning with the integration of computer technology into their teaching. The study was triggered in response to the overriding hegemony of educational computing as teaching and aims to demonstrate the primacy of teachers' roles as mediators of teaching within the culture-building process, integrating computer technology. The research questions; "How do teachers construct classroom meaning integrating computer technology?" and "How do teachers' beliefs influence this construction of classroom meaning integrating computer technology into teaching?" were the foci of this study.

A unified theoretical framework derived from a critical review of the educational computing research literature and four key theories of meaning construction (the Curriculum enactment theory, the Social Interaction theory, the Sociocultural theory and the Social practice theory) enabled the researcher to interpret the teachers' teaching actions with the integration of computer technology.

In order to investigate the research questions, the teaching actions integrating computer technology of six science teachers was examined over five months in the Republic of Singapore. Through a predominantly qualitative method (anthropological methods of field observations and interviews; and, the generation of narratives) the six science teachers' roles in constructing classroom meaning, integrating computer technology was investigated and theorised. The teachers themselves assumed the role of researchers by generating metaphorical statements that encapsulated their teaching with the integration of computer technology. Data consisted of field notes; transcripts of individual interviews, focus group interviews and classroom discourse; metaphorical statements; narratives; and teachers' metaphoric language identified within the interview and lesson transcripts. Data were analysed within a collaborative and participatory mode of interaction between researcher and participants throughout the five months of the study.
Findings revealed that teachers’ construction of classroom meaning integrating computer technology into teaching involved a complex process of negotiations and mediations of these negotiations through the use of psychological tools enacted within social contexts. Teachers’ negotiations created activity structures that are mediated by teachers’ psychological tools such that the negotiated components within the activity structures, including the computer technology, all converge onto the transfer of cultural templates. These negotiations and mediations are in turn influenced by the teachers’ beliefs, extant and functioning within these social contexts. In this way the critical role played by teachers’ beliefs and the complexity of teachers’ roles is reinforced.
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Chapter 1

Introduction

In many countries - the Republic of Singapore is no exception - recent reforms in teaching and professional education have put great emphasis on the use of computer technology for teaching (Vickers & Smalley, 1995). For anyone concerned with this area of educational computing, a better understanding of teaching with the use of computer technology is now urgently needed. For anyone concerned with the broader issue of teacher professionalisation, a better comprehension is also needed of the complexity that is at stake as teachers, together with the curriculum, students, student learning, computer technology and the classroom context, come together in educative experiences. The researcher begins by substantiating these claims. Firstly, the researcher will paint a picture of the broad educational context in which this study grew and the trends that emerged at its surface. Then the researcher’s agenda and intuitions are laid out. Thirdly, the researcher will describe the local context in the Republic of Singapore, where the study was undertaken. Next, the researcher will provide the purpose of this study. Finally, the researcher will sketch out the structure of the thesis.

1.1 Teachers’ construction of classroom meaning integrating computer technology: A relevant area to investigate

1.1.1 Trends

When this study began in 1998, there were interesting trends emerging in the educational computing literature. A person-centred vision of technology for education emerged alongside the move towards teachers as the primary agents in initiating the use of computer technology in their classrooms. That was a shift from a predominantly student, student learning and computer technology based
emphasis towards a teacher based emphasis. Furthermore, this emphasis was not seeking answers from a technical skill perspective (though pertinent), but from the teachers’ primary role in culture building. Other trends included the historical perspectives; lack of any theoretical perspectives underpinning educational computing within classroom contexts; the worrying research trends within the field of educational computing research; and, an avoidance of qualitative methodologies within educational computing research. These trends marked the researcher’s journey in framing a research question and articulating a plausible theory to explain the phenomenon being investigated.

The first trend that really captured the researcher’s attention was the person-centred vision of technology in education, something that was unique considering the vast amount of literature that enshrined computer technology as a sole imperative in the field of educational computing. This shift marked a trend towards human elements in the social context of the classroom (Kerr, 1996b) away from the technocentric and technoromantic pursuits that were unsuccessfully dogging educational computing research. This vision was calling for the framing of teachers’ use of computer technology in the classroom from a human perspective. Teachers’ roles, knowledge of classroom contexts and their structuring of the curriculum for educative performances and experiences of their students with the use of computer technology were being seen as areas that needed to be investigated from this person-centred vision of technology for education (Kerr, 1996b; Budin, 1999).

Other researchers were also citing teachers as primary agents for the classroom use of computer technology. This view was not from technocentric perspectives pertaining solely to the acquisition of technical skills or the manning of computer technology for educative purposes. But it represented a view that was centring on teachers’ primary role as transmitters of the cultural templates of the disciplines they teach (Bowers, 1988a; 1988b; 1990; 1995; 1997; 1998a; 1998b; Bromely & Apple; 1998; Miller & Olson, 1998; Olson, 1997; 2000; Olson, James & Lang, 1999; Selwyn, 1997). That is, how teachers, through their pedagogical practices,
are able to make their teaching goals, based on these cultural templates, common goals with students in the classroom. The use of computer technology was shifting towards the perspective of educational computing as a social practice (Bromley & Apple, 1998). Teachers’ “professional judgement” (Campoy, 1992: 20) was now the key focus. This professionalism was also reflected in the literature on skills training. Within this literature, there seemed to be a move away from the predominant emphasis on “dipping” teachers into computer technology (Lawson & Comber, 1999: 42) for technical skill proficiency. The emphasis was shifting towards integrating the computer technology into the culture building process taking into account the seriousness of teachers’ conceptual mappings of this process (Lieberman & Miller, 1991; Sleegers & Van den Berg, 2000). The aforementioned perspectives are also captured by Bransford, Brown, and Cocking (2000) propelling the need for research into this area of teaching integrating computer technology, they write:

What has not been fully understood is that computer-based technologies can be powerful pedagogical tools—not just rich sources of information, but also extensions of human capabilities and contexts for social interactions supporting learning. The process of using computer technology to improve learning is never solely a technical matter, concerned only with properties of educational hardware and software. Like textbook or any other cultural object, technology resources for education—whether a software science simulation or an interactive reading exercise—function in a social environment mediated by learning conversations with peers and teachers. (p. 230)

Up till now, the “extensions of human capabilities” in educational computing research have been concerned with the need to provide skills to equip teachers to handle the computer technology. What is apparent is that the very process of teaching, integrating computer technology, that centres on the transmission of cultural templates seems to be neglected.
Looking further into the literature at hand, there seemed to be an abundance of investigations into the computer technology's impact on classrooms and investigations pertaining to students, and student learning within the context of integrating computer technology (Black, Swan & Schwartz, 1988; Bracey, 1988; Brynner, 1998; Buckley, 2000; Butzin, 1992; Hannafin 1992; Hannafin & Land, 1997; Leper & Gurtner, 1989). There seemed to be a displacement or substantial lack of teachers' influence/perceptions/voices within this sphere of research. Whatever research there was, seemed pedantic and trivial, subjugated to the realms of skills training or professional development. It also circumvents pedagogy through gathering insights solely from the perspectives of students and student learning.

Apart from this person-centred vision of technology for education, the area of research involving the integration of computer technology into teaching seemed to be an area abuzz with much interest. This was derived from readings that concerned themselves with the limited scope and/or abuse of the use of computer technology in classrooms by teachers (Arnold, 1996; Bowers, 1988a; 1988b; 1990; 1995; 1997; 1998a; 1998b; Bork, 1981; Bromley, 1997; Bromley & Apple, 1998; Budin, 1999; Budin & Meir, 1998; Hadley & Sheingold, 1993; Hodas, 1991; Kerr, 1996a; 1996b; Miller & Olson, 1998; Moursand, 1981; Schofield, 1995; Winkler, Shavelson, Stasz, Robyn, & Feibel, 1985).

On the other hand, Miller and Olson (1998), Budin (1999) and Budin and Meir (1998) were emphasizing that teachers' use of computer technology was moving from a stage of questioning why they don't use it to how they should use it, especially as a tool integrated into the complexity and multidimensionality of the classroom context. Something even recent research is battling with at the present moment (Day, 2000; Lankshear & Snyder, 2000; Riel, 2000). Riel (2000: 10) writes: "The important question is not if we should use computers, but how we should be using this technology."
Another trend that was prominent was the concerns raised over the state of educational computing research. First, most of the educational computing research was severely lacking in any theoretical backing (Selwyn, 1997). That is, educational computing research was not utilising any of the major theories of learning or teaching to verify or substantiate findings. Most of the extant literature in the area was from descriptive research methodologies (Knupfer & McLellan, 1996) and/or diffusion and adoption studies (Holloway, 1996). The common element linking them was the over reliance on survey and quantitative methods of research. These in turn seemed to be skewed towards perspectives distancing themselves from culture building or the classroom complexity and multidimensionality in favour of goals of: designing and/or improving software/hardware (Andre & Veldhus, 1991; Dupagne & Krendl, 1992; Fuller, 2000; Higgins & Rice, 1991; Lowther & Sullivan, 1994; Hannafin & Rieber, 1989a; 1989b; Schumaker & Hossain, 1990; Zammit, 1992); attitudes and beliefs towards the use of computer technology (Koohang, 1989; Madsen & Sebastiani, 1987; Marcinkiewicz, 1993/1994; Scheffler & Logan, 1999) and an over emphasis on teachers’ efficiency in using the computer technology (Bracey, 1988; Chiero, 1997; Fishman & Duffy, 1992; Marcinkiewicz, 1994-1995; Vockell & Sweeney, 1996). Another area of research feeding into educational computing research is the advocacy-based methods including visionary theory research; lighthouse projects and large-scale implementation studies (Miller & Olson, 1998).

Although each of these research has their own agenda, it must be understood that survey or advocacy-based methods can obscure and over represent how the computer technology actually “lives” within the classroom ecology. Holloway (1996) notes that most of these researches lie within the parameters of public and private interest in seeking to determine what the computer technology should exemplify in the educative process. Furthermore, the computer technology becomes the focus of research and teacher action and/or change is drafted from the complexity of the technology rather than the classroom and teaching (Miller & Olson, 1998). This puts teachers’ professionalism into an unending spiral of coping with technology’s unending advancement.
More recently, some researchers have advocated for more interpretative qualitative methods to inform this area of research (Dede, 2000; Goodson & Mangan, 1995; Linn, 1998; Miller & Olson, 1998; Nissenbaum & Walker, 1998; Neuman, 1989; Selwyn, 1997; Yeaman, 1990; Young, 1984). This interpretative emphasis is being aimed at the culture building process, where the experience of the educators within this culture building process is the prime focus and includes attention to teachers’ philosophical arguments, theories, experiences and values. That is, there is identified a need to examine the rich human experiences that are affordable and scalable within educational computing. For instance, Selwyn (1997) calls for more ethnographic studies, while Goodson and Mangan (1995) and Miller and Olson (1994; 1998) emphasize research to be based on the cultural perspectives of classroom teaching.

As the research progressed throughout 1999 and 2000, these trends became even more evident and helped to further substantiate the claims made in the aforementioned discussion to focus on teachers within educational computing research. For instance, Bigum and Kenway (1998) and Lankshear and Snyder (2000) claim that teachers are the primary criterion, among the five principles for classroom practice integrating computer technology. Lankshear and Snyder state:

We see five principles as particularly useful to guide the effective integration of new technologies into classroom-based literacy education. They are also useful to guide curriculum activity more broadly. We call these principles: teachers first; complementarity; workability; equity; focus on trajectories. ... Teachers first asserts the imperative to take account of the needs of teachers in learning new technologies and their relationship to literacy education, even before tackling the needs of students (p.120-121).

Other recent research is also painting a similar picture of teachers as the crucial ingredients in shaping the learning environment (Watson & Downes, 2000). At the same time, Day (2000) writes:
Whilst technologies facilitate and enhance the provision of education, the educator's role is to preserve the human component because human interaction is the key to the successful application of communication technologies to the delivery of lifelong learning. (p. 110)

These trends were not the only reasons that persuaded the researcher to delve more deeply into this area. Some worrying trends appeared during the course of the study that reflected an atavistic move towards the technocentric and technoromantic pursuits that characterised so much of educational computing research. These worrying trends further compounded the necessity for and substantiation of this study. For instance, Ewing and Smith (2000) forecast a dualism for the teaching profession for the new century as:

...teachers will be trained and employed to teach/tutor in cyberspace...they will be knowledge workers translating content into programs to be used in different online formats, developing internet-based programs for specific topics or purposes or identifying and sanitising sites and preparing closed sites and servers... .(p. 68)

While Selwyn (2000a; 2000b) critically laments that policies directed at computer technology use in schools by teachers propagates the general aim of simply making teachers "generally feel confident" (2000a: 750) with the "material situations" (2000a: 774). Selwyn (2000b) further suggests that this leads teachers to be "visible" and "knowable" pertaining solely to the surveillance process with the total neglect of their teaching and learning activities integrating computer technology. He initiates and supports the contention that any technocentric basis of computer technology implementation will be "shaped and 're-written' by teachers, ...eventual construction will not be a one-way process" (p. 252).

Shifting and drawing the aforementioned trends together, there appeared to be a gap in the literature: How do teachers carry out the process of transmitting the cultural templates of the disciplines, they teach, within the context of teaching
with computer technology? There has been some peripheral knowledge substantiated by studies focussing on this gap in the literature. These studies tend to investigate teachers’ beliefs and attitudes about the computer technology and its purpose in the classroom. Basically this crucial aspect of schooling, cultural transmission has been looked at only from the perspective of “instrumental realism” (Murphy & Pardeck, 1991: 351)

Investigation of the teachers’ role within this context is relatively lacking and teachers’ conceptual mappings of their classroom practice seems not to be frequently undertaken, even though research from general educational research has continuously stressed these as the regulatory agents of the teachers’ practice. It is timely and appropriate that this gap be an area of investigation. But how was it to be structured into a research question that would be feasible in an empirical setting? This is further discussed in Chapter 2, where this gap in the literature is substantiated, discussed and a theoretical framework built to explain it. Now we turn to the researcher’s agenda and intuitions that in some ways also greatly helped in structuring the research question.

1.1.2 The researcher’s agenda and intuitions

The researcher had several questions in his mind when going into this study - questions for which the researcher had gathered only partial, though intriguing theories at the beginning of this study. They were part of the brainstorming of ideas resulting from the aforementioned trends (Section 1.1.1) and pragmatic reasons. As a science teacher, the researcher wanted to understand more about how science teachers used computer technology to transmit the cultural templates of the discipline they were teaching. Basically: How science teachers, in the context of teaching with computer technology, made their teaching goals, into an intersubjective agreement about meaning being made with students? What were the common threads that stitched classroom teaching when computer technology was an integral part of the science teaching agenda?
As a researcher, he wanted to know: What factors impacted upon science teachers when they used computer technology as an integral part of their teaching? What was the science teachers' world like, and how did they view that world when computer technology became an integral part in the transmission of cultural templates? What were the theories that were guiding their pedagogical endeavours with their use of computer technology? How did they view the learning and the constructive process now that computer technology was an integral part of their teaching?

Thus, on a pragmatic level, the study was focussing on the ways that science teachers live their lives within the context of transmitting cultural templates when integrating computer technology into teaching. Cultural templates, in reference to science teaching, refers to the scientific beliefs, ideas and conventions of the larger scientific community that science teachers bring forth in their classrooms when they engage in the practice of teaching science. At the same time the study was focussing on the realities that science teachers face as they use their pragmatic theories to develop classroom teaching and learning that shape their teaching actions. The study was heading towards a perspective that reflected heterodoxy (Reason, 1996): the voices and perspectives of the science teachers and researcher had to be discovered.

This heterodoxy perspective, adopted by the researcher towards this study, parallels Cohen's (1996, in Ainley, 2000) perspective on educational researchers and teachers in their pursuit of identifying good teaching.

What teaching has in common with research is above all a meaning creating meaning negotiating activity...How some people learn to culturally labour better than others, why some are more able than others to turn their cultural labour into realisable forms of cultural capital, is thus at the heart of the research agenda...What narratives of aspiration are available for the production or transmission of knowledge, and how are they institutionalised
in particular regimes of identity, formation...These are also questions at the heart of the teaching agenda. (p. 313-314)

1.2 Purpose of inquiry

Taking into account the trends and the researcher's agenda and intuitions, the purpose of the researcher's inquiry became more specific. The researcher wanted to know how science teachers developed classroom meaning, integrating computer technology into teaching, that led to the transmission of cultural templates, discovering the aesthetics of that meaning: teachers' personal actions and personal theories that underpinned them. And the study, at that stage, was being formulated such that the science teachers themselves would be the other major voices in the research: expressing how their lives are lived within this context of cultural transmission integrating computer technology. With these goals in mind a qualitative approach with its emphasis on interpretations of human experience and ethnography, seemed appropriate.

1.3 The Republic of Singapore: System of education

This section of this chapter introduces the reader to the context where the study was undertaken: The Republic of Singapore. This includes a general background of the education system, the politics and the goals of the education system; teacher education; curriculum and teaching methodologies; and the system of examinations.

First, a general background of the education system of the Republic of Singapore. Figure 1 (adapted and modified from Yeoh, 1994: 5477/5483) captures the structure of the formal education system of the Republic of Singapore together with the summary of the curriculum for the lower and upper secondary levels. Figure 1 reflects the centralised system of education where the national curriculum and the national examinations set the standards for school attainment. Although this is the norm, schools also maintain their own independent system of
FIGURE 1

Structure of the formal education system and the curriculum at the lower and upper secondary level-The Republic of Singapore (adapted and modified from Yeoh, 1994: 5477/5483)
continuous, formative assessment techniques to monitor students' academic demands. This includes monthly tests or term tests, but the end-of-year final examinations offer a profile of the students' progress over the school year.

This study was situated within the context of the secondary education subsystem of this structure. The school and participants of this study are located within this subsystem of the structure. Although the English language functions as the language of instruction within this education system, Malay, Mandarin, Tamil and English are all recognised as official languages. English also functions as the language of administration and commerce. The Republic of Singapore also follows a strong tradition of a bilingual policy of learning English and the mother tongue (Malay, Mandarin and Tamil) in its school systems.

The politics and the goals of this education system are centred on the individuals, students, who make up this education system. This education system adheres to four goals: First, to develop the maximum potential of each individual. Second, to create thinking individuals capable of creative and flexible skills. Thirdly, to inculcate leadership qualities and good work ethics. Finally, the cultivation of civic and moral values (Yeoh, 1994).

Teacher education in the Republic of Singapore is provided by the National Institute of Education (NIE) of the Nanyang Technological University, which is the sole teacher training institute. This institute provides both preservice and inservice training. Participants in this study hold the one-year Postgraduate Diploma in Education (Secondary) offered by this institute. This institute also provides ongoing courses at both levels (inservice and preservice) to better prepare its clientele for innovative methods and new teaching and learning strategies (Kam, 1990; Yeoh, 1994).

The curriculum for secondary 1 to 5 (grades 7 to 10) are jointly determined by the Singapore-Cambridge Board of Examinations (Ministry of Education-Singapore and University of Cambridge-United Kingdom) that lays down the content and
standards of assessment for the General Certificate in Education (GCE) Ordinary (O) level examinations. This provides a clear framework and structure for the rationale and specific objectives for teaching the subjects at this secondary level. It must be pointed out that teachers are free to choose the instructional materials that will best satisfy the needs of the students in their respective schools (Yeoh, 1994).

Although this brief description captures the general context of the school system, the significance of the internal features of the specific school where the participants taught, are not forgotten. These are further elaborated in Chapter 3 (Section: 3.2.4). This includes the school context and the "innovative capacity" (Van den Berg & Sleegers, 1996: 201) of the school: the competence of the school in implementing computer technology initiated by the government and/or by the school itself.

1.4 The organisation of this study

Figure 2 represents the procedures involved in the approach taken in this study. Figure 2 captures how the study first explored the important issues in the literature concerning how teachers integrate computer technology into their teaching, and science teaching practice. Then, it shows how philosophical issues underpinning the study were examined. These aspects are explored in chapter 2. Furthermore, Figure 2 highlights how the aforementioned issues were translated into a theoretical framework and how it was used to systematically analyse the phenomenon under study. The second chapter of this study deals with theoretical literature that substantiates the beginning of the inquiry and situates the study within its broader field. The theoretical framework is developed and presented in this chapter. This is also reflected in Figure 2. The Galilean approach to research on teaching was the convention that was adhered to in the development of the theoretical framework (Martin & Sugarman, 1993). Martin and Sugarman (1993) define this Galilean approach as a mode of investigation where
Important issues:
1. teachers integrating computer technology into teaching
2. everyday science teaching practice

Philosophical treatments (especially informal analysis)

Systematic theoretical perspectives for understanding issues of educational computing and science teaching

Translation to the context of science teaching integrating computer technology

The theoretical framework specific to the study

Application (eg. to lesson transcriptions)

Interpretations arising out of investigating phenomenon: to support, refute or refine

Systematically analysed phenomenon: Where science teaching integrating computer technology was prevalent

FIGURE 2

Schematic representation of procedures involved in this study
[adapted from Roberts, (1982; 1996); Roberts & Russell, (1975)]
the task of the scientist is to invent (not only to discover) constructs suspected to underlie and find expression in observed events. In pursuing this fundamental task, scientists consider observed events as clues to the dynamic processes arising from the interaction of elements in the events. These dynamic processes constitute an unseen domain that the scientist represents with a network of constructs that is then linked to observed events by explicit theoretical propositions (p.18).

This Galilean approach structures the process of developing a theoretical framework in four unique ways. First, it entails the requirement for an explanatory theory to map the navigation through empirical labyrinths. Second, it cautions against the deep obsession over methodological and epistemological paradigms for data collection. Instead, it emphasises the need to develop a well-articulated theory as an explanatory force derived from phenomenological, theoretical and empirical research to explain the theory of interest. Finally, it states that this articulated theory should determine the plausible methodological and epistemological paradigms suited for the empirical study to test the articulated theory (Cziko, 1989; Howe & Eisenhart, 1990). In seeking a stronger theoretical foundation to this study the researcher worked with a number of key theories for meaning making: the Curriculum Enactment theory of Doyle (1983;1986a; 1986b; 1988); the Social Interaction theory of Erickson (1982); and the Sociocultural theory of Vygotsky and Neo-Vygotskians. Having identified these key theories of meaning construction, the researcher considered how teachers’ professional landscape is also formed by the community of practice (Lave & Wenger, 1991; 1999). The aforementioned theories together with this community of practice perspective helped to support the researcher’s articulation of a theory to help in the interpretation of participants’ teaching actions integrating computer technology.

Chapter 3 illustrates the researcher’s journey of locating the study within a predominantly qualitative research paradigm, and the collection of data. Based on the theoretical framework developed using the Galilean approach (Martin &
the researcher articulated a methodological and epistemological paradigm based on traditions of qualitative interpretative research. In this study the participants were objects of the researcher's investigation and participants themselves were investigators of the phenomenon under study. This chapter also illustrates the analysis of data leading to the formulation and reformulation of interpretations and conclusions in accordance to the theoretical framework. That is, this chapter also provides an analytical openness (Van den Berg & Sleeger, 1996; Constas, 1992; Mishler, 1990): the specific procedures (analytical templates and descriptors) used to organise and interpret the data. The data was gathered in the Republic of Singapore, where the initial analysis and interpretations were completed within a relational context with participants. The major analysis was carried out in New Zealand. The final interpretations and conclusions, just like the initial analysis of data, were further marshalled within a relational context as the researcher brought back the interpretations and conclusions to the participants in the Republic of Singapore.

Chapter 3 also provides a brief illustration of how the researcher conducted the study within a complex and relational context of ensuring trustworthiness, and allocating authenticity for the claims made in this thesis.

Chapter 4 presents the findings of the study as a case study not of each individual participants, but as two distinct case studies of teaching actions that took place within the context of science teaching integrating computer technology. These are classified as communities of practice I, and II. Thus, this chapter fulfils the need to present the analysed raw data into forms accessible to the reader.

Chapter 5 goes back to the initial theoretical endeavour that was set within Chapter 2, the theoretical framework, to discuss the findings within this theoretical framework. That is, how teachers, (in this case science teachers), construct classroom meaning integrating computer technology into teaching. Thus, this chapter fulfils the aim of interpreting the analysed raw data and
integrating these interpretations into the researcher's articulated theoretical framework.

Chapter 6 serves to draw the major insights of this study. The contributions of this study are declared, followed by the implications for further research in educational computing, science teaching and teacher education (science education, skills training and educational computing). Thus, this chapter clarifies and states the statement/statements of significance and application of the study's findings.
Chapter 2

Literature Review

2.0 Introduction

The quest for an area to study began with a thorough, detailed, and critical review of the literature. In this case the researcher's background as a science teacher also played a part in framing the focus of the literature survey. Thus, together with aforementioned trends and pragmatic reasons in Chapter 1 (Section 1.1), the general education literature, educational computing literature, science education literature (inclusive of research on science teaching) played a crucial role in providing the theoretical framework that will hold and substantiate the design of the whole study, the data gathering and the final discussion.

This chapter is divided into eight sections: section 2.1 gives a brief discussion of what the researcher means by the construction of classroom meaning. Following this, section 2.1.1 sketches out what this construction of classroom meaning is in general educational research. Section 2.1.2 discusses the aspect of construction of classroom meaning in reference to the educational computing research. Section 2.1.3 provides some of the recent consensus about construction of classroom meaning from science education research. This section is important because the study takes place within the science teaching landscape. Section 2.1.4 provides an overall consensus of what construction of classroom meaning is within this study. The subsequent sections deal with the macro, meso and micro levels (Selwyn, 1997) of educational computing research: specifically the organizational impact of educational computing in schools and classrooms (Hadley & Sheingold, 1993; Kerr, 1996a; 1996b; Newman, 1990). Section 2.2 deals with the literature on educational innovation and change, and skills training (Section 2.2.1); the literature on teachers' roles and role changes (Section 2.2.2) and teachers' use of
computer technology as a tool (Section 2.2.3). Section 2.3 explores the literature on teachers' beliefs. Section 2.4 synthesizes the major insights from all these sections (2.1, 2.2, and 2.3) to articulate a theory of the phenomenon of interest: how teachers construct classroom meaning integrating computer technology into teaching. Section 2.5 provides a discussion of major theories of meaning making (Curriculum enactment theory, Social interaction theory, the Sociocultural theory and the Social practice theory). Finally, section 2.6 presents the researcher's articulation of the theoretical framework.

Before moving on to the review of literature proper, a few words about the typology adopted for the review of literature follow. This typology and the categories derived from the studies of Selwyn (1997) and Kerr (1996a), expressed as section 2.2 in this review, is not meant to overrun others. It could be argued that the categories (micro, meso and macro) used are not mutually exclusive, that some overlap and that some studies could be included in more than one category. The pertinent aim of the typology was to highlight crucial aspects of teachers and their teaching integrating computer technology, and these categories seemed expansive and relevant to substantiate the research question and articulate a theory to discuss it.

2.1 Construction of classroom meaning

The aim of this section is to provide an explanation of what the researcher means by "teachers' construction of classroom meaning"; it includes a brief survey of the literature followed by a definition of teachers' construction of classroom meaning as exemplified by the literature. This section of the review is structured by the question; "What is construction of classroom meaning from the teaching and learning point of view?" as captured within the three fields of educational research.
2.1.1 General educational research

The answer to what is “construction of classroom meaning” requires an understanding of the terms construction and meaning. Construction, coming from an educational perspective, includes all “productive human activities” (Fishman & McCarthy, 1998: 33) involving perceptions, actions, interactions, interpretations and evaluations (Collins & Green, 1990) made in social circles particularly the classroom and school context (Janesick, 1982) resulting in the synthesis of new links with identifiable positions in inclusive situations or context (Dewey, 1930; 1988). Steier (1995) articulates construction as the “actual process of building an object with descriptions to action” (p.73). Into this “process” goes the descriptions and articulations of links between features, properties and principles that are a part of making the “object”. From these descriptions two major aspects emerge: construction entails a constructive agent and a constructive process; and, the production of a cognitive product, the meaning, that brings about action in a meaningful context (Mishler, 1979: 11).

The nature of this meaning or cognitive product is further expanded in the literature in a number of ways. Meanings are constructed through the use of language. Social interaction and social nature of language merely shape the meanings that we abstract from our experiences. Meanings are always within context and contexts incorporate meaning. Both meaning and context are related by action, meanings produce actions, actions capture and encapsulate context. (Mishler, 1979). Gowin (1981: 201) adds that meaning “is a structure of actions” that captures the teaching and learning event. Thus, meanings are neither exclusively words nor cognitive meaning. That is, making meanings does not just extend to the mental processes but must be displayed as a structure–action paradigm (Gowin, 1981; Packer & Winne, 1995). Weade (1987) suggests that meanings are also reconfigured or new meanings are created when “construction of errors” are encountered in the uncertain, multidimensional and complex context of classroom teaching and learning. This constructed error is characterised in
teaching and learning actions where the constructed meaning is not satisfactory or not functioning.

Thus, the meanings teachers reflect through their actions and language can be a representation of the coherent interpretative frameworks through which educational experiences are lived in and through by teachers, and students.

Other researchers emphasize the teachers' role in this construction of classroom meaning as creating pedagogical tasks that generate purposeful tasks that are educative for students. That is, the artificial arrangement of cultural templates to enable problem solving and as stimuli for thought and actions, recreating the life of society within an interactive dynamic among students, teachers and subject matter (Copeland, Birmingham, DeMeulle, D’Emidio-Castron & Natal, 1994; Fenstermacher & Soltis, 1998; Proefriedt, 1994; Smagorinsky, 1995a).

The study of meanings can affirm affiliations and identify the demarcations that constitute one's professional identity. The affiliations may transcend and develop into traditions (Coldron & Smith, 1999) which may be teachers' mental representations of possible and actual practices and structures. The professional identity may serve as moral sources that guide actions by conferring opposition, possibilities and patterned set of meanings that would lead to creative articulation resulting in teachers getting a right feel even with external requirements. These also act as landmarks to position the teacher as a professional for achieving the goals of teaching and about the moral tradition they represent and not for the acquisition and/or propagation of techniques.

Based on Spivey's (1995) writer-reader dualism for the construction of classroom meaning, teachers construct classroom meaning for the produced culture of the classroom by anticipating students' construction of meaning – their constructive process. Capturing teachers' constructive processes gives an image of their perceptions of the students' constructive process, providing cues for how this constructive process works and the nature of constructive process.
Looking at meanings from a constructivist perspective, learning happens when students participate in the construction of classroom meaning through personal interpretations as a result of social interactions. They may also reconfigure meaning in this social interaction to transform them as personal constructs. Since this constructive process is a contribution of the teachers' constructive processes, investigation of the process may highlight the teachers' sequence of teaching as well as shed light on the students' conceptual changes (Duit, 1995) that the teacher envisions.

Thus, this review of teachers' construction of classroom meaning emphasizes that teachers' construction of classroom meaning is a guide/a mirror to see the coherence or incoherence of teachers' selection and adaptation of curriculum, instruction and assessment to their central purpose and goals.

2.1.2 Integration as a teaching approach

So far, what has been discussed is from the general education literature. Most of the educational computing literature seems to ignore this perspective of construction of classroom meaning. Much of what is present in the literature about this aspect of teachers' role has been reduced to what Bowers (1988: 89) refers to as "educational computing as teaching". Recent research, however, seems to be providing another perspective. The purpose of this section of the review is two fold: to examine the literature to frame the recent trends of what integration as a teaching approach entails; and second, to build up a notion of what constitutes classroom meaning within this literature.

Lauzon (1999) portrays education as a larger community of practice within which other communities of practice are located. He characterises teaching and learning events that have computer technology integrated within them as:

any educational domain that is practiced through a form of mediated instruction is embedded in the community of practice that is broadly
known as the educational technology. This community of practice is embedded in the larger community of practice called education... (p.270)

In contrast, Lauzon (1999) uses the term “surrogate classroom” (p.272) to describe classroom teaching practices that have subverted the technology into prior practices. Schofield (1995) refers to this subversion as the incrementalist approach. That is, classroom practices with the use of computer technology reflect prior practices, where instruction using computer technology mirrors instruction by traditional methods. Billett (1998) further emphasizes that teachers’ creations of these communities of practice result in moral dimensions that encapsulate norms and values that are typical and characteristic of these working communities. Billett also points out that experience within this community brings about normative ways of being engaged with the process of culture building. Thus, the construct of community of practice is seen as an analytical lens through which to examine teachers’ use of computer technology.

On the other hand, other phenomenological and empirical research from educational computing research identifies the nature of integration simply as a teaching approach. Figure 3 contains the descriptions of the extant teaching approaches with the use of computer technology as captured in the educational computing literature. That is, how the computer technology is used for teaching and learning activities in the classroom. Figure 3 also focuses and compares the integrated approach with the other extant approaches (avoidance, technical specialisation, and supplementary user).

This teaching approach (Hadley & Sheingold, 1993) is interpreted as a combination of pedagogy, teacher, student learning, learners and computer technology forming a whole (Alabalat & Tarrago, 1995; Cornu, 1995). Olson, James, & Lang (1999) based on major studies of integration across subjects, highlight integration as a developmental process that involves the teachers’
FIGURE 3

Spectrum of teachers' approaches to the use of computer technology in the classroom
analysis of curriculum for thematic use balancing this with students' conceptual development to make thematic connections to a wider field of application.

Drawing from these studies the researcher defines integration, in reference to the integration of computer technology into teaching as: A developmental approach that incorporates teachers, learners and the curriculum together with the computer technology within the processes of education based on teachers' goals (teaching, strategies, learning strategies and curriculum) to bring about an environment distinct from other teaching and learning processes (prior practice).

Using this definition, indicators were identified from the research literature. Tables 1 captures the salient issues identified in the research literature as being indicators of integration of computer technology into teaching and learning actions. These indicators of integration are categorised under the headings of curriculum, teachers and teaching, computer technology, and students and learning. These indicators of integration depict how the curriculum, the role of teachers, teaching, the role of computer technology, the role of students and learning would be if computer technology was integrated into the classroom.

In brief, Table 1 states that: When teaching occurs as a result of computer technology being an integral part of the classroom, there is a contextualisation of computer technology into teachers' thinking and actions (Hadley & Sheingold, 1993; Olson, 1988a; 1988b; 1992; Thurston, Secarus & Levin, 1997). When learning occurs as a result of computer technology being an integral part of the classroom, it is portrayed as engaged learning (Dias, 1999; Dirks, 1997; Jonassen, 1995) and occurs in expanded learning environments (Kimmel & Deek, 1995) where students are responsible for their learning. When computer technology is an integral part of the classroom, it is an ubiquitous tool that is an instrument for teaching, and an instrument for learning - a learning instrument encompassing an element of interactivity (Alabalat & Tarrago, 1995). Curriculum, as an integral
| TABLE 1
<table>
<thead>
<tr>
<th>Indicators of integration</th>
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<tbody>
<tr>
<td><strong>Curriculum</strong></td>
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<tr>
<td>• Integration of computer technology should not occur in a “curricular vacuum” (Budin &amp; Meir, 1998; Callister &amp; Burbules, 1990; Evans-Andris, 1995; Kimmel &amp; Deek, 1995).</td>
</tr>
<tr>
<td>• Integration is not computer technology functioning as an electronic worksheet or reward station (Dias, 1999).</td>
</tr>
<tr>
<td>• Replacing textbooks with electronic textbooks does not constitute integration of computer technology into the curriculum (Kimmel &amp; Deek, 1995; Lemke 1998; Ridgway &amp; Passey, 1995).</td>
</tr>
<tr>
<td>• Layering computer technology onto traditional curricular objectives and teaching strategies is not integration (Hannafin and Land 1997; Johnson, Schwab &amp; Foa, 1999; McKenzie, 1994a; Miller &amp; Olson, 1994).</td>
</tr>
<tr>
<td><strong>Teachers and Teaching</strong></td>
</tr>
<tr>
<td>• Teacher orchestrates activity structures that assist in students’ building their own meanings. Activity structures are characterised by student involvement, student centred, collaborative and team structures (McKenzie, 1994a; Swan &amp; Mitrani, 1993).</td>
</tr>
<tr>
<td>• Teaching styles vary along a continuum of instruction and construction where a balance is maintained by a variety of approaches for the benefit of the students’ learning: Teachers’ use of computer technology is not depicted as an end in itself in the learning-teaching process but as a means to an end (Sandholtz, Ringstaff, &amp; Dwyer, 1997).</td>
</tr>
<tr>
<td>• Teaching actions no longer depend on the transfer of knowledge from teacher to student (Hannafin &amp; Land, 1997; Scheffler &amp; Logan 1999).</td>
</tr>
<tr>
<td>• Teachers are responsible for guiding student learning, meeting complex individual and pedagogical needs (Swan &amp; Mitrani, 1993).</td>
</tr>
<tr>
<td>Computer Technology</td>
</tr>
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<td>---------------------</td>
</tr>
<tr>
<td>• Functions as an ubiquitous tool (Johnson, Schwab &amp; Foa, 1999).</td>
</tr>
<tr>
<td>• Provides interactivity - equity between student-teacher interactions; greater individualisation of learning, student-centredness and co-operation (Swan &amp; Mitrani, 1993).</td>
</tr>
<tr>
<td>• Functions as tools to enable students to do research, to analyse data; and to apply knowledge (Scheffer &amp; Logan, 1999).</td>
</tr>
<tr>
<td>• Provides information to be assessed from a variety of sources for both teachers and students.</td>
</tr>
<tr>
<td>• Functions not as a substitute for the teacher. (Callister and Dune, 1992 in Pepi &amp; Scheurman, 1996).</td>
</tr>
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<table>
<thead>
<tr>
<th>Students and Learning</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Students co-construct knowledge together with the teachers rather than “preserve” the knowledge delivered by teachers (Dede, 2000; Jonassen, 1995; Riel, 1994).</td>
</tr>
<tr>
<td>• Responsibility for learning rests on the students and not solely on the teachers or computer technology (Pugalee &amp; Robinson, 1998; Swan &amp; Mitrani, 1993).</td>
</tr>
<tr>
<td>• Students apply knowledge to authentic situations and leaning expectations like accessing information, evaluating knowledge sources and applying knowledge sources to issues and problems (Hannafin &amp; Sand, 1997; Johnson, Schwab &amp; Foa, 1999; Scheffler &amp; Logan, 1999)</td>
</tr>
<tr>
<td>• Integration should not be identified as student activities which utilize the computer technology as tools to keep students occupied or as reward stations (McKenzie, 1994a).</td>
</tr>
</tbody>
</table>
part of classroom with the integration of computer technology, is intertwined with the other integral elements of the classroom.

Integrating computer technology into teaching results in an environment that is identified by engaged teaching and learning. This involves expanded teaching and learning opportunities where the computer technology intersects with the teacher, students and subject matter resulting in greater student autonomy and responsibility for students’ learning.

Although this section of the review paints a “pretty” picture of teachers’ construction of classroom meaning as expressed by the educational computing literature, the reality is far from it. Most of the literature here tends to be phenomenological theorizing (Budin & Meir, 1998; Dede, 2000; Dias, 1999; Hannafin & Land, 1997; Jonnassen, 1995; Kimmel & Deek, 1995; Lemke, 1998; McKenzie, 1994a; Pepi & Scheurman, 1996; Ridgeway & Passey, 1995). Others tend to be descriptive, survey oriented empirical studies that seem to espouse trends and patterns (Hadley & Sheingold, 1993; Scheffler & Logan, 1999; Swan & Mitrani, 1993). Some of these studies seem to reflect pseudoscience research (Reeves, 1993). Pseudoscience research refers to research that purportedly adheres to the structure of a given scientific paradigm but fails to do so. Thus, this type of research fail to live up to the theoretical, definitional, methodological and/or analytical demands of the paradigms upon which they are based. The studies by Pugalee and Robinson (1998); Thurston, Secaras, and Levin (1997) reflect this pseudoscience research. Some of these studies seem not to mention the approach or paradigm taken in the research process (Aldrich, Roger & Scaife, 1998; Johnson & Schwandt, & Foa, 1999). Furthermore, most of these studies lack ethnographic approaches to the context in which the computer technology is used: thus the elements of the social dynamics of the classroom and profound qualitative changes that might occur are lacking. The Sandholtz, Ringstaff, and Dwyer (1997) study, although a pertinent study of how teachers integrate computer technology into classrooms, has been criticised for presenting theories of stage development.
in which simply having computers in the classroom pushed teachers from didactic to constructivist teaching (Budin & Meir, 1998).

Mergendollar (1996) and Olson, James and Lang (1999) contend that it is teachers who shape new ideas into workable forms and educational opportunities, and whose insights are therefore needed in the planning and delivery. The language of this practice is stated as a crucial imperative for the identification of teachers' use of computer technology. This perspective is lacking in the aforementioned research literature.

Thus, the notion of teachers' construction of classroom meaning seems to be peppered with a range of descriptions of what integration of computer technology in the classroom looks like. Most of these tend to be reported as behavioural aspects and there is no consensus that links the conceptual underpinnings of teachers' conception of integration in relation to the integration of computer technology into teaching.

2.1.3 Trends in science teaching

This section of the review on science teaching is not presented as a comprehensive critical review nor does it purport to be a historical representation of science teaching. It looks specifically at the trends that shape classroom meaning within this literature. The purpose of this review is to elucidate what entails as classroom meaning within this field of research.

For some time now, the main emphasis in science teaching approaches has been in bringing about changes in students' misconceptions about science. To bring this change, studies in science education research have highlighted the need to provide structured frameworks. That is, structured frameworks that enable students to integrate new information and help them build their own conceptions of science that cohere to the scientific beliefs, ideas and conventions of the larger scientific community (Driver, Squires, Rusworth, & Wood-Robinson, 1994; Hodson, 1994;

Riquarts and Hansen (1998) seem to capture this change as,

... approaches to the teaching of sciences recognize that an orientation to the pupil is becoming necessary, i.e. pupil's interests, learning abilities, needs, etc., have to be taken seriously... Findings from research on effective learning environments also foster the trend towards interactive learning, involving process-focussed pupil activities, teaching about science methods, and awareness of the importance of information processing skills... Furthermore, a shift in the teachers' role in the teaching-learning process can also be noted, turning the teachers' task away from the dissemination of information to a facilitation of the learning environment. (p. 667)

Within this perspective of science teaching and learning, science knowledge is a social product resulting from learning that takes place as an enculturation process (Driver, Squires, Rusworth, & Wood-Robinson, 1994; Hodson, 1994; Hodson, 1998; Hodson & Hodson, 1998a; Hodson & Hodson, 1998b; Matthews, 1993; 1994; Wiser, 1995). That is, where scientific phenomenon is introduced together with understanding and application through explanations and making predictions. It represents a particular way of knowing rather than the individual making sense of the natural world in their own. Scientific knowledge is also socially constructed and validated through a social process of teaching and learning (peers and teachers) rather than discovered personally through the setting up of environments conducive to construction of science knowledge (Driver & Erickson, 1983; Driver & Oldham, 1986; Driver, Squires, Rusworth, & Wood-Robinson, 1994; Leach & Scott, 1995; Posner, Strike, Hewson, & Gertzog, 1982; Pintrich, Marx & Boyle, 1993; Pope & Gilbert, 1988).
What is apparent within this field of research is that there has been a move away from the Piagetian concept of knowledge construction towards that of a social construction of knowledge (Soloman, 1987; Driver, 1989; Driver, Asoko, Leach, Mortimer & Scott, 1994; Hodson & Hodson, 1998a; 1998b; Tao & Gunstone, 1999). Borrowing heavily from Vygotskian and Neo-Vygotskian traditions, the teaching and learning of science is conceptualized as "an introduction to the 'symbolic world' and practices of science" (Tao & Gunstone, 1999: 54). What is recognized is that students' construction of science knowledge and understanding occurs in a social context where conversation and activities are inter-subjective and towards a common goal between teachers and students. This is opposite to that of the Piagetian tradition that emphasizes the students' individual emancipation through physical experiences and its effects on learning (Tao & Gunstone, 1999).

Within this literature on science teaching, teachers' roles in making classroom meaning that leads to students' conceptual change of scientific theories is widely elaborated on. The main consensus, concerning science teachers and science teaching, framed within the sociocultural perspective, is summed up as two crucial aspects. First, teachers are to assist students to construct explanatory models and concepts of conventional science acknowledging the constraints of applying these models and concepts and learning to apply them within the constraints. Second, teachers are to intervene within this teaching and learning process through negotiation that goes beyond the process of enabling personal empirical enquiry through physical experience and discovery. That is, this authentic negotiation aspect captures teachers who not only provide appropriate experiential evidence, but also enable students to make theoretical ideas and conventions of the scientific community their own personal constructions.

Hewson and Hewson (1988) stress that teachers have toolkits as resources for students' conceptual change to occur. These toolkits are the concrete expressions of the ways in which teachers' disciplinary knowledge can be transformed into pedagogical knowledge. This gives teachers a strategy and serves to strengthen the
link between teachers’ conceptions of teaching science and their science teaching performance. Understandings and intentions for teaching and learning actions lie behind these toolkits.

These toolkits seemed to be manifested in a number of ways in the science teaching literature. Some contend that it is the activity of the classroom that is crucial to the making of meaning through the language used; gestures, pictures, graphs and tables, experimenting and doing demonstrations are all part of this constructive process (Ogborn, Kress, Martins & McGillicuddy, 1996). Another view that emerges is that science teaching involves academic tasks and social participation structures that enable science teachers to bring about conceptual change in students (Tomanek, 1994). This view looks at how teachers shape the curriculum to enable student learning and constructive processes. The emphasis being that the task that students are involved in must be engaging both academically and socially so that scientific knowledge is built up within this social milieu. Teachers’ role in setting up the academic tasks and their role in the social participation structures are seen as crucial to the construction of classroom meaning in this view.

Others specifically talk about the importance of explanatory models to science products, methods, learning and teaching (Clement, 2000; Gilbert, 1993; Harrison & Treagust, 2000; Ogborn, 1996; Sutton, 1992). Sutton (1992) states this as:

I see all modelling as inspired by some associated imagery, which can in part be explored verbally. Models, like the metaphors on which I argue they are based, carry entailments or implications, and so they quickly yield the testable predictions that all scientists want (p. 98).

Explanatory models are given a special significance in science education: they are an important constructivist teaching strategy. This is because these explanatory models enable students to build their own conceptions of science through investigation, understanding and communication, key tools in thinking and
working scientifically (Clement, 2000; Gilbert, 1993; Harrison & Treagust, 2000; Ogborn, 1996; Sutton, 1992). The significance is further illustrated by the emphasis that they are the methods and the products of science and it is quite impossible to teach and learn science without using models. Science education research on explanatory models emphasizes the need for a consensual environment within the students' zone of proximal development where social negotiation can occur between teacher and students. This is made on a very strong claim that for students to become effective relational thinkers and to understand theoretical models, the aforementioned factors are required, not just the curriculum material and the teacher's decision to use them in their description and explanations (Harrison & Treagust, 2000).

The teachers' roles within this literature seems to be geared towards bringing about conceptual change in students' concepts of scientific knowledge away from the naïve theories that they hold. That is, teachers provide a learning environment where teachers mediate knowledge construction by helping students become intellectually independent thinkers so that they can construct their own knowledge. This review also stresses that science teachers possess toolkits that function within the social setting of the classroom to bring about this conceptual change: academic tasks, social participation structures, explanatory models etc. This conceptual change is being seen as socially constructed and validated, moving away from the Piagetian framework of individual emancipation towards knowledge construction.

2.1.4 Overall consensus: construction of classroom meaning

So far, teachers' construction of classroom meaning has been discussed from the three viewpoints: general education literature (section 2.1.1), educational computing literature (section 2.1.2), and science education literature (section 2.1.3). Drawing together the major perspectives from the aforementioned discussion of teachers' construction of classroom meaning the researcher provides a definition of teachers' construction of classroom meaning pertaining to this
study. Thus, teachers’ construction of classroom meaning when integrating computer technology is defined as: The teachers’ role in negotiating personal transformations in students of cultural templates, through constructive activity structures, is shaped by teachers’ interpretations of how to present the cultural templates within a social context/community of practice. These interpretations are the teachers’ conceptual underpinnings of the social context in which teaching integrating computer technology occurs.

2.2 The organizational impact of computer technology in classrooms

This section of the review deals with the macro, meso and micro levels of teaching integrating computer technology. The literature on teachers and teaching within the context of educational innovation and change is critically reviewed followed by the literature on teachers’ roles and role changes and teachers’ use of computer technology as a tool. To repeat: Since the thesis is looking at how teachers construct classroom meaning, this was the main emphasis in the review of these sections. Plausible explanations, as they emerge from the reviews, are highlighted in regard to this research question.

2.2.1 Teachers and teaching in the context of educational innovation and change

In the educational computing literature the organizational impact of computer technology in classrooms and teachers’ use of computer technology in the classrooms seems to be viewed through two major frameworks: the technological determinism, and social determinism (Bigum, 1997; Bromely, 1997). Within the technological deterministic framework, the computer technology is perceived as a technology that is a natural evolutionary and progressive consequence (Bigum, 1997; Bromely, 1997) of the teachers’ complex classroom technologies (McKenzie, 1994a; Miller & Olson, 1994; 1998; Olson, 1992; 2000). Cogent assumptions seem to perpetuate this view: teachers are solely responsible for students’ learning outcomes and thus can be replaced by new technologies
Teachers' views of technology are fixed (Kerr, 1991). These cogent assumptions are further fuelled by the premise that human actions like teaching can be controlled by external forces (top-down mandates). It is also influenced by the perspective that teachers and parents themselves advance this technological determinism by purporting the rationale that computer technology presence in schools will improve teaching and learning, together, benefiting students' future prospects outside school (Bigum, 1997).

Social determinism on the other hand differs from technological determinism in that it asserts that educational outcomes derive primarily from the sociocultural characteristics of classrooms and are largely independent of the nature and propensity of a particular technology...are delegated the work of providing neutral support for teaching and teacher (Bigum, 1997: 252).

According to this perspective, the computer technology exerts no bias or constraints and its use or abuse is largely dependent on the social conditions where the computer technology is used. This perpetuates teaching and learning landscapes where teachers' pre-existing technologies, comprising techniques and tools that sustain “familiar and predictable resources and routines” (Olson, 2000: 2) have greater control. This results in the computer technology having no effect on teaching and learning actions. The use of computer technology may also be conflated with those pre-existing technologies based on the assumption that the use of computer technology is neutral. This perpetuates the view that computer technology is applicable in all social contexts depending on the social conditions of the classroom alone. Thus, if students in a classroom face difficulties in comprehending a concept, this determinism provides support that the neutrality of the computer technology might be the answer. This forsakes the other social factors or theoretical foundations of learning or teaching that may underpin these teaching or learning difficulties. It reeks of simplicity in contrast to the complex
and multidimensional landscape in which teachers, students, computer technology and curriculum are located.

Basically, technological and social determinism claim that the use of computer technology is constant and context free (Bigum, 1997; Bromely, 1997). These two determinisms as mechanisms for teachers’ construction of classroom meaning is befuddled by the prospect that by accepting one over the other leads us into a another conundrum; Bromely (1997) writes:

Viewing ‘technology’ as a separate entity distinct from ‘society’ really leaves only two options for how to think of technology’s impact on society: either technology affects society or it does not. If it does, technology must be some autonomous, external influence on society, carrying its own intrinsic bias; if it does not, then technology must be neutral, and all that matters is how it is used. (p. 55)

The corpus of arguments from the innovation implementation and teacher change literature, and the skills training literature emphasise that this framework for understanding how teachers construct classroom meaning is limited and skewed towards technoromanticism (Agalianos & Cope, 1994).

2.2.1.1 Research from innovation implementation and teacher change literature

Research from literature on innovation, implementation and teacher change, including the implementation of computer technology in classrooms, has continually expressed that there exists a failure to acknowledge the teacher and teacher assets (Cohen, 1987; Cuban, 1990; Miller & Olson, 1994; 1998). These teacher assets are the real determinants or regulatory agents of classroom contexts. They include: experiences, personal theories and values (Fullan & Stiegelbauer, 1993; Fullan, 1998; Hodson, 1994; Mclaughlin, 1990; Van den Berg & Sleegers, 1996); educational visions and ideas (Ball & Cohen, 1996; Davis,
1999; Rubin, 1989; Willis, 1997); psychological and philosophical perspectives (Alexander, Murphy & Woods, 1996); and belief systems (Cohen, 1987; 1995; Cuban, 1986; 1990; 1993; Wiburg, 1997). Other researchers stress that innovation implementation and teacher change is privy to teacher interpretations and meanings that arise in the context in which they work (Sikes, 1992). This reinforces the permanent importance of subjective reality that teachers face (Van den Berg, 1999).

What is apparent is that innovation implementation suffers from the phenomenon of “one size fits all” (Lieberman, 2000: 221) where the teacher is treated as a technician who maintains and works within this “one size fits all" phenomenon. This results in unique classroom ecologies that contain pre-fabricated models suited for the technicians handling/coping (Agalianos & Cope, 1994).

Furthermore if we are to fully acknowledge the dominance of either technological or social determinism, the issue of teacher reflection (Halliday, 1998; Lankshear & Snyder, 2000) comes to the forefront. Reflection and reflective approach to teaching seems ill defined in this arena of technological and social determinism. From the technological determinism perspective, teachers’ formulation and reformulation of ends and means for teaching/learning actions lead to a dead end, since human control is deemed unfit in this evolutionary and progressive technology. While from the social determinism viewpoint, reflection is skewed towards the social conditions and does not take into account the presence or effects of the computer technology into the teaching and learning landscape: not a holistic view.

2.2.1.2 Research from skills training literature

Recent research from skills training literature points to a number of decisive factors that seem to be involved in teachers’ construction of classroom meaning. These decisive factors seem to be based on the structural-functional perspective versus the cultural-individual/culture building perspective dichotomy.
The structural-functional perspective states that schools operate in rational, forceful and goal-directed manner (Sleegers, & Van den Berg, 2000:805) where skills training is seen as the “dipping” of teachers into technology (Lawson & Comber, 1999: 42) to create proficiency in technical skills. Within this structural-functional perspective curricular, pedagogical and practical relationships and insights (Fabry & Higgs, 1997; Makrakis, 1991; Wild, 1996); educational significance of the computer technology attributes (Callister & Burbules, 1990); and the people effects (Gilmore, 1995) seem less important. Thus, within this structural-functional perspective skills training approach deals with the complex issue of teaching through technical routines, specialisation, productivity and behaviourism (Budin, 1991; Callister & Burbules, 1990; Gilmore, 1995); and theoretical essentials (Makrakis, 1991; Wild, 1996) pertaining solely to computer technology. There seems to be no reference to the belief systems or the images that teachers have of how classrooms operate even though research on images and teachers’ beliefs strongly emphasise the importance of images and beliefs in shaping teaching actions (Briscoe, 1991; Veen, 1993).

The emphasis on structural-functional perspective, as mentioned in the aforementioned discussion, has lead to manifestos that simply view teachers’ construction of classroom meaning as something learnt from transfer models (Bottino, Forcheri & Molfino, 1998). These transfer models advocate teachers to study expert teachers who are effective in their use of computer technology. Others (Sandholtz, Ringstaff and Dwyer, 1997) suggest that teachers follow the five-stage model based on the innovation diffusion theory (Rogers, 1995). But these studies seem to ignore the obvious and inherent problems that these transfer models carry. With regard to the novice-expert approach, it has been suggested that most teachers do not favourably look up to expert teachers (Olson, 1999; Watson, 1993). Furthermore, the five-stage model derived from agricultural studies is claimed not to be feasible within classroom contexts (Kerr, 1991). These so called solutions, novice-expert and five-stage models, can be summed up to Tanner’s (1998) descriptions of the disastrous scenario of the perils of dividing teachers based on skills:
Just imagine being a member of a school faculty divided evenly between those designated teachers of lower-order thinking and those anointed teachers of higher-order thinking and problem solving!... the disastrous impact on faculty morale.... (p. 349).

This hierarchy of placing teachers within stages simply does not work because no teacher would like to be referred to as a semi-professional based on one's position in the five-stage model. This only leads to labelling of teachers where context, teacher knowledge and approaches are surrendered to a scale.

The aforementioned discussion has highlighted that overemphasis on technical skills seems to be skewed and revolutionises teachers in accordance to the so-called evolutionary and progressive nature of the computer technology. Anyway, recent research has shown that gearing teachers with the mechanics of hardware and software of computer technology does not lead to a learning context (Bransford, Brown, Cocking, 2000; Persky, 1990 in Wills, 1999; Riel, Schwartz, Peterson & Henricks, 2000). But, it does point to the perspective that teachers' construction of classroom meaning, though pertinent, does not solely rely on technical skills.

At this point it is important to acknowledge that skills training literature is looking into the area of the culture building process (Lieberman & Miller, 1991; Sleeegers & Van den Berg, 2000) as an area where teachers' potential for integrating computer technology might be found. This cultural-individual perspective views the innovation implementation from the teachers' involvement during the process of cultural transmission integrating the innovation where prior experience, and subjective experiences together with the innovation underpin the teaching/learning environments. This perspective seems pertinent, as it is not divorced from the realities of classroom and school context (McKenzie, 1994b; Wild, 1996). That is, it takes into account the teachers' crucial role in engaging and enabling students in constructing their own conceptions of knowledge that coheres with the cultural patterns (Bowers, 1998a; 1998b) of the disciplines that they are teaching in their
classrooms. This is what recent research captures as the "miniature replica of the schools' staff and mode of organisation" (Sleegers & Van den Berg, 2000: 803; Birman, Desimone, Porter and Garet, 2000; Williams, Coles, Wilson, Richardson & Tuson, 2000). This displaces the view of the teachers as "passive recipients" undergoing a "new vocationalism" (Lieberman 2000: 226) that is prevalent within the structural-functional perspective.

Together with the literature on skills training, educational innovation and change, there has also been a continuous stream of research that places the importance of teachers' conceptual mappings of the classroom context as an imperative for teachers' use of classroom innovations. Teachers' perceptions and beliefs of learning, social factors, organisational factors; classroom context and school context have been cited as the regulatory agents shaping classroom actions, no matter what new skills are learnt from skills training/professional development (Bitter & Yohe, 1989; Cohen 1995; Fullan & Stiegelbauer, 1993; Fullan; 1998; Guskey 1986; Hadley & Sheingold, 1993; Mehan, 1989; Stein, Smith and Silver; 1999).

Basically what we are seeing from the aforementioned discussion relating to technological and social determinism; research from innovation implementation and teacher change literature; and, research from skills training literature pertaining to teachers' construction of classroom meaning with the integration of computer technology, is the lack of emphasis on the acknowledgement of psychological, philosophical and cultural roots that underlie the use of computer technology in the classroom. Furthermore, technological determinism and social determinism offer a single-focus approach to teaching and learning respectively: technological determinism views technology as a progression devoid of human influence, while social determinism views technology as a neutral entity that perpetuates teaching and learning without any outward effect/effects. If either determinism is taken into account as perspectives for how teachers construct classroom meaning, the computer technology becomes the focus with the
abandonment of the holistic and organic nature of classrooms (McLaughlin, 1990).

On the other hand, two proponents in this area of research propose alternative views that seem plausible in seeking answers to how teachers construct classroom meaning. They seem to capture teachers within the culture building process. Bigum (1997) sketching something close to a cultural-individual perspective, declares that teachers are professionals who negotiate and distribute competencies that allow for computer technology's place in the curriculum rather than succumb to the social or technological determinism and "dictates in hardware and software" (p. 254). He terms these negotiations as the "programs of action of each agent" (p. 254) which are played out when teachers set the humanistic agenda for classroom practice. He also calls for an investigation of these programs of action that characterises the teachers' role. Lankshear and Ball (2000), elaborating on Bigum's approach, picture his approach as a "‘mindset’: a way of teachers going about their business and perceiving the roles and modes of operation of other agents in the classroom" (p. 112).

On the other hand, Bromely (1997) advocates the social shaping approach to teachers' construction of classroom meaning where the social factors, previous technologies (the pre-existing complex technology) and the computer technology are all sifted through by the teacher to mediate teaching and learning with psychological underpinnings of each of the components of this computer technology-social context interaction.

2.2.1.3 A view of how teachers construct classroom meaning

A number of insights can be gathered from the aforementioned review. First, this review has highlighted that teachers' involvement in culture building process is a key determinant of how teachers construct classroom meaning. This is apparent in the skills training literature that states that skills training should look at this process and conceptualise skills training from this perspective rather than just
providing superficial skills. Second, teachers' conceptual mappings of the classroom context have to be investigated: these teacher assets are cited as the key determinants/regulatory agents that both shape the construction of classroom meanings and underlie the subjective realities that they face in the classrooms. This review does reveal some multiple realities of how teachers construct classroom meaning. It states that teachers possess a mindset that is reflective of the programs of actions that bring about negotiations resulting in teaching and learning centred on the culture building process rather than solely manning the hardware and software of computer technology. This mindset is also characterised as one that is aware of the intrinsic biases of the computer technology, together with the social setting and the social factors of the classroom.

2.2.2 Teachers' roles and role changes: Labels

This section of the review critically reviews teachers' roles in the literature in relation to the integration of computer technology into teaching. The main aim of this section is to provide an extensive and expansive view of teachers' roles and to derive plausible ways in which teachers' roles might be involved in the construction of classroom meaning. To do this, the literature concerning teacher labels and how they depict teachers' roles when they use computer technology for teaching and learning is reviewed.

Gleaning the literature, teacher labels depicting teachers' roles in their teaching with the integration of computer seem to be the norm. In general, these teacher labels are often founded on impoverished views of teaching. That is, teacher labels portray a simplistic and monolithic view of teachers' roles to account for the construction of classroom meaning with the integration of computer technology. These teacher labels collectively portray a utilitarian view, that involves an insufficient, unprofessional and an associated model view of the teachers potential and teaching within the context of teaching integrating computer technology. Teachers' roles, pertaining to these teacher labels, are portrayed as solitary thinkers and actors within a social vacuum (Nickerson, 1995). These aspects are
elaborated in the following discussion in which an attempt is made to draw out perspectives to substantiate the teachers' role in the construction of classroom meaning integrating computer technology.

Teacher labels like coach, guide, organizer, initiator, diagnostician, moderator, weaver, facilitator (of learning); catalysts, synthesizers, integrators, tutors, and sage abound in the educational computing literature and are used to account for the role replacement perception in the educational computing literature pertaining to teachers' roles and their use of computer technology for teaching. Basically these labels seem to be metaphorical imprints derived from the parameters that encapsulate the use of computer technology, rather than on "a base of human action" (Murphy & Pardeck, 1991: 395). That is, labels tend to be viewed as derivatives and commodities pertaining solely to the parameters of integrating computer technology into teaching, without an acknowledgement that the use of computer technology brings with it a meaning expressive of the human dimension as well. Selwyn (1997) refers to this as the neglect of the reciprocal influence that exists between humans and their use of computer technology.

McKenzie (1994a) on the other hand cautions that labels like "sage on the stage to guide on the side" completely ignore the "soft technology" that makes up the prior practices of teachers. These "soft technology" include teachers' beliefs; teachers' perceptions of classroom teaching and learning; and teachers' theories of teaching and learning. Other researchers conclude that the human dimension in classroom teaching is expressed in manifest ways: improving general problem-solving skills; focus on declarative knowledge and procedural knowledge; and, reinstating an enthusiasm for teaching (Mandinach & Cline, 1996, Mason, 2000). Labels derived from the use of computer technology alone will not suffice to capture the holistic endeavours of teachers and their teaching. Scrimshaw (1996) suggests that replacing one role for another, through the use of labels, undermines teachers' responsibility for understanding these multiple teaching actions. He suggests that role replacement produces a role and product dichotomy – assuming this role will
result in a certain type of response/learning outcome. Scrimshaw suggests that
teachers' roles pertaining to their use of computer technology be interpreted from
how they adapt and interpret them (computers) to fit their own philosophy
of education and the best interests of learners they work for...This implies
the teachers' role too cannot be rigidly pre-specified and then applied in
every situation (p.110).

Thus, role labels should encompass the teachers' need to capture the processes of
teaching and learning rather than products of teaching with the integration
computer technology.

On the other hand, Peck and Dorricott, (1994) propose that educators are looking
for a "paradigm shift" (p.12) to "re-place" (p.13) their roles in educative
experiences and performances integrating computer technology into teaching and
not to "replace" (p.13) traditional educational practices with technical proficiency,
routine and automation. This proposal is argued from a strong affective viewpoint
of three dualities. Peck and Dorricott (1994) write,

Teachers can build strong productive relationships with students.
Technology can't. Teachers can motivate students to love learning.
Technology can't. Teachers can identify emotional needs. Technology
can't. (p. 13).

But what this replacement means within the field of educational computing
research seems vague. As Dowling (2000) writes:

Where the teacher adopts the role of facilitator rather than instructor, a
scenario currently favoured in many existing learning contexts where
constructivist principles apply, will other, perhaps unanticipated
configurations and hierarchies of inter-relationships arise, and will these
necessarily be conducive to learning? (p. 169)
The researcher contends that this is the basic scenario depicted in literature with regard to teacher roles. Labels like facilitator or coach do not portray any teaching or learning paradigms within them. What is apparent in past and in recent literature on teachers’ roles is the instructional paradigm. This paradigm has the teacher overtly concerned with and immersed in tasks of teaching and keeping students occupied - the teachers’ behaviour. The learning paradigm stipulates for teachers two imperatives: to make knowledge construction an inter-subjective goal; and, for teachers’ to function differently in their roles of facilitators of learning. As Lasley (1998) vividly remarks:

...constantly ‘reading’ students to determine how to create a better atmosphere for student growth...get outside of themselves and get inside the minds of students. (p. 85)

Figure 4, from the recent study by Forcheri and Molfino (2000), together with the accompanying passage, illustrates the dire need to examine how teachers construct classroom meaning from a perspective that takes into account the educative environments that teachers are part of. Figure 4 captures the activities and the role of the educators as facilitators in classrooms integrating computer technology. It lists the learners’ activities in relation to the educators’ role as facilitators and the educators’ use of computer technology in the classroom.

Although this study by Forcheri and Molfino (2000), represented by Figure 4, focuses on computer technology as a tool for learning, the researcher feels that barricading and fortifying teachers “as facilitators and providers of stimuli, rather than driving the educational process” encapsulates that labels merely provide a utilitarian, insufficient, unprofessional and associated model of teaching.
Table 3. Activities, role of the educator and educator’s use of ICT

<table>
<thead>
<tr>
<th>Learners’ activities</th>
<th>Educator’s role</th>
<th>Educator’s use of ICT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Individualised self-learning</td>
<td>Indicate the tool</td>
<td>Private email, Analysis of student’s history</td>
</tr>
<tr>
<td></td>
<td>Monitor the activity</td>
<td>Chat</td>
</tr>
<tr>
<td>Analysis of different material</td>
<td>Suggest a range of tools</td>
<td>Analysis of student’s history</td>
</tr>
<tr>
<td></td>
<td>Monitor the activity</td>
<td>Use of shared database</td>
</tr>
<tr>
<td>Search</td>
<td>Engage a discussion, based on the learner’s previous experience</td>
<td>Discussion list</td>
</tr>
<tr>
<td>Role play</td>
<td>Assign the activity</td>
<td>Email</td>
</tr>
<tr>
<td></td>
<td>Solicit any work involved</td>
<td>Mailing lists</td>
</tr>
<tr>
<td></td>
<td>Monitor the activity</td>
<td>Discussion lists</td>
</tr>
<tr>
<td></td>
<td>Give help on demand</td>
<td>Electronic repository</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Frequently asked questions</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Private email</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Electronic repository</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Shared data base</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Shared mailing list</td>
</tr>
<tr>
<td>Teaching</td>
<td>Monitor the activity</td>
<td>Discussion lists</td>
</tr>
<tr>
<td></td>
<td>Give help on demand</td>
<td>Frequently asked questions</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Private email</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Electronic repository</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Shared data base</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Shared mailing list</td>
</tr>
<tr>
<td>Articulated projects</td>
<td>Suggest a theme, based on the learners’ interests</td>
<td>Electronic repository</td>
</tr>
<tr>
<td></td>
<td>Ask learners to organise the work and take over the management of the whole project</td>
<td>Shared data base</td>
</tr>
<tr>
<td></td>
<td>Take part in the project (without management responsibility)</td>
<td>Shared mailing list</td>
</tr>
<tr>
<td></td>
<td>Ask learners to choose the programme to use, from those available</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Give help on-demand</td>
<td></td>
</tr>
<tr>
<td>Problem solving</td>
<td>Set the assignment</td>
<td>Private and public email</td>
</tr>
<tr>
<td></td>
<td>Guide the learners’ work by means of explanations, further material, etc</td>
<td>Electronic repository</td>
</tr>
<tr>
<td>Management</td>
<td>Set the task</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Monitor the learners work</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Take control of the lab</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Give help on demand</td>
<td></td>
</tr>
</tbody>
</table>

Finally, we have to note that the teachers’ use of ICT to co-ordinate the classroom work helps them to assume the role needed to encourage students to acquire autonomous learning capabilities (see Table 3). To this aim, in fact, teachers have to act as facilitators and providers of stimuli, rather than driving the educational process. In our opinion, psychological reasons and habits make it difficult to act in this way when working in a classroom. Communication technology makes it possible to maintain contact between teacher and students but, at the same time, the physical distance naturally gives more independence from the teacher.

**FIGURE 4**

*Illustration of teacher as facilitator (from Forcheri & Molfino, 2000: 180)*
Moving towards science education research, there seems to be the same forecasting of teacher roles. Recent research from the “Web-Based Integrated Science Environment” (WISE) project (Linn & Slotta, 2000) and “Knowledge Integration Environment” (KIE) project (Bell, 2000; Jorde, 2000; Linn, 2000; White, 2000) also depict a somber portrayal of science teachers. For example the excerpts from the WISE project reveal:

Teachers also add Web sites that feature local house designs...Teachers can customize the hints, prompts, discussions, and even the focus of the project...teachers varied greatly in the frequency and duration of their interactions with students during the project. One teacher spent considerable time talking in depth with each student group, visiting groups once, at most, during a class period. Another teacher interacted for very short periods of time but visited each group several times...enable teachers to interact deeply with their students...(Linn & Slotta, 2000: 30)

Excerpts from the KIE project a similar portraiture of teachers’ roles:

KIE Project: introduced a new media for science teaching-the computer and the Internet...Computers and the Internet are used to teach science not because they are the newest methodology but rather, because they lend themselves to creating a better learning environment within the science classroom...(Jorde, 2000: 883)

One goal of these design experiments is the articulation of principles to guide future curriculum and software designs (Bell, 2000: 797).

The partnership works interactively to develop teaching materials, and adjusts the materials following research on their effectiveness (White, 2000: 875).
An earlier comment made by Linn (1998), in regards to the KIE project, portrays teachers as:

... freed to spend more time tutoring individuals or small groups...frees the teachers from mundane questions. The teacher can tutor students who need the most help... . (p. 279)

Although these projects have worthwhile intentions, like the common aim of increasing students’ lifelong learning by the design of curriculum materials that provide an integrated aspect of science content and computer technology, the role of the teachers seems limited and static. They reflect a very linear view of teachers as spectators who observe and act on an external world (Bowers, 1997). That is, teachers’ roles and teaching are seen as simple acts rather than complex acts that take into account the interaction between teachers’ beliefs, teachers’ perceptions of classroom teaching and learning, and their theories of teaching and learning. Furthermore, teachers’ roles, ascertained from the aforementioned KIE and WISE projects, also seem to contradict Linn’s (1998) previous stance that states that the role of teachers, within the scope of integrating computer technology, is to increase the effectiveness of science teaching. That is, by both creating effective learning communities and developing more sophisticated understandings of science teaching where there is a balance between student self-learning and teacher explanatory models. In addition, Linn (1998) also claims that “they (technological tools) in and of themselves, lack the power to transform science teaching and learning (p. 283)” and this contradicts the findings about teachers’ roles and the role of computer technology in science teaching as stated in the KIE and WISE projects.

The researcher is not suggesting that the studies do not portray aforementioned aspects for teaching with computer technology, but there seems to be dearth of explicit explanations when it comes to the teachers’ role in the educative processes within the classroom context. What prevails is the spatial and temporal actions that account for teacher behaviours: heavy on description but lacking any
potential explanatory force. Looking at this from a different angle, such studies seem to neglect or pay less attention to the knowledge about teachers and research. There exists literature that proffers sufficient information that teachers have a strong inclination towards research that clearly states relationships between subject matter, student learning and teaching (Kennedy, 1997; 1999; Warton, Goodnow & Bowes, 1992).

The aforementioned studies (Bell, 2000; Forcheri & Molfino, 2000; Jorde, 2000; Linn & Slotta, 2000; Linn, 2000; White, 2000) concerned with teachers’ roles and role change also seem to neglect the obligatory and orientational roles of teachers that provide social mechanisms for shaping teaching and learning actions (Buchman, 1986). The obligatory aspect refers to standards and goals that teachers’ roles carry. The orientational aspects of roles show keen interest in student learning and centre on the curriculum and an affective component. Buchman further states that the role orientations carry dispositions - “a bent of mind” (p. 534) a natural inclination relating to the social and moral qualities of one’s actions. They should not be envisioned as habits but as intelligent capacities. The intelligent capacities that are required should be more inclined towards the main goal of student learning. Labels, as proposed in the educational computing research literature, do not portray these orientations, obligations or dispositions.

Olson (1997) provides a description of teachers’ roles with the integration of computer technology into teaching which coheres with the aforementioned perspectives of orientational and obligatory roles of teachers. He writes:

Teachers establish work microcosms which are suffused with values and the values, like them or not, are connected to virtues that teachers think these students ought to have both as civilians and as workers. This is no narrow vocational socialization. Teachers have images of civility in mind which cut across specialized roles to encompass the whole person; all school subjects are taught with these images in mind. (p. 388)
Thus, this description by Olson provides a plausible idea of how teachers might construct classroom meaning with the integration of computer technology.

On the other hand, other researchers have provided other ways to look at how teachers’ roles might be involved in their construction of classroom with the integration of computer technology. Campoy (1992) suggests that teachers are effective, and discriminating users of any technology in the classroom. This concurs with Cuban (1990) who suggests that teachers make situationally constrained choices due to the isolation of their teaching practices; the security of being solo practitioners; and, to cope with external mandates. He further states that novel changes may occur that may reflect patterns that teachers use to guide their teaching. Apple and Jungck (1990) echo the views held by both Campoy and Cuban as:

...teachers are never dupes, never simply the passive puppets that structural models would have us believe. Their agency, their actions in concrete situations such as these, may have contradictory results. They may have elements of ‘good sense’ and ‘bad sense’ in tension as they construct their responses to a crisis in the economy, in authority relations, and in education. Yet, the fact that they do construct these responses once again shows the very possibility of difference. (p. 250-251).

Furthermore Ruberg, Moore and Taylor (1996) and Scott, Cole and Engel (1992) advocate strongly for the existence of “social cues” and “multiple threads” or “form of interaction” and “social arrangements” respectively (p.192) pertaining to the integration of computer technology into teaching. Merrill, Drake and Pratt (1996) in Wild and Quin (1998) refer to “natural principles” that may be responsible for instructional strategies occurring in teaching events that have the integration of the computer technology into teaching events. These social cues, multiple threads, forms of interactions, and/or social arrangements may be the natural principles that are the moral dimensions that encapsulate norms and ways
(Lauzon, 1999) that teachers encapsulate into teaching practices resulting in the various communities of practice.

So far, the discussion on teacher labels pertaining to teachers' roles and their integration of computer technology into teaching has provided some input into the issue of how teachers construct classroom meaning with the integration of computer technology. That is, labels pertaining to teachers' roles do not seem to provide sufficient explanations for how teachers construct classroom meaning with the integration of computer technology. The review now turns to literature that seems to provide some footing of how teachers' roles are related to their construction of classroom meaning with the integration of computer technology. These studies provide a different analytical lens to look at this issue of teachers' roles and role change and its relationship with the classroom culture and the integration of computer technology into teaching. One of these, the work of Bowers (1988a; 1988b; 1990; 1993; 1995; 1997; 1998a; 1998b) seems to provide a more substantive and plausible account of teachers' roles within the context of teaching integrating computer technology. Bowers captures teachers as mediators involved in the dynamic process of making education a form of transgenerational ritual of perpetuating the cultural patterns resulting in students gaining the communicative competence of cultural templates of disciplines. Teachers' metaphorical language and their deeper understanding of culture, language and thought underpin this mediation process. Bowers' s writes that there is a need to "take account of the role language plays in the very complex process of cultural reproduction" (1990: 76). He asserts strongly that teachers' can amplify those aspects of the cultural transmission process that are reduced by the selective characteristics of the computer technology. That is, teachers' roles are more than surrendering to the inherent characteristics of the computer technology. Instead, teachers' roles rest within their own knowledge of amplification/reduction potentials that they view as pertinent to the survival of the ecological landscape in which they work.
Another pertinent message that emerges from Bowers’ extended work in this area is the implications for teacher education. Bowers (1998b):

...the possibility that the professional education of teachers will include theory frameworks that help to understand the cultural characteristics of computers is nearly non-existent. Without this understanding few teachers will be able to recognize their responsibility for compensating for the inherent limitations of computers. Furthermore, they will not understand the importance of introducing a more critical and culturally informed understanding of technology into the curriculum. The consequence is that the computer industry, and its proponents within the educational community, will continue to educate the public about how computers fit into the larger picture of work, community, progress and the ecological crisis. (p. 78)

The perspectives from Bowers’s work also cohere with Knupfer (1993). She claims that teachers prevent themselves from becoming victims of educational change by considering the balance of incentives and disincentives that are feasible in the classroom context. The change caused by the use of computer technology effects the daily running of the classroom. Teachers may be using built-in imperatives or the social interactions within the classroom context to construct lessons. Knupfer further suggests that teachers may be “examining and overcoming tangible as well as intangible prejudices” (p. 178) to construct the classroom context with the integration of computer technology into teaching.

On the other hand, Mandinach and Cline (1994) indicate that teachers’ role is linked to the fundamental patterns of cognitive interactions in the classroom. They claim that the cognitive empathy that the teacher has is an important determinant of the cognitive structure of a subject domain that a student uses at any given time. This kind of cognitive empathy allows the teacher to recognize what steps can be taken next to help a student efficiently and effectively to move the learning
process along. This attribute and/or learned skill – cognitive empathy - is the most important competency of teachers in a computer technology rich classroom.

To further substantiate the aforementioned discussion a final reference to the higher echelons of educational theories provides much impetus to investigate teachers’ roles as mediators. Dewey, Vygotsky and Freire in their theoretical writings have stated that teachers are mediators, actively mediating the learning and the constructive process of learners from what is known, what is prematurely/conceptually known and what is not yet known rather than being facilitators of learning or setting up learning environments (Mason, 2000).

2.2.2.1 A view of how teachers construct classroom meaning within the perspective of teachers’ roles and role changes

From the aforementioned review it is clear that teacher labels do not proffer much to the area of how teachers might construct classroom meaning. These labels seem to be too monolithic and simplistic reflecting maligned views of teaching: utilitarian, insufficient, unprofessional and associated. But this review also captures a plausible way of articulating how teachers construct classroom meaning. Teachers as mediators, integrating computer technology into teaching, is proposed by a number of researchers directly or indirectly. This role captures teachers’ roles as active participants within the process of cultural transmission rather than from the peripheral limits functioning within spatial and temporal roles. This role is further expanded to include the establishment and running of microcosms where teachers' knowledge/cognitive empathy of classroom contexts and their personal theories of amplifying and/or reducing/balancing incentives and disincentives of the mediating characteristics of the computer technology, are seen as crucial imperatives. Furthermore this review has identified that teachers' images, language (including metaphorical) and thoughts as areas from which this construction of classroom meaning may be studied.
2.2.3 Using computer technology as tools in the classroom

This section of the literature review critically discusses and assesses the literature on teachers integrating computer technology as a tool for teaching and learning. This is done to gather plausible evidence that might shed some light on how teachers’ roles are influenced by their use of computer technology as a tool to construct classroom meaning.

Budin, (1999); Casey, (1996); Mellon (1999) and Sandholtz, Ringstaff, & Dwyer, (1997) clearly state that teachers envision computer technology as one of the tools for teaching and learning. Olson (1999, 2000) and McKenzie (1994a) further suggest that the use of this tool becomes part of the larger complex technology that already prevails in the classroom ecology that teachers tap into to perform educative actions. A number of perceptions seem to underpin how teachers use computer technology as a tool.

First, computer technology as a tool that the teachers use is encapsulated by much phenomenological theorising. As an educative tool in the teachers' hands, the computer technology is used to “enliven and illuminate the ordinary, commonplace and homely by using it to build up and appreciate situations previously unrealized and alien” (Blacker, 1993: 190). In other words, an educative tool that provides “enlargement” rather than constituting the passive assimilation of images that provide entertainment disguised as lessons (Hlynka & Belland, 1991; Papert 1980 in Bromley & Apple, 1998).

Although this view of teachers' use of computer technology might provide a pertinent view of how teachers' construct classroom meaning, there exists literature that proves otherwise. For example, Muffoletto (1994: 28) states: “Technology is more than a tool, however, it is a way of thinking”. On the other hand, Morton (1996) claims that this tool metaphor merely reflects the teachers' use of "supplies" and/or promotes the conception of “computer as add-ons” (p.417), as a separate entity.
Much of this phenomenological theorizing seems not to take account of the continuous and unresolved debate between Kozma (1991, 1994 in Mellon, 1999) and Clark (1994 in Mellon, 1999) over the power of the media and instruction. It is beyond this review to engage with this debate, but what can be derived from this is the consensus that computer technology is not the single and sole technological entity within the instructional process. It exists within a complex network of technologies that are needed to bring about the effective delivery of instruction (Mellon, 1999).

This critique and the aforementioned discussion help to provide some impetus in framing teachers' integration of computer technology as a tool in teaching actions. It also helps to eliminate perspectives like the mapping of computer technology as a catalyst (Becker & Ravitz, 1999; Dexter, Anderson & Becker, 1999; McDonald & Ingvarson, 1997) and/or vitamin (Dede, 2000) used by the teacher to enable classroom meaning: the learning and constructive processes of students. By capturing teachers' use of computer technology as a tool that acts as a catalyst or vitamin seems to reduce the holistic potential of the whole educative experience. This reduces the cultural activity of sharing the tenets of a discipline towards the process of catalysis: the effects of catalysts. This portrayal conjures up a number of scenarios. For example, teachers might bank on the computer technology to enable the management of unruly classroom or to supplement an already taught content with the attributes of the computer technology. It is critical to note that these mappings of teachers' use of computer technology are severely skewed towards the computer technology. The scientific meaning of catalysts as substances that either accelerate or retard chemical reactions does not really capture the complexity and multidimensionality of classrooms.

Although the aforementioned discussion substantiates the McLuhanesque shift of "medium is the message", the central trope from which computer technology use has been envisioned, towards that of "medium that shapes the message" (Buniske, 1999: 121; Swan & Mitrani, 1993) they fall short of explaining the teachers
psychological and philosophical underpinnings for how teachers make the medium shape the message (Noss, 1995).

Moving away from phenomenological theorizing, empirical studies, especially from science education research, seem to reflect a different perspective. The common theme that emerges from these studies is that teachers use the computer technology as a tool to bring about an “experience” of science teaching leading to an “experience” of learning. This experience simply maps onto the perspective of placing students in front of a computer technology generated simulation of scientific phenomenon where teaching and learning is reduced to watching these simulations or pressing buttons or clicking the mouse to provide interactivity. This falls short of any educative experience, because the need for conceptual change in students needs more than experiencing scientific simulations and upholds a Cartesian way of thinking (Bowers, 1990; 1997).

For example, Laurillard (1992) stresses the need to set the use of computer technology simulations within the academic tasks that are shaped by the teachers’ goals and for these goals to become inter-subjective. Snir and Smith (1995) contend that there needs to be a theoretical basis for framing how students transcend the hurdle of conceptual change when simulations are used to bring about conceptual change. These perceptions cohere with Fischer, Dwyer and Yocam (1996) who argue that: “Technology alone cannot improve teaching and learning, if it could, we would have documented improvements in student-learning in all subject areas in all our technology-related evaluation” (p. 201). Basically what is being interpreted is that the use of computer technology as a tool entails more than experience, it has to correlate to educative experiences.

Aldrich, Rogers and Scaife (1998) expand on the aforementioned discussion by emphasizing that teachers are at the core of any cognitive interactivity. They claim that teachers are the ones who are aware of the kinds of support (solving problems, reflecting, imagining, and creating) that the computer technology as tools can provide. Otherwise cognitive interactivity in the classroom will be
reduced to computer technology as tools that provide physical interactivity, button presses and mouse clicks. Others like Sandberg and Barnard (1997) support this contention; they write:

Courseware works like a television program: just sit back and relax...did not function to stimulate the students to think hard about the correct answer, but gave a false idea of having acquired knowledge because of frequently positive feedback that was given” (p. 34).

To prevent this, the role of the teacher is emphasized, especially when the students are acquiring and constructing knowledge. On the other hand, researchers like Ruberg, Moore and Taylor (1996) state that the role of the teacher involves providing social cues and means of integration within the topic being taught and other relevant topics. Although they do not refer to any cultural shaping that occurred in that teaching and learning environment that they were investigating, they do however mention that students modeled instructor thinking, especially when instructor is using the computer technology.

Furthermore, this perspective of “experiencing” seems to reduce the potential of educative experiences. For example, Nickerson (1995) frames a caveat over the potential of computer technology as a simulation tool. He contends that simulations take on the objectivist realm of being the one and only way to explain a scientific phenomenon in the classrooms, although it enables students' understanding. He further writes that there should be a faithful rendition of what aspects that are in congruence with the scientific community, what aspects are not, and that there might be other ways of comprehending the phenomenon. These could involve multiple explanatory models of the scientific community, teachers and students.

Two perspectives become clear from the aforementioned discussion: first, teachers’ use of computer technology in classrooms is framed as a fulcrum rather
than as a lever; and, second, the importance of the teachers’ roles in maintaining this fulcrum perspective. Kerr (1991) writes:

The fulcrum of technology may be in fact be providing a point around which classrooms can be restructured to feature the teacher, perhaps in a more complex and more demanding role than before, as organizer, encourager, director of and participant in classroom activities. (p.133)

Computer technology is thus portrayed as performing a supportive role, the fulcrum, for the educative events rather than being a lever to bring about change. It is not a lever to “push” students towards experiencing scientific phenomenon to bring about conceptual change.

Shneiderman, Borkowski, Alavi and Kent (1998) on the other hand, highlight the association of tool-based approach to that of the “knowledgeable teacher” (p.24). He claims that teachers’ knowledge and philosophies are the key elements to the “heart of the education process” (p.24). A mix and match of teachers’ knowledge and philosophies may occur when teachers’ use computer technology.

Blacker’s (1993) essay, which expands Dewey’s perspectives on teaching and learning onto the use of computer technology in classrooms and the meaning associated with it, states that teachers’ beliefs pave the way for educative uses of computer technology as a tool. Teachers’ use of computer technology as tool operates under a hierarchy that places their underlying beliefs “about the aims of education as the real determinants” (p.193) in setting up instructional strategies with the integration of computer technology into education. Blacker also propounds the relationship between tool-based approach (tool use) and meaning. He states that tool use either constructs the context or it makes the context clearer for the tool user. The meaning derived from these relationships results in habit formation, instincts and a foundation for the creation or comprehension of further meanings. A sort of cognitive guide (Nicaise & Barnes, 1996) that materializes into the “teachable moment” (p. 209). Nicaise and Barnes (1996) write:
... a cognitive agenda with supportive technology must address many issues and overcome definitive challenges. Creating cognitively guided classrooms, nevertheless, is an important step...without them, there may be difficulties imaging what they look like and how teachers interact with students. The next generation of researchers must examine the precise influence cognitively guided classrooms have on student learning and understanding (p. 210).

2.2.3.1 A view of how teachers construct classroom meaning within the perspective of using computer technology as a tool

This section of the review looks specifically at how teachers utilize the computer technology as a tool. Most of the aspects captured tend to be phenomenological theorizing with an emphasis on what teachers can do with the computer technology as a tool. But there is literature that also carries the emphasis that teachers’ use of computer technology has more than behavioural aspects, it is a way of thinking. Kerr (1991) for example, mentions that teachers envision the computer technology as a fulcrum rather than as a lever. This coheres with the science teaching literature from Section 2.1.3, which mentioned that science teachers possess mental toolkits that they use to perform teaching actions. It does point to the notion that teachers capture this computer technology as part of their cognitive guide for their classroom actions. One more crucial aspect which is signalled is the role of teacher assets, especially teachers’ beliefs that seem to shape this use of computer technology as a tool in the classroom.

2.3 Teachers’ beliefs in the construction of classroom meaning

The influence of teachers’ beliefs appears as a recurrent theme in the aforementioned review of literature (Section 2.1 and 2.2). This prompted the researcher to review the literature on teachers’ beliefs in general educational research, science education research and educational computing research in relation to teachers’ use of computer technology. The aims were twofold to
ascertain whether teachers' beliefs influence teachers' construction of classroom meaning, and if so how; and, to review the major perspectives that the studies on teachers' beliefs can offer to the study. First, the perspectives on teachers' beliefs from general education research and science education research are reviewed. This is followed by a critical review of the research to date on teachers' beliefs in educational computing research.

One of the key perspectives on teachers' beliefs seems to be set by Kagan, (1992) who states that since teaching occurs in an unmapped terrain, teachers' beliefs may be the guide to teaching practices in class. Pajares (1993) and Nespor (1987) both state that beliefs are an important part in conceptualising teaching tasks. Shulman (1974) in work that predates Kagan and others suggested that

... any innovations in the context, practices, materials or technology of education to be mediated through the minds and motives of teachers should take into account teachers' beliefs (p.334)

Research also represents this relationship between teachers' beliefs and teaching actions in the form of a paradigm: the beliefs-actions paradigm (McRobbie & Tobin, 1995; O'Loughlin, 1990; Sigel, 1985; 1992). McRobbie and Tobin (1995: 381) capture this paradigm as illustrated in Figure 5. This figure portrays teachers' beliefs as part of the holistic concept of action. That is, action is construed as a set of dialectic interactions that take into account an individual's goals, individual's beliefs concerning the action itself, the individual's construction of the context in which the action is embedded, and finally, the behaviour of the individual. Looking at teachers' beliefs in this fashion prevents the "fundamental attribution error" (Munby, 1982: 206) of attributing teacher behaviour to teachers' dispositions rather than to the situations. Furthermore, this also captures teachers' beliefs as situational and transferable in accordance with the complexities of the classroom, functional in the contextual boundaries that permeate teachers' work in the classroom (Calderhead, 1996; Desforges, 1995; Dobson & Dobson, 1983; Fang, 1996; Tobin, Tippins & Hook, 1994).
Teachers' beliefs are also said to: demarcate, delimit and guide teachers' pedagogical relationships to "objects, people and events" (Fang, 1996: 49); provide validity for reality (Calderhead, 1996); and, act as a self-reinforcing mechanism to provide consistency and congruency for teaching actions (Hollon & Anderson 1987, in Brickhouse & George, 1992). It is widely accepted that teachers' beliefs are the filters through which experience is screened for meaning (Cohen & Ball, 1990; Goodman, 1988; Nespor, 1987; Prawatt, 1992; Putnam, Heaton, Prawatt & Renillard, 1992) which influences classroom decision making and actions (Nespor, 1987; Pajares, 1992; Smith & Croom, 2000) which in turn determine the classroom atmosphere experienced by students.

Within the teachers' beliefs research there exists opposing views of the nature of teachers' beliefs. For example Pajares (1992) and Kennedy (1997) contend that teachers' beliefs do not change, while others like Beijaard and Vries (1997); Airasian, Gullickson, Hahn and Farland (1995 in Beijaard & de Vries, 1997); Bereiter & Scardamalia (1993) and Chinn and Brewer (1993) contend that teachers' beliefs develop as teaching involves more of a "doing environment" (Beijaard & de Vries, 1997: 245).
Pajares (1992) contend that beliefs are a part of a broader belief system. This coheres with the findings on teachers' beliefs being interlocking or interconnecting sets of beliefs that shape teaching actions (Burns, 1996; Hofer & Pintrich, 1997; Kennedy, 1997).

Before moving onto the critical review of teachers' beliefs in educational computing research, one crucial element had to be settled, the researcher's articulation of the knowledge/beliefs conundrum that seems to be a recurrent theme in the major studies of teachers' beliefs (Abelson, 1979; Calderhead and Robson 1991; Goodman, 1988; Kagan, 1992; Nespor, 1987; Pajares 1992; Tobin, Tippins and Hook, 1994). The convention of Tobin, Tippins and Hook (1994) is utilised in this study. They write: "belief is a form of knowledge that is personally viable in that a belief enables a person to meet his/her goals" (p. 246). This articulation seems to cohere with Kagan's (1992) contention that since classroom context is a landscape where set answers and theories do not prevail as solid foundations for teaching actions to materialise, the test of beliefs against experience in this classroom context is imperative. It also captures beliefs as a holistic concept rather than entities that exist in a one-to-one correspondence.

There are a number of perspectives concerning teachers' beliefs, emerging from educational computing research literature. First, drawing on the Dwyer, Ringstaff, and Sandholtz (1990; 1991) and Sandholtz, Ringstaff and Dwyer (1997) studies of teachers and computer technology use in classrooms, a common perspective seems to be the treatment of teachers' beliefs as barriers to change. These studies seem to ignore the perspective from other research works. For example Soloway, Krajcik, Blumenfeld and Marx (1996) and Richardson (1995) in Calderhead (1996) state that in the process of teacher change there is a constant interaction between beliefs and practices. Ross, Rolheiser, and Hogaboam-Gray (1998) claim that direct implementation of computer technology will not lead to teaching actions with computer technology. Beliefs about using computer technology have to be accommodated into those beliefs that form the "core teacher functions" (Rolheiser & Hogaboam-Gray, 1998: 475). Also, this contradicts Beijaards and de

There is also research that encapsulates teachers’ beliefs as first-order barriers and second-order barriers (Ertmer, Addison, Ross & Woods, 1999; Harrington, 1993). First-order barriers deal with teachers’ beliefs about lack of equipment, time and classroom help, while second-order barriers deal with lack of relevance, mismatch with classroom management, style and lack of confidence when integrating computer technology into teaching. These again do not provide much impetus to how teachers construct classroom meaning, if they do it is at a very superficial level. But they do reinforce the need to investigate the types of teachers’ beliefs that may be present.

The literature on how teachers’ beliefs, in relation to the integration of computer technology into teaching, may shed some light on how they influence teachers’ construction of classroom meaning seems to be very narrow. Most of the studies seem to ignore how teachers’ beliefs are influenced by the external pressures, school context and the classroom context: intercontextuality (Burns, 1996).

Amongst recent research, another emerging perspective can be seen. This transcends the barrier to change issues, the first-order and second-order categorizations, and reflects a move towards a social perspective. Robin and Harris (1998) claim that since computer tools are diverse enough to transcend the range of teaching approaches, teachers’ beliefs may be functioning in relation to the socialization processes that occur in the classroom context rather than solely towards the computer technology. That is, teachers’ beliefs play a part in teachers shaping classroom actions because they become viable in the educational context where goals and actions are set in motion in a social milieu. What is apparent is that teachers’ beliefs are involved in constructing classroom meaning, but teachers’ beliefs act in response to the socialization process. The aforementioned perspective, teachers’ beliefs are involved in constructing classroom meaning and
act within the socialization process, concurs with Ladewski, Krajcik, & Harvey (1994) who suggest that “teachers’ beliefs form a complex interconnected network consistent with the teachers’ experiences and contextual constraints” (p. 515). Furthermore this forms a coherent picture with the research on teachers’ beliefs in general educational research, where teachers’ beliefs act as filters through which experience is screened for meaning.

The perception of teachers’ beliefs as interlocking and intertwined sets of beliefs acting within the socialization process, as discussed in the aforementioned paragraph, proffers the notion of teachers’ beliefs as multi-determined. This coheres with the work of Sigel (1992) on parents’ beliefs and teaching strategies they possess for their children. Sigel claims that individuals possess a variety of mental tools/actions to resolve conflicting situations that arise in social situations. The choice of mental tools or tool is defined by the task and the social context where the resulting social situation is a problem-solving situation requiring humans to dip into the mental tools for ways to interact within that social context. This coheres with Briscoe’s (1996) contention that there may be a consistency between meanings and beliefs when teachers are confronted with innovations in their classroom context. She suggests that teachers refer to “constructed mental images” (p. 326) to comprehend thoughts and classroom actions in relation to teaching roles. These constructed mental images in turn influence the teaching or learning that takes place. Citing Olson (1980; 1981), Briscoe goes on to further embellish this situation by stating the relationship to beliefs:

> teachers’ beliefs are not consistent with beliefs implicit in an innovation because a teacher may reconstruct the innovation and its associated beliefs to match his or her own beliefs...making the innovation more familiar or practical to the teacher (p. 326).

Most of the research within this area of educational computing literature, research that delves into educational computing and teachers’ beliefs, seems to be assailed from quantitative surveys. For instance, the study by Robin and Harris (1998)
utilized extensive quantitative surveys. The researcher is aware that such surveys are emblematic of standpoints reflecting dimensions being investigated by researchers who plan these surveys in relatively decontextualised manner. But the study by Robin and Harris does make the point that if teachers' beliefs are to be studied, their broader belief systems have to be investigated. They suggest the Attitudes About the Reality scale as an instrument that is capable of this. They also suggest that teachers' beliefs be studied from a classroom perspective: the complex and multifaceted domain of the classroom where the socialization process exists.

2.3.1 A view of how teachers construct classroom meaning within the perspective of teachers' beliefs

Most of the review of the literature in section 2.3 provides comprehensive perspectives on how teachers' beliefs play a role in teachers' construction of classroom meaning integrating computer technology. But it did signal that teachers possess mental structures that cohere with the construction of teaching actions in the classroom and that interlocking sets of teachers' beliefs may be influencing this construction. That is, when these mental structures are conveyed as teaching actions, these mental structures are interdependent on the interlocking sets of teachers' beliefs prominent during the socialization process.

2.4 Synthesizing towards a consensus and an area to be researched-the gap

The main consensus that is reached by the researcher in critically reviewing the literature can be summed up in Figure 6. Figure 6 captures the role of the teacher as being a simple role that fulfils a set of propositions (highlighted in the rectangular box). This role caters to the computer technology and its task of being the mediator of students' knowledge construction. Thus, the teacher is not directly involved in the students' knowledge construction. Figure 6 can be mapped onto a proposition that coheres with Bowers' (1988: 89) articulation of computer technology into education: “educational computing as teaching”.
Teacher monitors student behaviour and serves as a technical advisor—
Tool user, teaching labels, technical expertise, and indicators of integration serve as constructs.

FIGURE 6
Linear view of teachers’ use of computer technology for teaching

The aforementioned proposition also reflects a learning theory that captures a master-apprentice situation but with the computer technology replacing the teacher as master. Callister and Dunne (1992) communicate this as:

Teachers no longer teach; instead, they are managers of relatively rigid delivery systems and immutable instructional content. While students sit at their workstations, vessels to be filled with facts suitably stored in machine-retrievable code, teachers oversee the operation like foremen in an automated factory (p. 325).

The centrality of computer technology frames teachers, students and curriculum into a “technopoly” culture (Postman, 1993: 24) where all meanings are tuned into and coheres with the computer technology forsaking the cultural and social imperatives that shape human social systems (Murphy & Pardeck, 1991). This view of teaching with computer technology also perpetuates the view of applied science where neat categories of means lead to specific ends. This compounds a skewed view of professional practice as a practice that resounds with predictable elements dealing with systematic pre-planning (Kupferberg, 1996). There seems to be no room for spontaneous and intuitive behaviour on the part of teachers. Also this vision of computer technology seems to be based on a single vision where the community aspect of a lived situation is missing (Pea, 1987). That is, the teachers’ roles seemed to be far removed from students’ learning activities. Another argument, in response to this linear fashion of instruction with computer technology, is that this displays an instrumental activity of teaching (Olson,
1988a, 1988b) where teachers have passed on from being the instruments of teaching to being an instrument-computer technology-maintenance activity. The expressive nature and activity of teaching, teachers’ expressions of classroom actions coupled with the ecological inhabitants, is not given much weight.

The linear view of seeing teachers’ roles and teaching with the integration of computer technology as being a simple role that fulfils a set of propositions (Figure 6), also carries with it a number of caveats. First, it places teachers far away from the perspective of educative experiences and performances that occur within the social milieu of the classroom. It does not capture the professionality of the teaching practice. Rubin (1989) writes: “All teachers think. But the best teachers tend to think about different things-in different ways” (p. 31). Second, professionalism, appears to be restricted to teachers manning the computer technology as depicted in Figure 6. This linear fashion of looking at complexity also dictates a discovery-oriented process of learning. The teacher sets up the computer technology that will set in motion the experience and circumstances that will fall in place for a predictable pattern to emerge: the means to one endpoint. This reduces the educative moments, experiences and performances to algorithms. Ross, Hogaboam-Gray & Hannay (1999), using a quantitative study of teachers’ confidence in their ability to implement computer-based instruction, reveal that it is not the experience that results from the use of computer technology that is decisive in teaching situations. They state that it is the teachers’ interpretation of the experiences and interactions that the computer technology provides that really matters.

What is also apparent from this linear view of teaching, in relation to the use of computer technology, is that only one of the two forms of teachers’ orchestration of instruction is emphasized, indirect instruction. Indirect instruction only captures the teachers’ intentions of students’ interacting with the computer technology leading to construction of intended cognitive understandings (Duffy, Roehler, Meloth & Vavrus, 1986). Direct instruction techniques (verbal interactions-explanations) seemed to be ignored or neglected.
This linear view of teachers and teaching with computer technology also falls into conundrums that parallel the interpretation of constructivism within science education research (Hodson, 1998; Mathews, 1993; 1994). It does not cohere with the recent trends in science education research towards a sociocultural perspective on knowledge construction where the "problems associated with subjective or psychological constructivism" (Matthews, 1994: 161) have been avoided. One gets the impression that teachers are setting up an environment that fosters Piaget's cardinal rule of learning: one is more likely to comprehend what one discovers for oneself than what one is taught by someone else (Matthews, 1993; Nickerson, 1995).

Furthermore this linear fashion of instruction seems to carry no conditions conducive to "understanding performances" even though it purports to do so (Perkins, Crismond, Simmons & Unger, 1995). It calls into question the myopic view of educational proponents who claim that a computer technology based curriculum "serves as a symbol of the quality of education children are receiving" (Bromely, 1997: 51), a number of questions arise – What is the symbol? What does it represent? Why is it that teachers' perspectives of this symbol are not explicit?

Before the researcher articulated the theoretical framework, garnered from sections 2.1, 2.2, 2.3 and this present section, 2.4., the researcher delved into the related theories of meaning making to provide insights that helped to shape the theoretical framework for this study.

2.5 Related theories of meaning making

Throughout the literature review a number of theories for meaning making have been identified by the various studies reviewed. For example, the curriculum enactment theory and social interaction perspective theory, sociocultural theory (Vygotsky's and Neo-Vygotskian interpreters) and the social practice theory (community of practice), seemed to be prevalent within the science education
research. It is also apparent that most of the educational computing literature reviewed seemed to be largely devoid of any theoretical input (Beynon & Mackay, 1989; Goodson & Mangan, 1995; Selwyn, 1997), in contrast to general education and science education research. It must be acknowledged that some of these theories are beginning to make inroads into educational computing: social practice theory (Lauzon, 1999: Section 2.1.1) and sociocultural theory. The researcher decided to delve into the aforementioned theories. This is not done to pre-empt any particular theoretical framework nor as a test of any theory or theories. The relevance of the theories is to provide a dialectical relationship with the data. They serve as a heuristics in the development of the researcher’s interpretations used to aid the interpretation of the data and further the understanding of how teachers construct classroom meaning. Each of these theories is reviewed, following which the major insights are examined in light of the preceding theorising (Section 2.6).

2.5.1 The Curriculum Enactment theory and Social Interaction theory

The curriculum enactment theory maintains that the central act of teaching/learning occurs in the classroom where three salient components are brought together by the teacher. First, content is “jointly constituted across time by teacher and students in close proximity to actual classroom events” (Doyle, 1988 in Copeland, Birmingham, DeMeulle, D’Emidio-Caston & Natal, 1994: 18; Doyle, 1983; 1986). This content is represented in the materials the teacher has selected and the academic tasks she has formulated for the students. The second component, pedagogical processes, including teacher demonstrations, explanations, presentations, questions, feedback, accountability practices, and grouping mechanisms, according to this theory are deeply embedded in and specific to the content of the curriculum. The third component is classroom management. Doyle (1983; 1986; 1988) maintains that order in classrooms which is fundamental to successful teaching and learning, is not achieved separately from the work students are asked to accomplish.
The social interaction theory on the other hand, helps to explore the nature of the classroom events and it examines the meanings constructed in everyday events in classrooms. Meaning in the classroom context and experience according to Erickson (1982) are characterised as academic task structures. Meaning includes a subject matter structure within a social participation structure and collectively named as the classroom activity structure – the action. Taking a more microscopic perspective, the activity structure manifests into the “interactive opportunities” that enable the teacher to select the relevant and suggested content, organise the content and relate it to what their audience already know. Thereby, the teachers enable themselves and their students to “publicly display thinking and reasoning and for their students to gain access to learning and to demonstrate social and academic competence” (Weade, 1987: 17).

Both the curriculum enactment and social interaction perspective provide the mechanism for interpreting the meaning making expressed in teaching actions. Support for these frameworks come from Hollingsworth (1989); Freeman (1991; 1994), and Yinger (1986). The common consensus is that the conception of practice provides a bridge among the individual’s internal meaning making, the socially constructed meanings used and the actions in the world. These theories do advocate for ethnographic methods like participant observation and micro-ethnography to capture the teaching and learning actions that result from teachers’ construction of meaning.

On the other hand, these two theories fall short on three crucial aspects. First, they neglect to take into account the contexts, practice, cognition and structuring resources—the physical settings and physical systems (Packer & Winne, 1995; Yinger & Hendricks-Lee, 1991) but delve specifically into the social participation structure. Although the Social interaction theory and Curriculum Enactment theory provide a conceptual key to the analysis of the constructed meanings that reflect the classroom context they do not take into account the tacit elements that contribute to classroom teaching actions: teachers’ beliefs: teachers’
perceptions of classroom teaching and learning; and teachers' theories of teaching and learning.

Second, adhering to the aforementioned perspectives of how content, pedagogical processes, classroom management (derived from the Curriculum Enactment theory); and subject matter structure and social participation structure (derived from the Social Interaction theory), alone undermines the multidimensionality, complexity and the uncertainty of classrooms and classroom interactions. That is, these two theories seem ill equipped to describe contexts or to account for teachers' practice or teachers' cognition.

Finally, the description of construction of classroom meaning, derived from the Curriculum Enactment theory and Social Interaction theory, depicts the classroom context as a static image. Rather, the social participation demands act upon the academic demands and vice-versa, transforming, extending and reconfiguring the meaning of the produced classroom (Weade, 1987).

Therefore, in order to attend to the structuring resources of the classroom context, the researcher had to go beyond the Curriculum Enactment theory and Social Interaction theory. The researcher had to draw upon the insights gathered from these two theories but also from the forthcoming theory to further gain insights that helped in the interpretation of the data and further the understanding of how teachers construct classroom meaning.

2.5.2 The Sociocultural theory

Sociocultural theory literature falls into two general types: that produced by propounders, in this case Russian psychologist Lev Vygotsky (1896-1934); and those that are produced by interpreters of Vygotsky's sociocultural theory (Neo-Vygotskians). Differing from Piagetian constructivism and radical constructivism, sociocultural theory pays serious attention to three crucial aspects: the structural characteristics of schooling; the social organization of instruction; and the cultural

Vygotskian theory has often been promoted for comprehending students' learning, yet few studies have examined this theory in relation to teachers' understanding of teaching or teaching with the integration of computer technology. This theory does place a clear emphasis on the teachers' role within students' construction of meaning. These are expressed as a number of constructs by the researcher, pertinent to this study. First, the teacher is cited as a mediator of students' learning. The teacher is expressed as being involved in the continuous interaction between instruction and development (Howe, 1996; Mason, 2000); Howe (1996: 38) states this as:

The development of the psychological foundations for instruction in basic subjects does not precede instruction but unfolds in a continuous interaction with the contribution of instruction...

Thus, the teacher is not one who just facilitates or creates an environment (Bowers, 1998b; Crawford, 1996; Mason, 2000; Moll & Greenberg, 1990). The key role of teachers is to mediate students to be active members and contributors within social contexts: mediated by cultural tools (material and psychological tools) (Blanck, 1990; Miller; 1996).

This dialectic connection between, cultural tools, interpersonal relations and students practical activities transform students' natural cognitive functions into cultural ones. Thus, mediation is seen as a process that "involves thinking triggers and the generation of meaning not just another system of content" (Frawley, 1997: 182; Kozulin, 1990). Within this theory teaching is seen as assisted performance, where assistance is provided by the teacher at points within the students' zone of
proximal development: the zone where the students' current development involves intentional mediation towards the students' potential development.

The zone of proximal development is created by teacher and student in the context of specific tasks for intersubjective agreement about meaning being made together: not simply announced by the teacher but carried out through mutual participation. This assisted performance entails the active mediation by the teacher through the use of cultural tools to actively mediate between what is known and what is yet to be known by the students (Calderon, 1999; Davydov, 1995; Hedegaard, 1990; Hodson & Hodson, 1998a; 1998b; Lemeryse, 1993; Miller, 1996; Salomon, 1998; Samaras & Gismondi, 1998; Tharp & Gallimore, 1988; Wertsch & Tulviste, 1992).

Furthermore, this theory captures teachers as experts in the use of cultural tools leading to cultural amplification and extending students' cognitive processes. That is, a toolkit of mediational means incorporating psychological tools (semiotic: speech, writing, language etc) and physical tools (computer technology, models etc) which mediate thought and activity within the zone of proximal development (Davydov, 1995; Kozulin, 1990; Sigel, 1992; Smagorinsky, 1995a; 1995b; Smagorinsky & Coppock, 1994; Wertsch, 1991).

Wertsch (1991) emphasizes that these psychological tools are culturally sanctioned in particular situations. Vygotsky himself elaborated on the similarity and differences of the cultural tools (material and psychological) that his theory espouses. Kozulin (1990) captures Vygotsky's elaboration on the similarity and differences of the cultural tools. Kozulin writes:

... an analogy is the mediatory nature of both instrumental and symbolic action...in instrumental action the tool mediated human action directed at nature, in the symbolic act a psychological tool mediated man's own psychological processes: "The most essential feature distinguishing the psychological tool from the technical tool, is that it directs the mind and
behaviour whereas the technical tool, which is also inserted as an intermediate link between human activity and the external object is directed toward producing one or another set of changes in the object itself". Vygotsky indicated that the psychological aspects of material instrumental activity and symbolic mediatory activity are intertwined: "The mastery of nature and the mastery of behaviour are mutually related, [because] in the course of man's transformation of nature, his own nature changes as well" (p.115)

Another key construct of this theory is the relationship between language and thought within the zone of proximal development. In the sociocultural theory thought is expressed through language. That is, teachers act through metaphors and other figures of speech, like tools to shape and specify their relations to students and their teaching circumstances: a repository of linguistic artifacts for the use in meaning making (Hodson & Hodson, 1998a; 1998b; Howe, 1996; Kozulin, 1990; Miller, 1996).

One other construct that can be derived from this theory is its derivative analyses methods pertaining to the analyses of the social context of interaction. Palinscar (1998) captures these analyses as three types: institutional; interpersonal and discursive. The institutional analysis captures the cultural systems, representing educational, social and communicative norms and priorities. The discursive analyses captures discourse as the primary symbolic, and mediational tools for cognitive development. This analysis uses the micro-analysis of naturally occurring instructional discourse to examine patterns and opportunities in the classroom context. That is, it examines the univocal function and the dialogic function of instruction. This dialogic function looks at the speaker's utterances as thinking devices (generators of meaning) rather than conduit metaphors (Wertsch & Toma, 1995)

The work of Jerome Bruner (1986; 1990; 1996) further clarifies and builds on this theory emphasizing that the zone of proximal development reflects the historical,
social and cultural context in which the cultural templates of society are made intersubjective for students to create meaning. He states that language, thoughts and actions within the constructs of paradigmatic and narrative modes of thought reflect the multiple ways of viewing reality within this zone of proximal development: symbolic devices. That is, language, thought and actions, expressed within narratives are key analytical templates to view the meaning making processes within the zone of proximal development.

Therefore, in order to attend to classroom teaching and learning, this Sociocultural theory emphasizes the investigation of language and psychological aspects of student and teacher interactions within the zone of proximal development.

On the contrary, the heavy emphasis on language and psychological aspects of student and teacher interactions within the zone of proximal development, as espoused in this theory, are cited as limitations by some researchers. That is, an over-emphasis on linguistic competence lacking conceptual depth (Frawley, 1997; Miller, 1993).

But Neo-Vygotskians have expressed that analysis of language and psychological aspects have to be taken into account with ample consideration of the social context of interaction in which they occur (Confrey, 1995; Tudge & Winterhoff, 1993). Frawley (1997) on the other hand, recommends that the inhibitory functions of language and its boundaries, be captured within the analysis of language in social contexts.

In summation, Figure 7 captures these major constructs pertaining to teachers and teaching as perceived within the sociocultural theory. Figure 7 was developed to assist in describing the researcher’s thinking about the constructs of zone of proximal development and cultural tools and how they interact between and among teachers and students leading to student learning: mediation.
Thus, in order to attend to teachers' construction of classroom meaning with the integration of computer technology, the Sociocultural theory states that the teachers' language, thoughts, and actions, expressed within the zone of proximal development, help one to view the meaning making processes of teachers.

2.5.3 The Social Practice theory

The social practice theory reflected in the concept of community of practice is depicted in the seminal work of Lave and Wenger (1991). By using ethnographic techniques of anthropology, Lave and Wenger (1991) provided some footing into the nature of community of practice. This work centred on various communities of practice (midwives, tailors, butchers, and non-drinking alcoholics) where the purpose of the work was to capture the negotiation of meaning within these communities of practice and to identify the ways in which these negotiated understandings reflected the practices of these extant communities. A number of constructs were derived from their work with these communities of practice. For example, Lave and Wenger's 1991 book uses the idea of legitimate peripheral participation to indicate that they have advanced the notion of "situated cognition"
(which implies a static context), to one in which there are "multiple, varied, more- or less-engaged and -inclusive ways of being located in the fields of participation defined by a community" (p. 36). That is, learning is located in the processes of co-participation, as opposed to within the heads of individuals. Understanding is not perceived as a simple process of mental activities of an individual in relation to achieving objectives; rather it is perceived to arise from an individual's participatory actions defined by a community. Thus, learning can be a feature of various practices and it is not delimited to examples of training and apprenticeship: being a participatory member in a social world rather than simply knowing about that social world.

These constructs are further expanded on in Lave and Wenger's 1999 work (Lave & Wenger, 1999) and related to learning and pedagogy in communities of practice. In this work they define a community of practices "as a set of relations among persons, activity, and world, over time and in relation with other tangential and overlapping communities of practice" (Lave & Wenger, 1999: 25). In addition, they expand on the construct of legitimate peripheral participation in terms of learning. In this work, they describe legitimate peripheral participation as learning activities that provide and contain a number of features. That is, learning activities should provide strong goals for learning; they should develop a holistic view of what is to be learnt; and, they should provide access to structuring resources for learning that come form a variety of sources and not only from pedagogical activity. They should contain improvised activities that provide opportunities for engagement in learning activities and not just sets of dictates for proper practice.

Lave and Wenger (1999) also expand on the construct of membership pertaining to the concept of community of practice. They identify membership as gaining access to ongoing activities, old timers, other members, information, resources and participatory opportunities evident within a community of practice. Furthermore they emphasize that this membership involves engagement, that is,
involvement with ongoing activities, old timers, other members, information, resources and participatory opportunities evident within a community of practice.

In this work, Lave and Wenger (1999) also provide portraiture of the teacher as a member of the community of practice: As a pedagogue who is involved in the organization of the community of practice in which the teacher is a member himself. Lave and Wenger (1999) state that by constructing the role of the teacher in this fashion, the focus of analysis shifts from the sole emphasis on teaching actions to an analysis of how teachers play a part in the “intricate structuring of a community’s learning resources” (p.23): the negotiation of meaning. That is, how teachers provide access, engagement and membership within communities of practice.

Thus, in summation, negotiation, access and engagement seem to be the inherent aspects in a community of practice, and inherent aspects that capture the role of the teacher in this community of practice. Before moving onto the perspective of how this Social practice theory helped the researcher to build an articulated theory for this thesis, the researcher would like to review the work of Lave and Wenger (1991) as appropriated by general educational research.

Lave and Wenger’s (1991) work has been appropriated into educational research as a way to comprehend the study and improvement of practice as a model of professional development. Studies (Davis & Sumara, 1998; Mitchell, 1994 in Palinscar, Magnusson, Marano, Ford & Brown, 1998; Palinscar, Magnusson, Marano, Ford & Brown, 1998; Stamps, 1997; Stewart, 1996; Westheimer and Kahne, 1993); emphasize that communities of practice provide a focal point for the study of teachers’ teaching practice. These studies further present a number of features that characterize the nature of communities of practice. For example, Stamps (1997: 38) captures a community of practice as a social practice. Stamps writes:
What is shared by a community of practice—what makes it a community—is its practice. The concept of practice connotes doing, but not just doing in and of itself. It is doing in a historical and social context that gives structure and meaning to what we do. When I talk about practice, I am talking about social practice. Such a concept of practice includes both the explicit and the tacit. It includes what is said and what is left unsaid; what is represented and what is assumed. It includes the language, the tools, the documents, the images, the symbols, the well-defined roles, the special criteria, the codified procedures, the regulations, and the contracts that various practices make explicit for a variety of purposes. But it also includes all the implicit relations, the tacit conventions, the subtle cues, the untold rules of thumb, the recognizable intuitions, the specific perceptions, the well-tuned sensitivities, the embodied understandings, the underlying assumptions, the shared world views, which may never be articulated, though they are unmistakable signs of membership in communities of practice and are crucial to the success of their enterprises. (p. 36)

Thus, based on the above quote, communities of practice are the prime context in which we can work out common sense through mutual engagement. Therefore the concept of practice highlights the social and negotiated character of both the explicit and the tacit in our lives. Indeed, practice is ultimately produced by its members through the negotiation of meaning. The negotiation of meaning is an open process, with the constant potential for including new elements. It is also a recovery process, with the constant potential for continuing, rediscovering or reproducing the old in the new (Palinscar, Magnusson, Marano, Ford & Ford, 1998).

In addition to the tacit, explicit and the negotiation of meaning, thinking also seems to be a strong component within communities of practice. Stewart (1996) states that thinking provides the “structures and strictures” (p 173) for the functioning of communities of practice. Stewart further explains the communities of practice by referring to them as “the shop floor of human capital the place
where stuff gets made" and as a “group of people who are informally bound to one another by exposure to a common class of problems”. They function around a value. The communities of practice are also shaped by culture and customs that develop concurrently as the communities of practice function around a value. They strive for accountability and reflect a mutual sense of purpose and a sharing of ideas.

Also, Westheimer and Kahne (1993) portray communities of practice as a process marked by interaction and deliberation among individuals who share interests and commitments to common goals - a relationship that educates and thus practically defines communities of practice. This captures the functional aspect of communities (Strike, 1993). Westheimer and Kahne also mention that communities of practice require an institutional culture and a set of practices that are capable of regenerating community. This accords with Palinscar (1998), who citing Billet (1995) and Hicks (1995/96) stresses that learning takes place as communities of practice undergo processes of interaction, negotiation and collaboration.

In conclusion, the concept of community of practice in relation to the teaching profession in general and to classrooms in particular, derived from the aforementioned discussion based predominantly on the works of Lave and Wenger (1991; 1999) and the interpreters of their work (Mitchell, 1994 in Palinscar, Magnusson, Marano, Ford & Brown, 1998; Palinscar, Magnusson, Marano, Ford & Brown, 1998; Stamps, 1997; Stewart, 1996; Westheimer and Kahne, 1993), is defined by the researcher as a process of co-participation where learners acquire the skills to perform by actually engaging in the processes of co-participation under the conditions of legitimate peripheral participation. Learning here is distributed among teachers and students rather than as a one-person act. Understanding is located in the participatory actions that both teachers and students engage in accordance to the objectives of the lessons. This co-participation and the underlying constructs of learning and understanding function around a value and are shaped by the culture and customs evident within that
community. It is also a practice that includes the explicit: the language produced within the practice (open process of interaction and deliberation/negotiations); and the structures that capture the community of practice perception of learning as a way of being in a social world rather than simply a way of coming to know about it. It also includes the tacit: the strictures, the unarticulated thinking that guides the practice and serve as the signs of membership in that practice.

2.5.4 Summary

In summation, the four theories (Curriculum Enactment theory, Social Interaction theory, Sociocultural theory and the Social Practice theory) reviewed raise a number of crucial aspects that enabled the researcher to gain insights in developing the theoretical framework. Construction of classroom meaning is expressed as an interactive and deliberative open process of the teacher as mediator through cultural tools. This results in the jointly constituted interactive pedagogical processes: activity structures (academic tasks and social participation structures). The social context of interaction that reflects this community of practice is evident within the repository of linguistic artifacts, the structures (legitimate peripheral participation, access and engagement) and strictures (thinking), thoughts, images, cultural tools, actions and narratives that give life to the community of practice. This also provides insights into how analysis may be done in investigating the research question of this study as well.

2.6 Articulating the theoretical framework

Drawing the illuminating insights from the previous sections (2.1; 2.2; 2.3 and 2.4) and together with the insights garnered from the discussion of theories of meaning making (Section 2.4), it is apparent that a more holistic portrayal of how teachers construct classroom meaning with the integration of computer technology can be plausibly derived from the various empirical and phenomenological theorizing. Salomon (1998) proposes a relationship between technological affordances, psychological insights and pedagogy to account for teachers' use of
computer technology. The technological affordances provided by computer
technology provide needed tools and novel teaching and learning opportunities for
classroom teaching. This, he states, requires novel psychological insights to
materialise in the classroom. Salomon claims that human understanding of
cognition and the technologies educators develop and utilise as tools for teaching
are comprehended metaphorically. Both are thus linked as the quote below
signifies:

Historically, our understanding of the human psyche, particularly
cognition and the technology we employ as metaphor or as tools for
teaching tend to go hand in hand...this parallelism between our
psychological understandings and the technologies available to us remain
unchanged...The way we believe people learn and think and the
information technologies we develop to make that possible continue to live
in a tight, reciprocally supportive marriage (Salomon, 1998: 4)

This perspective strengthens the notion that the way we conceptualize our
psychological insights in relation to pedagogical actions afforded by technologies
can provide a plausible explanation of how classroom meaning is constructed
(Subramaniam, 2000).

To further support this approach to teachers’ construction of classroom meaning
some researchers contend that human understandings carry with them explanation
structures. These explanation structures are characterised by the revisable and
extensible networks of relationships, stable and momentary extensions that
consolidate into teaching and learning actions (Carter, 2000; Nickerson, 1995;
Perkins, 1985; Perkins, Crismond, Simmons, & Unger, 1995).

Thus, based on the available theoretical, empirical (Sections 2.1; 2.2; 2.3) the
aforementioned propositions and caveats (Section 2.4), and the insights garnered
from the discussion of the related theories of meaning making (Section 2.5); a
theoretical framework comprising the following propositions, is developed by the
researcher to explore how teachers' construct classroom meaning integrating computer technology into teaching.

To recap, this construction of classroom meaning with the integration of computer technology was articulated by the researcher as: The teachers' role in negotiating personal transformations in students of cultural templates, through constructive activity structures, is shaped by teachers' interpretations of how to present the cultural templates within a social context/community of practice. These interpretations are the teachers' conceptual underpinnings of the social context in which teaching integrating computer technology occurs.

Thus, to bring about this construction:


2. This mediator role involves a mindset (Bigum, 1997; Carter, 2000; Lankshear & Snyder, 2000; Mandinach & Cline, 1994; 1996; Morton, 1996; Muffolletto, 1994; 1996; Perkins; 1985; Perkins, Crismond, Simmons & Unger, 1995 Saloman, 1998)

3. This mindset carries out negotiations: programs of actions (Bigum, 1997; Bromley, 1997; Bromely & Apple, 1998; Lankshear, & Ball, 2000); balancing of incentives and disincentives (Knupfer, 1993); and amplifications and/or reductions (Bowers, 1988b; 1998a; 1998b). These are open processes of interaction and deliberation (Lave & Wenger, 1991; Westheimer & Kahne, 1993; Wenger, 1998) that uphold the culture building process resulting in negotiations for structures and strictures (Stewart, 1996)/negotiations for actions (Lave & Wenger, 1991; Westheimer & Kahne, 1993; Wenger, 1998)/cognitive guides (Blacker 1993; Nicaise & Barnes, 1996).
negotiated actions/structures and strictures/cognitive guides embody the activity structures (Doyle, 1988; Erickson, 1982), the social cues, multiple threads of interactions and social arrangements (Merill, Drake & Pratt, 1996 in Wild & Quinn, 1998; Lauzon, 1999; Ruberg Moore, & Taylor, 1999; Scott, Cole & Engel, 1992).

4. Through these negotiations for actions/structures and strictures/cognitive guides, teachers, as mediators, create microcosms (Olson, 1997)/communities of practice (Lauzon, 1999; Lave & Wenger, 1991; 1998) in which the roles of all the components of the social milieu including the computer technology are defined. This allows the enculturation process to take place, significant to the cultural templates rather than pertaining solely to the computer technology. Collectively these result in the zone of proximal development where social interaction enables joint activity in accomplishing academic tasks resulting in intersubjectivity between teachers and students.

5. These negotiations for actions/structures and strictures/cognitive guides are reflected in the language (including metaphorical), culture, thought, images of teachers who undergo these open processes of interaction and deliberation within the social context of the classroom teaching integrating computer technology.

6. These negotiations of actions/cognitive guides and structures and strictures are in turn influenced by the interlocking sets of teachers’ beliefs that act within the microcosms/communities of practice (Apple & Jungck, 1990; Bigum, 1998; Blacker, 1993; Briscoe, 1996; Becker, 1991; Buchman, 1986; Campoy, 1992; Ladewski, Krajcik & Harvey, 1994; Robin & Harris, 1998; Sigel, 1992). These influence the negotiated actions/structures and strictures/cognitive guides that constitute the community of practice.
Thus, the researcher was now able to plan the investigation of how teachers construct classroom meaning with the integration of computer technology into their teaching within a theoretical framework provided by these propositions.
Chapter 3

Methodology

3.0 Introduction

In this chapter, the researcher describes the procedure that was used to collect and analyse the data of this study. To begin, the researcher will discuss why a qualitative approach was chosen and why some parts of the study utilised a quantitative approach (Attitudes About Reality Scale and quantification of metaphoric language). An account is given of the issues related to the utilisation of a predominantly qualitative approach: the reasons behind the choice of a qualitative methodology. This is followed by an account of the research: the ethical concerns, the practical concerns, the methods used to elicit practice and the analysis strategies adopted.

Before moving onto the description and the discussion of this part of the thesis, the researcher would like to clarify the distinction between methodology and methods as used in this thesis. The term methodology as used in this thesis is derived from the conceptions of qualitative research, the conceptions of quantitative research, and the philosophical and methodological debate that engulf these conceptions (Seale, 1999b) together with the researcher’s articulated theory. Thus, methodology is defined as the awareness that guides the researcher through the various contexts of the study (procedures for gathering and coding data, the inference process and the end product) in light of the articulated theory (the explanatory force that drives the study). This is discussed in section 3.1 of this chapter. The term method is defined as the tools that permit the researcher to study the phenomenon in “depth and detail” (Patton, 1990: 13) with strong guidance from the methodological approach taken. This is discussed in sections 3.4 to 3.6.
3.1 Searching for a research paradigm

The search for a research paradigm was decided on a number of pertinent issues based on the Galilean approach to qualitative research (Martin & Sugarman, 1993) as stated in Chapter 1: section 1.4; and the educational research methodologies literature.

There were three issues, as stated by the Galilean approach that the researcher adhered to in his search for a research paradigm. First, there was need for an explanatory theory to map the navigation through empirical labyrinths. The explanatory theory for this study was articulated in Chapter 2: section 2.6. Second, the Galilean approach cautions against the deep obsession over methodological and epistemological paradigms for data collection. Third, according to the Galilean approach the explanatory theory had to determine the plausible methodological and epistemological paradigms suited for the empirical study. Thus, these three issues helped the researcher to structure his search for a research paradigm. In addition to the aforementioned issues, educational research methodologies also provided some pertinent issues that helped in the search for a research paradigm.

The educational research methodologies literature revealed a number of pertinent aspects that structured the search for a research paradigm. The educational research methodologies literature reveals the consensus that educational research methodologies are marked by a larger political framework, embroiled in the debate on empirical/non-empirical and qualitative/quantitative distinctions (Bryman; 1992; Fetterman, 1988; Hammersley, 1992a; 1992b; Lincoln & Guba 1985; Miles & Huberman, 1984a; 1984b; Pring, 2000; Rist, 1977; Saloman, 1991; Shulman, 1998; Smith, 1983; Smith & Heshusius, 1986). It would be beyond the scope of this study to dive “head first” into the conundrums and shibboleths that hold sway in both camps of the debate issue: “paradigm wars” (Gage, 1989). On the other hand, the review yielded other fruitful insights that the researcher utilised in the search for a research paradigm to frame the overarching goal of the
methodology: to examine and theorise how teachers construct classroom meaning when integrating computer technology. These critically gathered insights centred around constructs such as “compelling”, “constitutive”, “pragmatic”, and “historical” and “epistemological”.

3.1.1 The “compelling”, and “constitutive” issues of deciding on a research paradigm

The theoretical readings of qualitative and quantitative research paradigms both revealed no “compelling” priority over one another: each one seems to have its own limits and assumptions about knowledge. While one needs to be cautious about generalisations, it might be argued that both qualitative and quantitative paradigms are geared towards the quest for knowledge (or truth) but differ at an ideological level. The qualitative paradigm incorporated the intentionalistic force to capture and encapsulate the intentions and meanings akin to the situational contexts and subjectivities of humans. While the quantitative approach is concerned with the acquisition and interpretation of data to confirm or negate externally imposed pre-determined systems of meaning: its relative strength being the objectivist pursuit of finding knowledge. Both suffer from putative weaknesses or severe attacks from the scholarly communities based in opposing camps. They seemed to be engrossed in “philosophical discussion to justify divisions between schools of research...” (Seale, 1999b: 31) rather than looking for ways to provide avenues for the realisation of multiple realities of the world. The researcher’s stand on this “compelling” construct is further compounded by Marecek, Fine, & Kidder (1997):

Many of the distinctions propped up between quantitative and qualitative methods are fictions. As we see it, all researchers—whether they work with numbers or words, in the laboratory or in the field—must grapple with issues of generalizability, validity, replicability, ethics, audience, and their subjectivity or bias. Moreover, all researchers must engage questions of authority and interpretation. Whether numbers or words, data do not speak
for themselves. They acquire meaning only within the framework(s) of theory and interpretation imposed by researchers. No matter what the method, no researcher can escape questions about the selection and interpretation of data, about his or her responsibilities to participants, about the interests and commitments that spawned the project in the first place (p. 632).

This is further communicated by Stromquist (1999) as “no methodological approach ensures a perfect grasp of truth” (p. 150).

Perspectives from the aforementioned review led the researcher to assume a position on both paradigms being “constitutive” to one another. This concurs with Clark (2000) who contends that; “...the qualitative is constituted by the quantitative...The quantitative is constituted by the qualitative.” (p.252). Clark states two aspects that embellish this conception of quantitative and qualitative paradigms. First, the quantitative paradigm is broad enough to include simple numerical facts “one”, “two” or “some”. These numerical facts are characteristic of the qualitative paradigm. Thus, quantitative paradigm transcends into the realm of qualitative research. Second, Clark states that the qualitative research aspect of gathering evidence through collective interpretation of events is evident within quantitative research. That is, quantitative research itself is dependent on a system of collective agreement among individuals about shared understanding over the acquisition and interpretation of data where the importance of statistical technique, the explanations, significance; and the impact of these techniques, explanations, and significance are shared between researcher and participants. Thus, the qualitative paradigm transcends into the quantitative paradigm.

Based on the aforementioned discussion it seemed that both paradigms, qualitative and quantitative, provided steps to illustrate fruitful interpretations that demonstrate the multiplicity of meanings in the study of a phenomenon (Heath, 2000; Inbar, 1996; Silverman, 1985, 1995). Heath (2000: 55) further validates this by writing:
constant interplay of rich descriptive materials from field notes and simple quantitative steps as frequency/ratios helps researchers guard against rushing to select the "perfect" example from their qualitative data to illustrate a point.

Thus, suffice to say for the moment the educational research methodologies literature concerning the quantitative and qualitative paradigms did not provide any compelling priority of one paradigm over the other. Apart from the "compelling" and "constitutive" issues and their relationship to the search for a research paradigm another issue emerged from the educational research methodologies literature that further helped the researcher to structure the search for a research design: the "pragmatic" issues.

3.1.2 "Pragmatic" issues

Researchers like Eisenhart and Howe (1992); Freeman, (1996b), Saloman (1991); Shulman (1998) claim that the choice of a research design lies within the research question of the proposed study and refer to this choice as the "pragmatic" stance. Henwood and Pidgeon (1993: 17) eloquently note this "pragmatic" stance as "where a researcher does rely on either qualitative or quantitative methods, this will tend to be justified on pragmatic rather than epistemological grounds". Salomon, Shulman and Freeman go one step further by advocating that researchers' search for a research design paradigm should incorporate the perceived nature of the phenomenon to be studied; the questions to be asked about it and the data to be collected. Thus, two realisations were gained. First, some areas of the inquiry may be suitable to pursue through a qualitative context or quantitative context of research. Second, there was a need to go back to the researcher's articulated theoretical framework to further ground the search for a research design.

Taking into account the researcher's theoretical framework, the initial step was to locate classrooms that contain teachers who are integrating computer technology into science teaching. The next task was to work with classroom teachers through
the observation of a series of in-class activities, integrating computer technology. To do this a series of methods were needed to allow the researcher to interpret the communities of practice that were extant within teachers’ teaching practices integrating computer technology. These methods might include participant observation which allows the teacher, students, computer technology, and curriculum interactions/actions to be observed and recorded and furthermore, this might help capture, in action, the instantiation of teachers’ stated beliefs. Lesson transcripts and interview transcripts might provide the needed analysis of language, metaphors, and images which might reveal the cultural tools that shape these in-class activities: open processes of interaction and deliberation that uphold the culture building process. Narratives, with their emphasis on ordering experiences might provide an in-depth account of teachers’ in-class activities especially of their mindset in relation to the phenomenon.

This basic planning of data collection for the empirical investigation of the researcher’s theory reflected the researcher’s “heart of the research agenda” as stated in Chapter 1: Section 1.1.2. The “heart of the teaching agenda” (Cohen, 1996 in Ainley, 2000: 313-314) had to be discovered as well: to reflect the heterodoxy (Reason, 1996) of both teachers’ and researcher’s voices and perspectives of the phenomenon under study. Throughout the review of literature a number of researchers have emphasised that teachers’ metaphors (Bowers, 1990), images (Olson, 1997) and narratives hold the knowledge that substantiate teaching actions and perceptions of their teaching actions. To empower teachers to be researchers of their own teaching actions integrating computer technology could be resolved by enabling teachers to investigate their own metaphors, images and narratives. Since participants’ use of computer technology for teaching was the focus in this study, the cultural context and the cultural tools which were extant within teaching and learning activities had to be determined as well.

Thus, this “bare bones” planning for an empirical investigation of the researcher’s articulated theory seemed feasible in a number of ways. First, analysis of classroom discourse, interviews and narratives, through analysis of language and
metaphors would make explicit the open processes of interaction and deliberation that uphold the enculturation process. That is, the cultural tools that mediate teaching and learning when integrating computer technology. Analysis of field notes and narratives would reveal the activity structures that also form the meaning making processes of teachers. Second, the instantiation of teachers' beliefs that influence the negotiations of actions/cognitive guides/structure and strictures of the communities of practice and the applicability of cultural tools that result from teacher as a mediator, would be assessed through interviews, participant observations and narratives resulting from the study of the phenomenon under investigation.

Taking into account the pragmatic issues, examining teachers' construction of classroom meaning within the researcher's articulated theoretical framework called for a qualitative context of inquiry for two main reasons. First, the complexity of classrooms along with the fragmentary and limited knowledge about teachers' practice integrating computer technology suggested that the researcher look at the whole context of teaching integrating computer technology. Second, the existing knowledge about teachers' practices integrating computer technology, limited by a litany of advocacy-based studies, descriptive studies, diffusion and adoption studies and quantitative studies (Chapter 1, section 1.1.1) did not persuade the necessity for another study that centred on the computer technology itself. There was a commitment to a person-centred vision of technology for education (Kerr, 1996b). That is, looking at the use of computer technology from the teachers' perspective of cultural transmission rather than centering on the computer technology alone was a crucial reason for the evolution of this study. Thus, for these reasons the researcher needed an inquiry that would envision the wholeness of both the teaching practice and the contexts. Furthermore, the researcher needed an inquiry that would allow an interplay between data and theoretical framework articulated by the researcher. That is, an inquiry that could lead to a re-negotiation of core propositions of the theoretical framework. A qualitative inquiry therefore seemed more appropriate.
Thus, it was determined that five sets of data had to be collected:

1. observations of actual teaching integrating computer technology;
2. records of actual classroom discourse between teachers, and students when involved in teaching and learning activities integrating computer technology;
3. interviews with teachers to capture the perceptions underpinning these teaching and learning activities integrating computer technology;
4. narratives that captured the teaching agenda;
5. and the participants' belief system also had to be made explicit and analysed.

In conclusion, a qualitative research design, based on the pragmatic reasons, seemed more appropriate. But then, there were also some historical reasons to choose the research design, especially considering the nature of the study that was looking at teachers' thoughts, belief and actions as determined from the five sets of data that had to be collected. Therefore the choice of a qualitative research design had to be validated by historical reasons as well. The discussion now shifts towards these historical reasons and how they helped to substantiate the choice of a qualitative research design for this study.

3.1.3 “Historical” issues

In addition to the pragmatic issues, the data collection methods had to be compatible with current and past studies of teachers' thoughts, beliefs (with and without the integration of computer technology) and actions: historical issues. These historical issues are discussed and their importance to the choice of a methodology is elaborated.

Studies that look at empirical investigations of research on the pedagogically sound use of computer technology in classrooms, also informed the search for a research paradigm. Levine (1990), Marshall (1993), and Winkler, Shavelson, Stasz, Robyn and Feibel (1985) argue that any research on the pedagogically sound use of the computer technology depends on three factors: first, the teacher
preactive, interactive and evaluative thinking of classroom teaching; second, the "hands-on" observations of classroom practices in real time for documentation; and finally, the need for an in-depth analysis of classroom computer technology-social system interface. Thus, these studies supported the researchers' pragmatic reasons for a qualitative context of inquiry.

On the other hand, other researchers remind us that access to the organizational culture (the general rules, prescriptions, basic assumptions, beliefs and the supra-individual meanings) that participants work under is crucial to understanding any teaching practice (Kelchtermans & Vandenberghhe, 1994, Moallem, 1994; Page, 2000a; 2000b). This concurs with Sheingold, Kane & Endreweit (1983) who identify the community, school system, individual school and the classroom as essential elements that affect the shape and the scope on computer technology's impact on classroom teaching.

Since teachers' beliefs were a key component of the study, two protocols derived from the empirical studies that examined teachers' beliefs (Abelson, 1979; Calderhead, 1996; Eisenhart, Shrum, Harding, & Cuthbert, 1988; Fang, 1996; Kagan, 1992; Kagan & Tippins, 1991; Nespor, 1987; O'Loughlin, 1990; Pajares, 1992; Sigel, 1985; 1992) were adhered to. First, central to these protocols is the understanding "beliefs cannot be directly observed or measured but must be inferred from what people say, intend to do-fundamental prerequisites" (Pajares, 1992: 314). With this in mind belief statements (core beliefs, what beliefs); action components; and intentionality (how beliefs) have to be taken note. This is to prevent the reductionist perspectives of seeing beliefs as "simple cohesive units" (O'Loughlin, 1990: 1) having a cause-and-effect remedies; leading to technical approaches to teaching actions. This also prevents teachers' beliefs from being branded as standards-composite of statements (Brousseau, Book & Byers, 1988). Teacher actions and intentionality resulting from their beliefs are more reliable as they reveal the context specificity to the teachers' beliefs studies. Second, images to reveal intentions are a better measure of beliefs which are "inside the head" (Wertsch, 1991 in Moje & Wade, 1997: 693) and thus difficult to fathom. The
images from the activities of teaching are more appropriate for studying beliefs (Tobin, Tippins & Gallard, 1994). The orientation is that the "broader, general belief system" that teachers possess (Pajares, 1992: 316) must also be considered. These belief systems give bearings for instructional activities and envisioning of future events; provide accommodation and assimilation in the light of uncertainties and multidimensionalities and impose an affective component that is more overpowering in any situation marked by cognitive disorder. This is mentioned by Robin and Harris (1998) in their investigation of teachers' beliefs (Section 2.3) and their suggestion of a quantitative approach: Attitudes About Reality scale. Therefore, these studies that examined the protocols for the study of teachers' beliefs supported a qualitative context of inquiry for the study.

Therefore, the above discussion, based on historical reasons, pertaining to studies that examined educational computing and teachers' beliefs, had highlighted that a qualitative context of inquiry would be more suitable for this study.

3.1.4 The "epistemological" issues

As well as the pragmatic reasons and historical reasons to choose a qualitative context of inquiry the epistemological perspectives surrounding qualitative context of inquiry were also influential in the choice of a qualitative inquiry. The traditions that qualitative methodology encapsulated was a major push towards a qualitative inquiry for the research design.

Qualitative research is not a “one-approach” (Jacob, 1988: 16), but one that is characterised by orientations or traditions (Jacob, 1987; 1989). The research literature captures qualitative research as comprising multifaceted traditions. The researcher utilised a combination of these anthropological traditions: holistic ethnography, microethnography/constitutive ethnography, and cognitive anthropology and symbolic interactionism (sociology). These traditions were adopted because they collectively:
1. suggest that cultural standards; patterns of social interaction; and environmental context influence cognitive activity;
2. stress qualitative analysis but do not eliminate the necessity for quantitative analysis;
3. offer richer and fuller understanding of education;
4. provide a set of orientating assumptions about what to study;
5. do not hinder the "open" stance of a qualitative stance;
6. allow for assumptions like: (a) certain aspects of culture are important in all societies; (b) maintaining an open stance concerning the specifics of how behaviours are defined in a particular culture and (c) how the components of a culture are linked (Jacob, 1987, 1988).

Thus, these traditions enable a unified and interlinked approach to the human nature and society focus of the study and methodologies implemented something that cohered with both the pragmatic and historical reasons.

3.1.5 Settling for a predominantly qualitative context of inquiry

The choice of a qualitative context of inquiry and the reasons behind it, pragmatic, historical and epistemological ones, supported the aforementioned data collection strategies (Section 3.1.2) - classroom observations (holistic ethnography and symbolic interactionism), lesson transcripts (microethnography) and interview transcripts (cognitive anthropology) and narratives - into data collection strategies strengthened and informed by the broader context of qualitative inquiry. Most important of all this adoption of a qualitative inquiry helped to enable the purpose of inquiry of this study to be investigated from the voices and perspectives of both participants and researcher. Also it posited the study within the person-centred vision of technology for education, since the voices and perspectives enshrining the use of computer technology for cultural transmission becomes the focus and not the computer technology (Bowers, 1988a; 1988b; 1990; 1995; 1997; 1998a; 1998b; Kerr, 1996b)
3.1.6 The quantitative methods amidst the qualitative methods

Although research design was predominantly qualitative, one type of data collection method used was quantitative, the Attitudes About Reality Scale the purpose of which was to derive the general belief systems of participants. The Attitudes About Reality scale is elaborated in section 3.4. At this juncture, it is relevant to point out that this quantitative method was applied independently and concurrently to that of the qualitative methods including interviews, observation, metaphorical statements and narratives. This independent and concurrent application of the quantitative method preserved the assumptive and methodological integrity of each paradigm qualitative and quantitative respectively (Greene & McClintook, 1985).

Within the predominantly qualitative data "simple quantitative steps as frequency counts" (Heath, 2000: 55) were used to help the researcher provide a different type of evidence where necessary. This concurs with what Jick (1983) refers to as scaling - the quantification of qualitative measures. That is, qualitative data were added to together to represent numerical values or frequencies. This was especially so for the analysis of the metaphoric language which were identified in all verbatim verbal transcripts (Section 3.8.2.2).

The researcher was also aware of the critique that combination of naturalistic and positivistic research paradigms requires preplanning (Lincoln & Guba, 1985 in Gilner, 1994); otherwise unnecessary tensions may arise (Greene & McClintook, 1985; Knapp, 1979; Trend, 1979). The use of quantitative steps was by no means a retreat in response to the complexity, but was in response to pragmatic, historical (Attitudes About Reality Scale) and constitutive issues as discussed in sections 3.1.2; 3.1.3; and 3.1.4.

An account of the data collection is presented next, the ethical and practical concerns are discussed first. This is followed by a description of the school context and the participants who took part in the study. The methods of data
collection, encapsulated by the insights from the theoretical framework and discussion of the research paradigm, are then discussed.

3.2 The account of the study

Before providing an account of the study, a number of benchmarks had to be set: specifically who the participants were; the ethical and practical concerns of the study; the researcher and the research site; and the presence on the site.

3.2.1 Participants

The participants in this research study were six teachers at a secondary school in the Republic of Singapore. The participants comprised five female teachers (Angela, Ning, Sundari, Tan and Woo) and one male teacher (Anthony). The demographics of participants are presented in Table 2. Table 2 contains the participants’ names, their age, their ethnicity, the levels they taught, the subjects they taught, the number of years they had taught and the number of years they had taught with computer technology in the classroom.

All participants were trained teachers. Angela, Ning, Sundari and Woo were graduates with the post-graduate diploma in secondary teaching from the National Institute of Education. Anthony and Tan were trained as teachers at the old Institute of Education. All participants with the exception of Tan were graduates of the National University of Singapore, majoring in either biology (Sundari); chemistry (Anthony); microbiology (Woo) or physics (Angela and Ning). Tan is a graduate of a Canadian university and her degree is in chemistry. These six participants described in this study, expressed interest in the study and readily agreed to participate. Other essential details are presented in Table 2.

All six participants explained that the motivation for participating in this study enabled them to reflect on their teaching; particularly on their integration of computer technology into teaching.
<table>
<thead>
<tr>
<th>Participant</th>
<th>Age/Ethnicity</th>
<th>Level Taught</th>
<th>Subjects Taught</th>
<th>Years Teaching</th>
<th>Computer Experience/Years</th>
</tr>
</thead>
<tbody>
<tr>
<td>Angela</td>
<td>20's/Chinese</td>
<td>Sec. 2, &amp; 3</td>
<td>Physics, General Science</td>
<td>5</td>
<td>Inservice Staff Training; School Based Training &amp; National Institute of Education/3</td>
</tr>
<tr>
<td>Anthony</td>
<td>40's/Chinese</td>
<td>Sec. 3</td>
<td>Chemistry</td>
<td>19</td>
<td>Inservice Staff Training &amp; School Based Training/2</td>
</tr>
<tr>
<td>Ning</td>
<td>30's/Chinese</td>
<td>Sec. 3</td>
<td>Physics</td>
<td>8</td>
<td>Inservice Staff Training; School Based Training &amp; National Institute of Education/2</td>
</tr>
<tr>
<td>Sundari</td>
<td>30's/Tamil</td>
<td>Sec. 3 &amp; 4</td>
<td>Biology</td>
<td>7</td>
<td>Inservice Staff Training; School Based Training &amp; National Institute of Education/3</td>
</tr>
<tr>
<td>Tan</td>
<td>40's/Chinese</td>
<td>Sec. 3</td>
<td>Chemistry</td>
<td>20</td>
<td>Inservice Staff Training &amp; School Based Training/2</td>
</tr>
<tr>
<td>Woo</td>
<td>20's/Chinese</td>
<td>Sec. 4</td>
<td>Biology</td>
<td>2</td>
<td>Inservice Staff Training; School Based Training &amp; National Institute of Education/2</td>
</tr>
</tbody>
</table>
Each of the participants’ science classes was large with 40-42 students. Participants belonged to departmentalized (Science Department) team-based teaching groups. That is, they collectively plan the curriculum and activities that they share and use in their classes. These were done formally during departmental meetings as well as subject level meetings to understand one another's roles and needs or solve problems together. Informally, participants shared their ideas and perceptions about their use of computer technology for teaching during free periods or lunchtime.

Apart from the overwhelming response for the proposed collaboration by participants and the principal of the school, the researcher felt that selection of participants had to be based on other justifiable criteria. First, the professional rapport that the researcher had with the participants allowed confidence about their participation in such a long-term joint venture. The researcher made clear the aim of the study, its methods and duration to build up a participatory relationship. The participatory relationship was marked by open-feedback and dialogues between researcher and participants. Participants who felt comfortable with this type of relationship were selected. These participants were also aware that study was not a counselling/advice endeavour for their use or researcher’s use of computer technology.

3.2.2 Ethical concerns

On considering the nature of the study it was acknowledged that the participants were in a situation of great vulnerability (Denscombe, 1982). As it involved disclosure of the participants personality as well as their teaching practice which now had an audience comprising their students and the researcher. Thus, it was decided to reduce the visibility of the study as far as possible. This was done by empowering the participants as much as possible. For instance, the researcher wrote formal letters and sent information sheets regarding the study to the principal of the school that took part in the study. These formal letters and information sheets, containing the interview questions and study design, were
approved by the Ethics committee of the University of Otago (Appendix A). The researcher then approached prospective participants who were interested in taking part in the study. The participants were given a detailed account of the purpose of the study and the level of commitment required of the participants. The researcher stated strongly that the study “was totally dependent on the potential participants’ willingness to ‘give’ their time to the researcher” (Limerick, Burgess-Limerick, & Grace, 1996: 453) and that they were free to withdraw from the study without any obligations anytime they chose to. Participants were also made aware that there were no tangible rewards for participation.

3.2.3 Practical Concerns

Participants in this study nominated the place and time for the researcher to meet them for the collection of the various data (semi-structured interviews, narratives and classroom observations and discourse). This ensured that participants’ verbal transactions were conducted in places that were familiar to participants, thereby empowering participants and maintaining the balance of power between interviewer (researcher) and interviewees (participants). For instance, most of the interviews, and narratives were collected from the participants during free periods, after school or on Saturdays when the participants were in school for extracurricular activities.

3.2.4 The researcher and the research site

The choice of the site by the researcher was dependent on a number of decisions and reasons. The researcher decided that a research site closer to home (Republic of Singapore) would be a better choice. The researcher was comfortable and experienced in the symbols, language and the culture that the teachers in the research site used to convey the subtle meanings that shaped teaching actions. Furthermore the researcher was aware and had experienced the external pressures/urgencies (Cuban, 1993) that these participants were immersed in. Also the researcher had taught at the site for the previous three years (1996, 1997,
and was comfortable with the site. Also rapport had been built up with the participants at the research site. Most important of all there was overwhelming response from the principal of the school and participants to the researcher's request for participants.

3.2.5 School context

The study was conducted at an all girls secondary school. The students were in the age range of 13 to 16. Students aged 13 to 14 were in the lower secondary (first and second years of secondary school, while those aged 15 to 16 were in upper secondary (third and fourth years of secondary school). The student population was about 1800 at the time of the study. The student population was ethnically diverse with representative students from the four national languages that the Republic of Singapore recognises. Each class had a predominantly Chinese student population (3/4) with Malay, Tamil and/or Eurasian students making up the rest of the class.

3.2.6 Innovative capacity

The researcher was also familiar with and aware of the innovative capacity (Sleegers & Van den Berg, 2000; Van den Berg & Sleegers, 1996; Van den Berg, 1999) of the school. That is, the school's competence in the implementation of computer technology and infrastructure. These are represented diagrammatically in Appendix B. The number of computers, and the arrangement of classrooms in response to the computer technology were the key features noted in reference to the innovative capacity of the school.

3.2.7 Presence on the site

Given the research question which sought to the investigate how teachers construct classroom meaning and given empirical studies that had examined teachers' use of computer technology over a period of time (Goodson, & Mangan,
the researcher concluded that he had to be on site for a sufficient period of time. This enabled the researcher to immerse himself in the contexts that participants were intimately involved in. Based on a more theoretical stance, the researcher felt that this avoided and helped to detect “fronts” (Hammersly, 1990: 14), if any, that participants had sustained consciously or unconsciously throughout the joint venture of the study.

3.3 Self as researcher

This section of the study presents the researcher’s professional and personal biographies, perspectives, beliefs, values, of the researcher encapsulated under the banner of self as researcher (Manning, 1997). This provides the necessary context of situating the researcher within the study.

“...researchers cannot presume that they are in any way removed from the social environments they study. Indeed it had been suggested that researchers are as deeply involved in the construction of social environments they analyse as they are in the subsequent representation of these...” (McGettigan, 1997: 367).

The above quote is also a backing for the researcher’s stance that self as a researcher had to be made evident to the reader. First, the researcher’s professional training and experience in interpretative/qualitative research. As a master of education candidate at the University of Florida, the researcher gained extensive training in observation/fieldwork techniques, stimulated recall techniques (video and audio) and conducting interviews as he was involved in micro-teaching activities organised by the Curriculum and Instruction, and Science Education departments respectively. This training involved the extensive use of interpretative research in the study of researcher’s own teacher training and those of his peers. This interpretative research became a primary orientation that the researcher was continuously exposed to during his masters’ candidacy. Furthermore, the researcher believes that through this training experience, an
interpretative research approach provides an emphasis on the humanistic approach to documenting human actions in given contexts. This approach also gives a broader and richer foundation for explaining these actions from both the participants' and researcher's perspectives of these human actions: mutuality and co-construction.

From a personal perspective, the researcher's extensive exposure to the use of computer technology for teaching and learning-preservice training (University of Florida); teaching and inservice training in the Republic of Singapore and the computer technology courses attended also prompted a close affinity of the researcher to the study. Having published a paper on the innovative use of computer technology in classrooms (Subramaniam, 1999) and presenting seminars on the innovative uses of computer technology in the classroom further prompted the researcher to delve into the study.

The definition of self as researcher was not only influenced by these professional and personal perspectives but also by the mutually evolving context of the study. Within this mutually evolving context the researcher did not exist as a single entity but one with multiple roles. First, the adoption of qualitative traditions (Jacob, 1987, 1988, 1989) resulted in the adoption of the role of anthropologist. Second, it involved the role of story listener, evoking participants' narratives of the phenomenon. These roles had to maintain rapport and mutuality with participants. Since the study also utilised participants as researchers themselves (generation of metaphorical statements), self as researcher had to respect participants as co-researchers. The researcher understood that participants as researchers of their own classrooms provided accounts enmeshed in the context of their knowledge of classrooms: subject knowledge, teacher knowledge, student knowledge and beliefs (MacLean & Mohr 1999 in Painter, 2000). This phase of self as researcher provided ample ammunition as a negotiator to gain empathy for the participants and to describe the complex social system in which the participants were situated (Marshall & Rossman, 1995).
Self as researcher was also moulded by the need to maintain the atmosphere of “vital partners” (Saphier, 1982 in Cole, 1989; Cole, 1990; Cole & Knowles, 1993; Neuman, 1989) since participants in this study were influencing the choice of methods; data analysis and the use of the findings (Elden, 1987). Furthermore, both researcher and participants were building and adopting strategies for balancing bias in interpretations and maintaining rapport, due to the collaborative nature of study. That is, participants and researcher had the opportunities to be reflexive and critical in a participatory relationship: co-constructing the comprehension of the phenomenon under study.

Although, the construct of “vital partners” was acknowledged, respected and adhered to throughout the study, self as a researcher was also defined by the need to evoke self reflexivity and take responsibility and not to rely on “intersubjective validation” only (Salnar, 1986 in Kvale, 1989: 86). Thus, participants’ accounts were taken into account as further insights, multiple realities (Lather, 1993) and not as an endorsement of reality.

Thus, the aforementioned discussion provides the context in which the researcher was situated within the mutually evolving context of the data collection, analysis and substantiation of interpretations. The researcher’s role in maintaining rapport with participants, respecting participants as co-researchers and vital partners within the mutually evolving context of the study marked the professional relationship between researcher and participants in this study. This set the foundation for the trust and development of shared meanings which were derived from the study.

The format of the upcoming sections (Section 3.4-3.7) on how data was collected is divided into the three genres of research methods that were used to elicit data in this study: quantitative (Attitudes About Reality Scale); anthropological traditions (semi-structured interviews, participant observations, and focus group interviews) and narratives. The focus now shifts towards this discussion of data collection and analysis.
3.4 Quantitative genre of the study

The aim of this quantitative aspect of the study was to identify the general belief systems of participants involved in the study.

3.4.1 The Attitudes About Reality Scale

Although the research methodology utilized in this study was strongly geared towards a qualitative approach, one of the data collection methods used was quantitative in nature. The "Attitudes About Reality Scale" (Unger, Draper & Pendergrass, 1986) was used to elicit participants' "philosophical view of the world" (Robin & Harris, 1998: 27) that is, participants' assumptions of reality in general.

Since participants' beliefs were an area being investigated the utilisation of this quantitative instrument provided for the correlation between participants' beliefs and participants' broader belief systems. This was stated as a precautionary measure by Robin and Harris (1998) (Section 2.3) in studying participants' beliefs. This also coheres with Pajares's (1992) warning about the danger of studying beliefs with no relation to teachers' prior or developed belief systems. This is summarised by Pajares as "seeing educational beliefs as detached from and unconnected to a broader belief system...ill advised and probably unproductive" (in Robin & Harris, 1998: 27). The need to investigate the prior and developed beliefs of teachers is also advocated by Smith and Neale (1989) as cited by Calderhead (1996). They emphasize strongly that researchers should comprehend which orientation that participants started from prior to the study of participants' beliefs.

It was the researcher's intention that this quantitative method together with the other qualitative methods used to elicit participants' beliefs would alleviate inherent limitations in the data collection strategies especially those geared to investigate participants' beliefs.
3.4.1 The Scale

The shorter form of the Attitudes About Reality Scale (Appendix C) was used in this research study. Twenty-eight items were selected from Unger, Draper and Pendergrass (1986: 78) sample questions. The twenty-eight items contained various aspects of personal worldviews (Robin & Harris, 1998) which Unger, Draper and Pendergrass (1986) referred to as “attitudes about reality” (p. 67). The items were characterized by a number of declarative statements from which participants choose a response from a continuum of choices ranging from “agree almost completely” to “disagree almost completely”. Sample items included “The facts of science change over time,” “It is important to decrease the distance between the ‘real world’ and the scientific laboratory,” “The way scientists choose to investigate problems is influenced by the values of their society,” and “It is maladaptive to refuse to conform to the demands of society.”

The twenty-eight items were placed in a Likert-type index/questionnaire with a seven-point scale, ranging from agree almost completely (score of seven) to disagree completely (score of one). Four questions were scored in the reverse direction as stated in Unger, Draper and Pendergrass (1986: 78) format for items and scoring (refer to Appendix C).

The items were designed to measure participants’ personal philosophical worldview on a continuum that ranged from social constructionism to logical positivism. The instrument produces a score ranging from 28 to 196 with a midpoint of 112. Lower scores (28 to 111) represented social constructionist worldviews and higher scores (111 to 196) indicated logical positivist worldviews. The midpoint score of 112 indicated a worldview encompassing a balance between social constructionism and logical positivism.

The issue of what defines social constructionism and logical positivism was a matter to contend with and it was decided by the researcher to take a perspective that encompassed the views of the following relevant literature that utilized the
questionnaire namely; Harris & Grandgenett (1999); Harrison & Atherton (1992); Robin & Harris (1998) and Unger, Draper & Pendergrass, (1986). Participants who supported a social constructionist worldview were characterized as asserting the idea of reality as "changeable and largely a matter of cultural and historical definition" (Unger, Draper, & Pendergrass, 1986: 71). On the other hand participants who supported a logical positivist worldview were characterized as asserting that "reality is stable, irreversible, and deterministic".

One apprehension with regard to the validity and reliability of the Attitudes About Reality scale was the issue that the scale was measuring participants' "view of self in relation to society rather than his or her epistemological assumptions about reality in general" (Harrison & Atherton, 1992: 338). Robin and Harris (1998) assert that this itself is a world view. Harris and Grandgenett (1999) assert that both Harrison and Atherton 's interpretation and Unger, Draper and Pendergrass's (1986) interpretation are acceptable.

3.5 Qualitative genre of the study

This aspect of the study utilised; semi-structured interviews, focus group interviews, and participant observations to capture participants' teaching actions integrating computer technology.

3.5.1 Semi-structured interviews

Interviews served as a dominant data collection strategy in this study. The major focus of the interviews was to gather "descriptive data" (Bogdan & Biklen, 1998) in the participants' own words, to enable the researcher to construct insights into participants' teaching integrating computer technology. The researcher sought to elicit data reflecting the participants' teaching actions integrating computer technology, participants' perceptions of their teaching with computer technology and their beliefs.
According to Tuckman (1972 in Cohen & Manion, 1989) interviews, as a research technique, enabled researchers to investigate participants' knowledge, values, preferences and thoughts. In addition to this, interviews also served as a tool to verify other data collection strategies (the multimethod approach). Cohen and Manion (1989) citing Kerlinger (1969) suggested that interviews can be used to gain deeper insights into participants' responses in relation to the phenomenon under study. Furthermore, the research literature on interviews characterises the research interview as a “purposeful conversation” (Berg, 1998: 57; Bogdan & Biklen, 1998: 96) for “evaluating and assessing a person” and thus “gathering data” (Cohen & Manion, 1989: 309). Kvale (1996: 127) described the research interview as a process where knowledge is built as interviewer and interviewee play out their roles.

In this study, interviews served as a technique to elicit participants' experiences and perceptions integrating computer technology into their teaching, leading to portraits of teaching actions. The portrait encompassed the range and scope, and beliefs of participants' teaching with computer technology. Some questions were adapted from the convention set by Kagan and Tippins (1991) for deriving participants' beliefs: Interview 3 of this study (Appendix D).

Five interviews and two verification interviews were conducted with each participant throughout the five-month study at the research site, in the Republic of Singapore (refer to dates and time in Appendix D).

3.5.2 Focus group interviews

The third major source of data collected was from focus group interviews. Focus group interviews generate high-quality data in a social context thus enabling the collection of data that highlights the collective concerns and solutions that participants experienced with the integration of computer technology into their teaching practices. This data collection method also enabled the researcher to capture “the signs and symbols” (Moallem, 1994) that were culturally patterned
and were part of the meaning making process or meaning systems of this group of participants.

Focus group interviews served as "self contained means of collecting data" (Morgan, 1988) and contributed to the study as a part of a "larger effort to triangulate" (p.25) different forms of data from individual interviews, metaphors, metaphorical statements, participant observations, anecdotal data and narratives. A brief introduction to focus group as a qualitative method, the advantages and the relevant literature to support the use of this method in this study are discussed next.

3.5.2.1 Focus group interviews – A qualitative approach

Focus group interviews are basically group interviews with a small group of participants (Berg, 1998) on a specific subject (Patton, 1990) "with the objective of better understanding the attitudes, beliefs, practices and values on a specific subject" (Bertrand, Brown, & Ward, 1992). Alternations do not occur between researcher's questions and participants like in individual interviews, but between researcher's questions to all participants, using group interaction to investigate the specific subject (Morgan, 1988).

Focus groups generate large amounts of data in less time than other methods (Liu, Spicuzza & Erickson 1999; Patton, 1990; Stewart & Shamdasani, 1990). They give rise synergistically (Brown, Collins, & Duguid, 1989) to insights that may not occur in individual interviews resulting in greater depth and details associated with the meanings constructed. Berg (1998) characterizes this synergy as participants in a focus group relating to other participants resulting in brainstorming each other's responses. Focus group interviews enable the researcher to carry out the exploration of themes and issues in complex and unanticipated ways. Participants may reveal greater diversity of opinions – an amplification (Krueger, 1998), and there is always the emergence of shared understandings (Erwin & Stewart, 1997). Focus group interviews also enable
participants to recognize “hidden parts” of themselves and reconstruct opinions from other’s stories (Morgan, 1993) unfolding in discourse, the “practical ideologies” that are not revealed during individual interviews (Weatherell, Striven, & Potter, 1987). Patton (1990) suggests that this method of data collection provides quality controls, as participants tend to provide checks and balances on each other which lessen false or extreme views. He also states that group sessions are highly enjoyable to participants.

According to Morgan (1988) focus group interviews integrate aspects of individual interviews and participant observations (both established qualitative methods) but maintain an identity of their own. This makes it feasible to discuss data not easily obtainable from either, such as revealing “why” participants think as they do (p.25). The “why” in this study was to reveal the cultures of teaching that were affecting participants’ construction of classroom meaning.

3.5.2.2 Method

Two focus group interviews lasting about two hours each were conducted during the five-month study, one in February 1999 and one in May 1999 (refer to calendar of research, section 3.7). Each focus group began with an overview of the research agenda and a brief synopsis of research purpose. In the first focus group session participants were introduced to the focus group format. The convention, as specified by Kreuger (1994), was utilized for both sessions. The researcher presided at both sessions as a moderator and an assistant moderator was appointed (non-participant). (For an expanded view of the mechanics, roles played by the assistant moderator and the formats used to collect data refer to Appendix E).

The researcher guided the focus group interviews with a series of questions focussed on the study. Each focus group discussion was audio taped and the resulting dialogues were transcribed. In addition to this, a summary report (Krueger, 1994, 1998) was prepared for each of the two focus groups. The summary report followed the descriptive-interpretative format in which selected
participants’ quotes and an inventory of points discussed by participants (Bertrand, Brown and Ward, 1992) (descriptive) were presented together with meaningful insights from the analysis of data (interpretative). This helped to verify the group discourse, and to gain clarification and further insights from participants. Two summary reports were prepared in this study. One was prepared after each focus group interview session. The first session summary report was given to participants at the beginning of the second focus group interview session for participant assessment and validation. The second summary report was verified with each participant individually. Data that arose from this individual verifications were not disregarded but were used in the analysis with special attention paid to the lack of group amplification that countered this utterance (Krueger, 1998).

Thus, the adoption of this qualitative method enabled the researcher to substantiate participants’ interpretations within a larger context: the culturally patterned signs and symbols extant within the larger community in which they were situated.

3.5.3 Participant observation and anecdotal data

Another source of data collection for the study consisted of classroom observations during the five-months of the study. The primary purpose of this phase of the data collection was to attempt to generate inductively the structure/content of lessons; the pedagogical functions; and, the context as evidenced by the patterns of classroom teaching integrating computer technology. This then assisted the researcher in focussing onto the “congruency and incongruency of beliefs and behaviour”, to check the verbal verbatim responses (Pearson, 1985: 128) and to see the meanings expressed in participants’ verbatim verbal reports played out with contextual coherence in natural settings (Connelly & Clandinin, 1986) and to capture the classroom discourse.
Participant observation has been described as one of the best ways to comprehend a participant’s world and a participant’s interpretation of that world, since a participant’s view makes the setting (Berg, 1998). Participant observations were interspersed with individual and group interviews, the participant observations enabled the researcher to “verify perceptions and patterns” (Savenye & Robinson, 1996: 1177) arising from the interviews. Berg (1998) suggests that participant observations enable researchers to observe actions in a meaningful context – the natural settings in which the teaching actions took place. Morgan (1988) further states that this kind of qualitative approach gives the advantage of collecting larger ranges of behaviours, a variety of interactions and propagates for a “more open discussion of the research topic” (p.16).

Participant observations provide first hand data which is not possible with individual interviews where issues of complete disclosure of events may be marred by participants’ memory, perceptions, re-representations of reality and reconciliation. Yinger (1986) further suggests that participants may not be aware of all the events in a teaching and learning situation resulting in a biased outlook on aspects familiar to participant or researcher. Participant observation itself may be characterised by incompleteness or partial focus on a phenomenon. Brown and McIntyre (1993) contend that to alleviate this inadequacy, participants’ own perspectives have to be collected together with the observations of the session/sessions to gain a holistic account of the phenomenon under study. Mishler (1979: 11) advocates for the participants’ “perspectives or definitions of the situation” as a means of “enduring reciprocities” and as a “dialectical unity” to constitute the findings of the phenomenon under study.

In line with theoretical framework, three types of data were collected and analysed: classroom observation (field notes), classroom discourse and anecdotal data (Gess-Newsome & Lederman, 1995). Classroom observations were prearranged and occurred within a class of the participant’s selection. Attempts were made to observe as wide a range of classroom situations as possible. The number of classes observed dates, duration, location are listed in Appendix B. All
verbal transactions between the participants and their students, where possible, were audio taped and merged with the field notes. A sensitising framework (Patton, 1990) was developed prior to the study. This sensitising framework oriented and highlighted the importance of the following: participant’s movements in the classroom; student interest; general classroom tone; participant actions; student actions; use of computer technology by participants and/or students; observer impressions of the overall class proceedings referenced as “Observer comments” (OC) (Meriam, 1998); and classroom physical structures (refer to Appendix B).

The sensitising concepts expressed within the aforementioned sensitising framework (Patton, 1990) were not observed as separate entities but as part of the holistic classroom context. This was in line with what Erickson (1986) refers to as:

In fieldwork one never considers a single system level in isolation from other levels; that is a basic feature of the sociocultural theory from which participant observational methods derive. (p.143)

This also helped to prevent the researcher from bringing into the observation his own preconceptions of reality. In general the threats to accurate data collection were also considered and appropriate recommendations for improving observer accuracy were taken account and listed in Table 3. Table 3 lists two aspects crucial to any study that uses participant observation as a data collection method: threats to accuracy and the recommended steps taken to alleviate these threats.

Although all these precautions and the sensitising framework were set in motion, this phase of the data collection resulted in a “blocked research” aspect (Reinharz, 1993). This blocked research phase occurred due to the number of participants, the large number of periods taught by participants, and timetable clashes between one participant and another. Thus, it was impossible for researcher (the only participant observer) to observe an extensive number of classes as it was impossible for the researcher to be at two classes at the same time. The researcher
TABLE 3
Participant observation-inherent threats and steps to alleviate threats
(adapted and modified from Repp, Nieminen, Olinger & Brusca, 1988)

<table>
<thead>
<tr>
<th>Threats to Accuracy</th>
<th>Recommended steps</th>
</tr>
</thead>
<tbody>
<tr>
<td>Participant and Observer reactivity; Reliability;</td>
<td>Observing unobtrusively.</td>
</tr>
<tr>
<td>Observer bias; Contamination; Observer drift; Hawthorne</td>
<td>Use of permanent products-audio</td>
</tr>
<tr>
<td>effect; and Halo effect.</td>
<td>tapes.</td>
</tr>
</tbody>
</table>

did not want to make generalisations based on the "brief slices of time" (Savenye & Robinson, 1996: 1177). To address this blocked phase a number of possible avenues were explored. First, video recording of classes as a solution was mooted, but participants rejected the idea and the researcher respected their wishes. Thus, two other possible avenues were sought by the researcher to address this dilemma. First, to use participants' classroom cases (Kagan, 1993) of specific subjects/topics taught with computer technology as a "check for the consistency of teacher stated philosophies into practice" (Gess-Newsome & Lederman, 1995: 305). Second, it was hoped that the anecdotal data collected would complement classroom observations conducted.

Anecdotal data, often in the form of spontaneous conversations surrounding lessons after participant observations, were documented for analysis. Such conversations often provided information on participants' general classroom philosophies and perceptions of teaching and learning actions (Brown & McIntyre, 1993; Mishler, 1979) with the integration of computer technology. These conversations were not purposefully structured by the researcher. Furthermore, at the end of each conversation, the researcher was also able to clarify any observer comments made in field notes and classroom discourse.
3.6 Narratives as a qualitative genre of the study

This aspect of the study utilised narratives as a source of data. Since the study was looking at how participants constructed classroom meaning (within the context of teaching integrating computer technology), narratives seem to be highly recommended as one of the ways of giving the participating teachers a voice. As a qualitative method, narratives upheld some of the tenets, in the aforementioned discussions (Sections: 3.1). Narratives validated multiple representations and dimensions of participants’ purposes, values and orientations; and, acknowledge the participants’ way of knowing the social context in which they work—their goals, actions and intentions (Beattie, 1995; Carter, 1993; Connelly & Clandinin, 1986; 1988; 1990; Goffman, 1974 in Tirri, Husu & Kansanen, 1999). Furthermore, Smyth (1992) contends that narratives serve to uncover teachers’ theories-in-use/operational theories/local theories that encapsulate their teaching actions. On the other hand, Jensen (1989) claims that narratives also contain participants’ “evaluative statements and arguments” for their teaching and learning actions (p.101). Narratives as data sources have features that contain a beginning, a middle and an end: temporal and logical features (Kagan, 1993; Reissman, 1993 in Coffey & Atkinson, 1996). These features gave narratives their “compelling power” (Gottdiener, 1993: 664) to be used as a data source. Furthermore, narratives provided another avenue for data collection: a mutual researcher and participant reconstruction of meaning-in-action within a context of story telling (Carter, 1990) where “the creation of situations of trust” (Connelly & Clandinin, 1990: 12) empowers the participants (Limerick, Burgess-Limerick & Grace, 1996).

Gottdiener (1993) contends that narratives have two inherent limitations that may restrict their use. First, narratives tend to be causal in nature and neglect the “configurational influences, conjunctures and contexts” (Gottdiener, 1993: 664): the social relations that participants are situated in. Second, narratives tend to be one-dimensional and do not take into account of the participants’ critical reflection of the configurational influences, conjunctures and contexts that are also
crucial to the development of narratives. In this research, the use of metaphorical statements addressed this lack of critical reflection in the development of narratives.

Within this qualitative genre of the study, participants were researchers of their own teaching actions integrating computer technology. Participants generated metaphorical statements following which a mutual participant-researcher collaboration resulted in the generation of narratives. Another source of narratives was the participants’ construction of classroom cases that captured their integration of computer technology into teaching.

3.6.1 Metaphorical statements, narratives and “The teacher as ...” metaphors

The approaches to research on metaphors for teaching fall into two categories. The first category is the natural metaphoric language (Morine-Dershimer & Reeve, 1994) or speech metaphors (Connelly & Clandinin, 1988) that are prevalent in teacher discourse. The second category is the generation of verbal or written explicit metaphors or metaphorical statements by teachers resulting from assigned or instructional activities (Coffey & Atkinson, 1996; Gurney, 1995; Marshall, 1990; Miller & Fredericks, 1988).

The speech metaphor analysis approach and metaphorical statement approach have both been extensively used in educational research. The identification and analysis of preservice and inservice teachers’ metaphors have contributed to the understanding of teachers’ thinking, professional knowledge, beliefs, teacher role conceptualisations, images of teaching and teaching actions. This section presents the metaphorical statement approach and section 3.8.2.2 presents the speech metaphor analysis approach.

In the field of explicit metaphorical statements research, metaphors have been used to investigate the images of how teachers view themselves and their learners in the classroom (conceptions of teaching and learning) (Coffey & Atkinson,
1996; Gurney, 1995) images that teachers have of themselves in fulfilling their roles (Berliner, 1990); and the images of personal practical knowledge (Ritchie & Russell, 1991). The underlying themes in the utilisation of metaphors in these areas of research were based on the assumptions that "images lead to metaphors"; "metaphors provide a careful means for clustering images"; and "images are metaphorically embedded" (Bullough, 1991: 200). Ritchie and Russell (1991) also claim that images are expressed as metaphors and that these metaphors make the images (embedded within the metaphors) graphic and visible. The relationship between metaphors and images is expressed clearly by Calderhead and Robson (1991) as follows:

In fact being able to recall images and to adopt and manipulate these images in reflecting about action in a particular context is possibly an important aspect of the task of teaching... Images, whether representations or reconstructions, provide us with an indicator of teachers' knowledge attributable to different training experiences and the relationship between knowledge and observed practice. (p. 3)

Thus, metaphors can shed light on the images that teachers capture and encapsulate and refer to in the course of their teaching.

Coffey and Atkinson (1996), Gurney (1995) and Miller and Fredericks (1988) have provided much support for the use of metaphorical statements. In a study conducted with preservice teachers' metaphorical statements of the teaching and learning process, Gurney demonstrated that metaphorical statements could be a device in the envisioning of teachers' conceptions of teaching. This, he suggested, could be done by analysing metaphorical statements for themes and moods. Miller and Fredericks (1988), in a study involving 25 students in a sociology of education class, had also demonstrated that metaphorical statements helped to "reflect and structure individual experience" (p. 263) and claimed that metaphorical statements were viable as a "rich source of qualitative data" (p. 269). Coffey and Atkinson (1996) contend that the knowledge encapsulated within
metaphorical statements may be the knowledge that structures and enables working actions of individuals.

On a final note, Dickmeyer (1989) has suggested that metaphors can depict an oversimplified view of the phenomenon under study. In this study such oversimplification is viewed as a “virtue” following the convention of Bullough (1991: 44). It is acknowledged that the simplification would enable the teachers to reflect on and analyse more easily their teaching with the integration of computer technology.

3.6.1.1 Data collection

Data for this part of the study was elicited by the second approach to use of metaphors; explicit metaphors generated in response to an instructional task. The data collection consisted of three steps. Firstly teachers were instructed to write down personally constructed metaphors (Munby 1987 in Ritchie, 1994) in the form of explicit metaphorical statements. This was followed by narratives (Tobin & Tippins, 1996) of teachers’ selected metaphorical statements. The last step of this data collection stage involved the teachers’ derivation of metaphors for “The teacher as...” (Berliner, 1990; Ritchie, 1994; Ritchie & Russell, 1991; Tobin, 1990a; Tobin, 1990b; Tobin, 1993; Tobin & LaMaster, 1995; Tobin & Tippins, 1996) from the narratives of their respective metaphorical statements.

3.6.1.2 Step I: Generation of written metaphors

The use of metaphorical statement approach followed the convention of Miller and Fredericks (1988), Gurney (1995) and Inbar (1991). The purpose of generating personal metaphors in this study was to capture and encapsulate participants’ teaching actions with computer technology in graphic and visible ways. Metaphorical statements were elicited during the five-month study The participants were asked:
Please write three or four metaphorical statements of your teaching process with computer technology

The purpose of writing more than one metaphorical statement was to prevent teachers from responding to the task by giving one-sided emphasis on selected aspects of the phenomenon under study (Inbar, 1991). In addition, Bullough (1991) cautioned that single metaphors would not suffice in capturing the phenomenon under study. All the metaphorical statements were collected and compiled by the researcher (Appendix F).

3.6.1.3 Step II: Derivation of narratives from metaphorical statements

The collected metaphorical statements were returned to the participants for corroboration. This step followed the convention of Tobin and Tippins (1996) and Inbar (1991). Participants were asked to select one metaphorical statement each that was representative of their teaching with computer technology from the metaphorical statements which they had written. The participants were then asked to read their respective chosen metaphorical statements and describe the metaphorical statements. The following phrase was used by the researcher to assist the participants in explaining their metaphorical statements.

Choose one metaphorical statement which is the most representative of your teaching with computer technology and please explain it in a few words.

The main purpose for this procedure was to make explicit the meaning underlying the chosen metaphorical statements rather then rely on the researcher's interpretation of the meanings. Aspin (1984) had stressed the need to use metaphors as a generative tool for educational discourse and not merely as “fixers or thought stoppers” (p. 34). In addition, Inbar cited two important justifications for the above step: first, teachers’ choice of a representative metaphor was made explicit, the “deeper meaning” (p. 25) that they had for the chosen metaphor; and second, teachers’ explanations served as connections between the tacit and the
explicit domains of their knowledge. Therefore, by exploring the narratives, a better perspective of the images of teaching and of teaching with computer technology were elicited.

3.6.1.4 Step III - Metaphors for “The teacher as...”

This stage involved the participants in reading their narratives three times and relating their narratives to the following phrase

Metaphors for “The teacher as....”

Responses were transcribed by the researcher and participants were asked to verify their metaphor by reading their narratives again and confirming their choice of metaphor for “The teacher as....”.

The purpose for this procedure was to allow participants to read their narratives in order to capture their own images of teaching with computer technology and encapsulate it into another metaphor. This step gave the participants an opportunity to reflect on their own practices, and look at the language they had assigned to their teaching actions (Briscoe, 1991). This was also a way for the participants to “re-vision” (Connelly and Clandinin, 1988: 77) their construction of metaphorical sentences, related narratives and contextualise the teaching actions into another metaphor, thereby structuring one’s teaching practices and making explicit personal practical knowledge.

Furthermore, by looking back at the construction of practice especially with computer technology, participants were reflecting back onto what they perceived as the “visual imagery” (Berliner, 1990: 85) embodying the requirements of their roles in the classroom. In addition “The teacher as...” metaphors could reveal the thoughts and perceptions that teachers’ have of themselves (Anderson, 1995). This process enabled the researcher to get a further set of coherent and consistent metaphors that alleviated the major concern of single metaphors not being enough
to describe the complexities of the teaching process integrating computer technology.

Thus, by eliciting a second set of metaphors from the participants’ own narratives, insights into participants’ images of teaching actions were explored. Table 4 illustrates the data collection steps depicted above. This table lists the data collection actions, instructions to participants in eliciting the data, and the nature of the data that data collection actions produced in Steps I, II, and III respectively.

### TABLE 4

Components of the data gathering process by steps of occurrence

<table>
<thead>
<tr>
<th>Data collection actions</th>
<th>Instructions that prompted actions</th>
<th>Data that actions produced</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Step I : Personally written metaphors</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Collection of metaphorical statements from teachers.</td>
<td>‘Please write three or four metaphors for your teaching process with computer technology”.</td>
<td>Teachers’ hand written metaphorical statements (Appendix F).</td>
</tr>
<tr>
<td><strong>Step II – Derivation of narratives</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Teachers’ select the most representative statement from their own set of metaphorical statements.</td>
<td>“Choose one metaphorical statement which is most representative of your teaching with computer technology and please explain in a few words.”</td>
<td>Audio recording and verbatim verbal transcript of participants’ explanations of their most representative metaphorical statement.</td>
</tr>
<tr>
<td><strong>Step III – Metaphors for “The teacher as…”</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Derivation of metaphor for “The teacher as…” from teachers’ own narratives.</td>
<td>“Please read the narrative for your representative metaphorical statement at least three times. Can you now complete the phrase “The teacher as…”</td>
<td>Audio recording and verbatim verbal transcript of teachers’ responses.</td>
</tr>
</tbody>
</table>
3.6.2 Classroom cases

Another source of data collected was classroom cases (Kagan, 1993). The classroom cases were narrative accounts of participants’ own classroom teaching and learning experiences integrating computer technology. These accounts were constructed by participants and collected by the researcher throughout the five-month study. The purpose of utilising classroom cases was twofold. First, it was hoped that classroom cases would reveal the coherent meaning systems and the underlying cognitive patterns. Second, to verify participants’ beliefs (collected from previous data sources) in relation to the actions described in the classroom cases. Following is a description of classroom cases as a “qualitative” source of data (Kagan, 1993: 703), and the description of how classroom cases were collected and how classroom cases were analysed.

3.6.2.1 Classroom cases as a qualitative method

Kagan (1993) describes classroom cases as

> a real or realistic classroom situation that incorporates all the facts needed to clarify and solve the target problem(s)...often include descriptions of participants’ thoughts and feelings as well as their behaviours...possesses sufficient detail and depth and represents an attempt to understand a situation in its full complexity. (p. 705)

Classroom cases are simply verbal or written constructions of classroom experiences. Classroom cases differ from case studies in a number of ways. Classroom cases are qualitative data while case studies are a type of research method. Second, classroom cases focus on the “whole population of cases” (Stakes, 1988 in Kagan, 1993), but in the case studies approach the focus is on one case only. Furthermore, the use of classroom cases as a qualitative data source enables the search for normative patterns with context specificity and generic attributes to be undertaken, whereas in case studies the key interest may or may
not be in the generalizable. Although they differ in a number of ways, classroom cases are similar to case studies in two ways. First, both are involved in the search for patterns. Second, they can also reveal the uniqueness of teaching practices.

According to Kagan (1993) classroom cases are used in three different ways in research literature with differing epistemological backgrounds. First as instructional materials in preservice courses, second, as raw data in research on teacher cognition and lastly as catalysts that can promote change among experienced teachers. In this study classroom cases were used as raw data in assessing participants’ cognition, the meaning systems and the patterns underlying these meaning systems, in relation to teaching and learning integrating computer technology.

Classroom cases are also examples of the narrative mode of events or series of events (Kagan, 1993). Two levels of differentiation occur when classroom cases are treated as narratives. First, at the simplest level, classroom cases encompass “actors, goals, actions, descriptions and intentions” (p. 709) that endow meaning to the event or series of events. Second, at the abstract level, the narrative mode is propounded as a distinct way of constructing reality, within a temporal dimension. This is a process by which human beings assign meaning to the events they experience.

Classroom cases are characterised by a number of features. First, they are highly personalised depictions of reality, depicting “mental models” (Kagan, 1993: 709) possessed by the narrator of the narrative, thereby, reflecting the assumptions, beliefs and meaning systems through which patterns underlying cognition are revealed. Kagan (1993) further suggests that classroom cases are “heuristic artefacts, high-inference indices of pedagogical thinking” (p.709) where normative as well as unique qualities of thought processes are revealed.

A number of researchers cite the importance of classroom cases in the narrative mode as being crucial in the understanding of teacher cognition, justifying
classroom cases as a legitimate qualitative source of data. Tirri, Husu, & Kansanen, (1999) citing Goffman, (1974) state that personal constructions of experiences are organised to reflect social events like teaching in a social context with an added emphasis on organisation of these social events and one’s role in these social events. Kagan (1993) citing Eisner (1991) has argued strongly that classroom cases constructed by teachers are highly qualitative in nature. The cases contain “the naturalistic, interpretative, expressive and attentive to the particular” accounts of classroom teaching actions (p.720). According to Kelchtermans and Vandenberghe (1994) “interview fragments” (p.57) that showcase participants’ teaching views and principles are supported, conveyed and clarified by the descriptions of the “complex interaction of the teacher …and environment” (p.57). The narrative form also legitimises and gives backing to the views and principles with “concrete practice experiences” (p.57). Kagan & Tippins, (1991) have clearly elaborated that how a teacher constructs classroom teaching actions could be reflective of the teacher’s pedagogical beliefs.

3.6.2.2 Method

Instead of asking participants to convey specific classroom cases at a certain interval of the study, questions to elicit classroom cases were threaded into semi-structured interviews, spread throughout the five-month study. Verbal responses to interview questions including, “Tell me a bit about how you use computer technology in the classroom. Can you give me some examples?” and “Think about a computer technology based lesson and a text-based lesson. Can you tell me some of the differences in students’ responses?” were questions that were normally asked whenever participants gave examples of their teaching integrating computer technology throughout the five month study.

3.7 The calendar of the research

The calendar of the research (Figure 8) followed the semester and term calendar of the school, which follows the Ministry of Education (Republic of Singapore) calendar
FIGURE 8

Calendar of Research
for school semesters and terms. One whole semester comprising the first two terms of 1999 was identified to carry out the study. This timeframe was agreed upon by the participants, as the second semester would be the time for exam preparations and revision for school exams and the GCE "O" level exams. Figure 8 shows the timeline for the research. Figure 8 shows how the methods of data gathering were conducted throughout the five months of the study (January to May 1999). Then Figure 8 shows when the AAR scale was administered to participants, when the five semi-structured interviews were conducted, and when the focus group interviews were conducted throughout the five months of the study. Figure 8 also shows the duration in which the data from classroom cases, participant observation and anecdotal data, and metaphorical statements were collected. This figure also shows that narratives and "The teacher as..." metaphors were elicited during April and May 1999.

Figure 8 not only presents the calendar of research, but also displays the diverse data sources gathered to provide evidence of participants' teaching and teaching activities. Data collection procedures involved data generated in four ways: by participants (metaphorical statements); by mutual researcher-participant reconstruction of meaning-in-action (narratives from metaphorical statements; "The teachers as..." metaphors from narratives; and classroom cases); by participants and researcher as a group (focus group interviews); and by the researcher (Attitudes About Reality scale; participant observations; semi-structured interviews). The researcher now describes how the data was analysed through a dialectical relationship between the articulated theoretical framework and data: Section 3.8.

3.8 Analysis as a public event

This section presents the analysis of the data that was collected for this study. The purpose of this chapter is to provide, for the reader, an analytical openness (Vanden Berg & Sleeger, 1996; Constas, 1992; Mishler, 1990). That is, the public inspection of how data was analysed - qualitative research has at times been
criticised for less than rich accounts of data analysis. This is done by presenting the analytical templates utilised in the study: the methods of analysis and analytical descriptors used to organise and interpret the data. Five sets of data were collected, (Section 3.4, 3.5 and 3.6). They were:

1. the scores for the Attitudes About Reality scale;
2. lesson transcripts;
3. semi-structured interview transcripts;
4. field notes and anecdotal data of participants' teaching actions integrating computer technology;
5. and narratives.

As discussed in Section 3.1.2, verbatim verbal data (lesson transcripts, semi-structured interviews, and anecdotal data) were to be analysed to reveal the open processes of interaction and deliberation that marked the construction of classroom meaning. That is, the cultural tools that mediated participant teaching actions integrating computer technology. This was done by the analysis of the language and metaphors present within the verbatim verbal data (Section 3.8.2). Narratives were also analysed to reveal the participants' construction of classroom meaning integrating computer technology (Section 3.8.3). Field notes were analysed to reveal the structure and forms of the activity structures which were operating as a result of participants' construction of classroom meaning (3.8.4). Section 3.8.5 describes the analysis of the focus group data. The instantiation of teachers' beliefs, beliefs that influence the cultural tools extant within the communities of practice and the applicability of cultural tools that result from participants as mediators, were analysed through the semi-structured interviews, participant observations and narratives resulting from the study of the phenomenon under investigation (Section 3.8.6). Analysis of the quantitative data is provided first (Section 3.8.1) and this is followed by the description pertaining to the analysis of qualitative data. All the analysis was done within a dialectical relationship between data and the theoretical framework of the study.
3.8.1 Analysis: Attitudes About Reality scale

The Attitudes About Reality scale (AAR scale) was administered at the beginning of the five-month study (refer to calendar of research, Figure 8). The score for each participant and the mean score were calculated. A scale with the continuum ranging from social constructionism to logical positivism was constructed and the scores of each participant were placed on the scale. Figure 9 shows the participants' individual scores relative to the social constructionist and logical positivist continuum. This figure shows that Angela, Ning, Sundari and Tan had scores that placed them on the social constructionist part of the AAR scale (left hand side of the scale) while Woo had a score that placed her at the midpoint between the social constructionist and logical positivist continuum. Angela had a score that placed her on the logical positivist part of the AAR scale (right hand side of the scale).

![Diagram showing participants' scores on the AAR scale]

**FIGURE 9**

Participants' individual scores obtained from the AAR scale

The score obtained by each participant was then compared to the score range that captured specific characteristics of social constructionists or logical positivists. These specific characteristics, 5 for social constructionist and 4 for logical positivist, are depicted in Table 5. For instance, Tan scored 98 points and that cohered with the social constructionist world-view (left-hand side of Table 5).
This enabled the researcher to deduce the orientations of the six participants' personal belief paradigms respectively.

**TABLE 5**

**Characteristics of Social Constructionist and Logical Positivist [adapted from Unger, Draper & Pendergrass (1986:71) and Robin & Harris (1998:27)]**

<table>
<thead>
<tr>
<th>Social Constructionist (Score range 28 to 111)</th>
<th>Logical Positivist (Score range 113 to 196)</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Believe in environmental causality for many social problems</td>
<td>• View the world from an internal or biological position rather than from a societal or environmental one.</td>
</tr>
<tr>
<td>• See control by factors outside oneself as a vital part of how society works</td>
<td>• Believe in individualistic rather than societal determination of power and status</td>
</tr>
<tr>
<td>• Less content with status quo</td>
<td>• Generally accept status quo</td>
</tr>
<tr>
<td>• Less likely to view negatively individual efforts toward social change</td>
<td>• Believe in an individualistic rather than a societal assignment of status and power</td>
</tr>
<tr>
<td>• Not to be convinced that meritocracy works in science as well as in other aspects of society</td>
<td></td>
</tr>
</tbody>
</table>

**3.8.2 Analysis of verbatim verbal data**

Participants' classroom discourse and semi-structured interviews were audio-taped, transcribed and then transferred to the text analysis computer program “Ethnograph V.5.0” to assist in organisation and sorting stages of the analysis. As stated in the theoretical framework, participants’ language, including metaphorical language, could serve as the templates through which their construction of classroom meaning could be deduced. That is, the mindset and the open processes of interaction and deliberation that uphold the culture building process resulting in
the negotiations for classroom teaching actions. Thus, this section of the analysis dealt with the language and metaphoric language within the semi-structured interviews and the lesson transcripts. This analysis consisted of three stages. In the first stage transcripts from each interview were used to develop concept maps (Peterman, 1991) (Section 3.8.2.1). This was done concurrently with the analysis of natural metaphoric language present in verbatim verbal data (lesson transcripts, semi-structured interview transcripts and narratives) (Section 3.8.2.2). Section 3.8.2.3 covers the analysis aspects of classroom discourse.

3.8.2.1 Analysis using concept maps

The use of concept maps enabled the researcher to focus deliberately onto what Scheurich (1995: 240) refers to as “complex ambiguities of language, communication and interpretation”. This form of analysis is clearly supported by the relevant literature. Freeman (1991) characterises participant interviews serving a “cognitive function” (p.454) whereby the interviews organise and articulate teachers’ thinking about teaching actions. Interpreted teaching actions are then communicated and expressed as language of practice (Johnston, 1992), thus providing a comprehensive picture of teaching practices.

Miles and Huberman (1984b) eloquently advocate this approach towards the analysis of participants’ language, communication and interpretation.

Our experience tells us that narrative text alone is an extremely weak and cumbersome form of display. It is hard on analysts, because it is dispersed, spread out over many pages and is hard to look at; it is sequential rather than simultaneous, making it difficult to look at two or three variables at once; it is usually only vaguely ordered; and it can get monotonous and overloading (p. 9).

Nielsen (1995) suggests a solution to the problem by stating that relationships between “units, variables, values and context” (p.6) have to be established. From
such a standpoint it was recognised that analysis was more of a construction of reality than a mere discovery of it. The text in the interview transcripts was treated as participant's actual construction of reality and this construction was determined by the textual patterns and conventions that occurred naturally. Thus, the use of concept maps enabled the researcher to connect and state the relationship between “units, variables and context” and thereby to analyse the “communication and interpretation”.

Responses to interview questions were mapped to develop concept maps of participants’ understandings of the relationships of their teaching with the integration of computer technology. Participants’ words, phrases, nouns and descriptions were used as concepts together with the relations implied in the interview questions. This was done for each participant and for each individual interview. After this process one central concept map with “Teaching with computer technology” as a central concept was developed for each participant.

The extent and content of each concept map was dependent on participants’ verbal responses. Participants’ words were used to name and describe teaching, learning, activities and assessments – the purposes, processes and their relationships (Copeland, Birmingham, DeMeulle, D'Emidio-Caston & Natal, 1994) – integrating computer technology were represented as concepts on the individual concept maps. The verbs and adverbs from interview questions were represented as the relations among concepts and appeared in the line connecting the concepts. The main criteria was that concept maps had to show instances of teaching integrating computer technology, the purposes for this, the processes involved and the relationships to student learning. The individual concept maps served as concepts themselves and they were extrapolated to represent the entirety of participants’ responses to all the questions in the interview and the central concept of “Teaching with computer technology” together with the additional relations implicit in each interview. Thus, this central map allowed the researcher to develop a semantic network of the participants’ understandings of the relationship inherent in each interview, the communications and interpretations. The central
concept map was then used by the researcher to do a descriptive analysis to identify themes. These themes expressed participants' stated beliefs, and perceptions of teaching with computer technology.

3.8.2.2 Analysis of participants' natural metaphoric language

The natural metaphoric language of participants occurring within transcribed semi-structured interviews was collected and analysed. The intent of this analysis was to gain insights into participants' cognitive constructions of teaching integrating computer technology through their natural metaphoric language. The researcher wanted to gain a "conceptually coherent" (Collins and Green 1990: 76) set of metaphors and to subsequently derive the relationships between this set of metaphors and construct a "web of meaning" (p. 77) that illustrated the "constructed nature" (p. 77) of participants' teaching actions with computer technology.

The main impetus to utilise participants' natural metaphoric language was also based on:

1. the power of metaphor as a device for transforming qualitative aspects of teaching actions and experiences into language (natural metaphoric language) that "intimates, discloses, reveals, imports, suggests, implies" (Eisner, 1994: 223) these teaching actions and experiences (Bowers, 1990)
2. a product of this process of transformation promised to enable the researcher to "see" the qualitative aspects of teaching actions and experiences – "metaphor as seeing as" (Munby, 1990; Russell & Johnston, 1988)

Researchers have suggested that metaphors reflect how teachers perceive, describe and cope with puzzling situations, problem situations, new teaching approaches and alternative teaching approaches encountered in the classroom – teaching actions. This was investigated and demonstrated by Munby (1986; 1987); Munby and Russell (1990); Russell and Johnston (1988b) and Russell, Munby, Spafford,
and Johnston (1988a). A feature that is emphasised in the literature is that teaching events (including alternative and new teaching approaches, puzzling and problematic teaching situations) were perceived metaphorically by teachers. Based on this, the aforementioned researchers suggested that metaphors assisted in the understanding of how teachers framed and reframed teaching approaches and situations in conjunction with professional and practical knowledge. Russell and Johnston (1988b) in their study involving teachers' learning from experiences of teaching, conceded that metaphors were also reflective of "in action" or "intelligent practice" (p.1). Provenzo, McCloskey, Kottkamp and Cohn, (1989) in their study of speech metaphors have characterised metaphors as disclosing new meanings resulting from new experiences and situations in the classroom.

Munby (1986; 1990) in an examination and analysis of speech metaphors suggested that metaphors reflected how teachers conveyed their teaching roles in the realm of professionalism and of practicality. Provenzo et.al. (1989) and Munby (1990) in their use of metaphoric analysis of teachers' discourse propose that metaphors were useful linguistic tools that communicated teachers' self-understandings of what it means to be a teacher. What is apparent from the range of literature is the power of metaphor to enable one to see a phenomenon as the process of teachers' thinking beyond the perspective of teachers' thinking as "contents of the mind" (Freeman, 1996a: 733).

Based on the conceptual and experiential frameworks suggested in the aforementioned literature on metaphors and metaphor as a research methodology respectively, the following guidelines were subscribed to in this study, for the analysis of natural metaphoric language:

1. adoption of a clear and concise way to identify and label metaphoric language;
2. development of a classification of metaphors as used by the participants in this study;
3. determining if there were linguistic relationships between the metaphors used by participants across their verbatim verbal transcripts;
4. exploring the usefulness of this information for developing an unique account of each participant’s construction of teaching actions and experiences
5. generalising the unique accounts across participants and, where possible, to enable normative accounts; and
6. identify possible issues with the use of metaphoric language analysis as data and find plausible solutions to protect the validity of metaphoric language analysis findings.

The literature on metaphors also highlights a few issues and critiques in the use of metaphoric language as data and the analysis of metaphoric language. First, the literature states that teachers resort to metaphors to explain complex experiences (Kagan, 1990). “Structure is defined by the data themselves and findings can be highly inferential” (Kagan, 1990: 422). This is parsed by the understanding that metaphors are pervasive in everyday human thoughts, actions and conceptual systems (Lakoff & Johnson, 1980).

Second, it is stated that movement and spatial metaphorical figures are predominant in teachers’ thoughts of teaching actions (Kagan, 1990). Teachers’ metaphors should convey relationships to student outcomes (Kagan, 1990). Black, (1955) in Holyoak & Thagard (1995) contends that the relationship between teachers’ movement and spatial metaphors may link to student outcomes once the context in which the metaphors are prominent is taken note.

Third, polysemy - property of words in natural language having more than one meaning is cited as a major hindrance in the analysis of metaphoric language. This tends to typify metaphors as lacking little or no fine structures; giving the impression of metaphors having multitude of beliefs resulting in the incorporation of multiple and varied interpretations (Shotter, 1992 in Roth, 1993). Shotter (1995) claims that “metaphors act to shape and specify relations between humans and their circumstances, thus to further shape and specify themselves” and thus analysis of metaphors needs to be done with participants who generate these
metaphors in the first place. That is, to gain a coherent and conceptual understanding of that metaphor.

Fourth, different metaphorical figures may be present under different times and circumstances in teachers discourse (Munby, 1986). This could result from an overburdened imagery (Bullough, 1991; Bullough & Stokes, 1994). This can be resolved by utilizing verbatim verbal transcripts recorded over a period of time with an emphasis on recurring and habitual metaphorical language (Munby, 1986).

Fifth, teachers' use of metaphors might be case of appropriation and legitimization to depict a desirable norm with no change in teaching actions or beliefs (Roth, 1993). Textual analysis has no standard procedure to alleviate or eliminate this appropriation. Analysis of teacher discourse itself follows no fixed procedure (Kagan, 1990) and this further makes this problem of appropriation inevitable. Munby (1986) suggests that researchers look for teachers' own elaboration of the metaphorical language in verbatim verbal transcripts (Munby, 1986) to resolve this problem.

On a final note, the researcher feels strongly that just having teachers' explanation of their metaphorical language and the identification of the context in which the metaphorical language occurs will not suffice. Together, with the aforementioned resolutions to the study and analysis of metaphorical language, the study and analysis of metaphorical language should be substantiated by prolonged and persistent classroom observations.

The analysis began with the identification of metaphorical language from the verbatim verbal transcripts of participants. The identification of the metaphorical language was based on the analytical approaches of Lakoff (1994); Lakoff and Johnson (1980) and Reddy (1979) as cited by Munby (1986; 1987). Metaphoric language and plausible suspect metaphorical language were identified and categorized under the types, ontological and orientational. Table 6 highlights the
categorical descriptions of metaphors, based on which participants’ metaphoric language were identified. Table 6 lists the characteristics of ontological metaphors and its subsets (commodity metaphors and conduit metaphors), and orientational metaphors. Metaphoric language and/or plausible suspect metaphoric language which did not fit any of the categorical descriptions of metaphors in Table 6 were categorized under a miscellaneous category. The categorization procedure was only an initial categorization of metaphoric language that enabled the researcher to identify the metaphoric language. Lists of metaphoric language were created for each participant (Appendix G). Once a metaphoric language was found in a transcript, the lines containing the metaphoric language above and below were copied and coded (Munby, 1986). The use of text analysis program Ethnograph V5.0, enabled the researcher to highlight the metaphoric language and the corresponding transcript lines above and below.

TABLE 6

Characteristics of Ontological and Orientational metaphors
[Lakoff, (1994); Lakoff & Johnson, (1980); Munby (1986; 1987)]

<table>
<thead>
<tr>
<th>Identification based on</th>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ontological metaphors</td>
<td>1. present concepts as objects</td>
</tr>
<tr>
<td></td>
<td>2. give concepts properties usually accorded to objects</td>
</tr>
<tr>
<td>Commodity metaphors</td>
<td>1. a subset of ontological metaphors</td>
</tr>
<tr>
<td></td>
<td>2. present concepts as an ontological metaphor that can be traded, exchanged, or passed among people</td>
</tr>
<tr>
<td>Conduit metaphors</td>
<td>Concept-exchange metaphor, concepts mapped onto commodity metaphors are transferred from one person to another along a conduit.</td>
</tr>
<tr>
<td>Orientational metaphors</td>
<td>Employ a direction or orientation to depict concepts that have no inherent directionality.</td>
</tr>
</tbody>
</table>
This was done to preserve the "communication goal" (Katz, 1996: 2; Munby, 1986) that the metaphoric language was conveying. This is because an analysis of decontextualised metaphoric language does not provide the ecological validity in which the metaphoric language was encountered and conveyed (Katz, 1996; Roth, 1993). Furthermore the context under which the natural metaphoric language was uttered could provide the reasons why participants used it to give a perspective for their communicative meanings. In addition this procedure enabled the researcher to identify the function of the metaphoric language in context (Munby, 1986) and to identify linguistic relationships between metaphoric language across the verbatim verbal transcripts.

From analysis of the list of natural metaphoric language and the context under which they appeared in the verbatim verbal transcripts, categories emerged and the metaphoric language and corresponding transcript lines were coded according to these categories. Categories enabled the researcher to identify emerging themes from the participants' use of natural metaphoric language. Using these lists, the rest of the verbatim verbal transcripts (lesson transcripts; anecdotal data transcripts, narratives) were analyzed to look for corresponding metaphoric language. For example, when metaphoric language were identified, the interview transcripts were thoroughly searched to find out if the participants had "elaborated the metaphor to accommodate the processes involved." (Munby, 1986: 198).

Once the interpretation surrounding this metaphoric language and its respective context was identified, the researcher verified this interpretation in a participative fashion with the participants. This provided participants the opportunities to review and modify the interpretation if necessary. After this phase, participants and researcher nominated a category to represent the interpretations.

By following this convention, the issues of polysemy (property of words in natural language having more than one meaning) (Provenzo, McCloskey, Kottkamp & Cohn, 1989; Shotter 1992 in Roth, 1993; Shotter, 1995) and appropriation of metaphors with no legitimisation of use were also resolved (Kagan, 1990;
Munby, 1986; Roth, 1993). Participants' own elaborations were used to pinpoint the conceptual coherence. Furthermore this interpretation was then triangulated with the interpretations arising from other verbatim verbal transcripts: narratives and focus group interviews. On a final note, actual classroom observations and the accompanying anecdotal data were used to further consolidate and corroborate the interpretations of metaphoric language and participants' conceptual mappings of them.

Finally, after the identification, nomination and interpretations of categories of metaphoric language, highlighting the construction of classroom meaning, had been categorised, they were quantified (Bryman, 1992; Heath, 2000; Jick, 1983; Saloman, 1991; Silverman, 1985) (Chapter 3:Section 3.1.6). This frequency was then expressed as a percentage of total frequency of all the metaphoric language identified and categorised. Table 7 illustrates this quantification process. Table 7, presents the frequencies of each category of metaphoric language (supporting, developing, equipping, visualising and lesson as a moving object) and the total frequency of these categories. It also lists the percentage of each category (supporting, developing, equipping, visualising and lesson as a moving object) in relation to the total frequency of these categories.

**TABLE 7**

<table>
<thead>
<tr>
<th>Categories</th>
<th>Frequency, according to source and percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Frequency</td>
</tr>
<tr>
<td>Supporting</td>
<td>304</td>
</tr>
<tr>
<td>Developing</td>
<td>250</td>
</tr>
<tr>
<td>Equipping</td>
<td>176</td>
</tr>
<tr>
<td>Visualising</td>
<td>151</td>
</tr>
<tr>
<td>Lesson as a moving object</td>
<td>268</td>
</tr>
<tr>
<td>Total</td>
<td>1149</td>
</tr>
</tbody>
</table>
The researcher adopted the convention stated by Mishler (1990) to justify the use of quantitative steps in relation to the analysis of metaphoric language:

...quantification...are not truth tests but methodic accounting procedures, and a researcher's documentation of their use is part of the rhetoric of a particular form of scientific life. (p. 436)

Furthermore, other researchers (Heath, 2000; Inbar, 1996; Silverman, 1985, 1993) claim that simple counting techniques give the reader a chance to gain a sense of flavour of the data as a whole. Also it gave the researcher the ability to test and revise his interpretations. The point being made here is that those countable data, in this case the number of metaphoric language in the categories identified by both the researcher and participants, were treated in this fashion. Silverman (1985) writes: "Simple methods of counting can deepen and extend qualitative analysis of linguistically structured realities" (p. 140) and this coheres with the adoption of quantitative scaling of metaphoric language in this study.

3.8.2.3 Analysis of classroom discourse

Unlike the previous two analysis strategies, this section deals with the language expressed by participants in actual classroom discourse. The analysis of classroom discourse followed the convention set by Palinscar (1998) and Wertsch and Toma (1995). First, all transcribed classroom discourse were analysed to see if they contained an effective context for teaching and learning and if they were communicative. The dialogic function of the classroom discourse was then analysed. In this analysis, participants' utterances, classroom discourse, were closely scrutinized together with the classroom actions that followed. This enabled the researcher to pinpoint the ways in which participants were mediating the integral parts of the classroom, including themselves and the computer technology, which than lead to potential educative events: students' conceptual change.
3.8.3 Analysis of the narratives

Narratives were chosen as data source because they had a “compelling power” (Gottidiener, 1993:664) to uncover participants’ theories (Smyth, 1992) goals, actions, intentions (Beattie, 1995; Carter, 1993; Connelly & Clandinin, 1986; 1987; 1990; Goffman, 1974 in Tirri, Husu & Kansanen, 1999), and the “evaluative statements and arguments” for teaching and learning actions (Jensen, 1986, p.101). encapsulated within temporal and logical features (Kagan, 1993; Reissman, 1993 in Coffey & Atkinson, 1996). These constructs were used to identify the open processes of interaction and deliberation that characterised the participants’ construction of classroom meaning integrating computer technology. These constructs enabled the researcher to identify the structure and strictures, the activity structures and how the participants mediated the computer technology to bring about teaching and learning. The following analysis of a participant’s narrative illustrates how this analysis was done.

Sometimes I just present a lesson using computer technology, just a small part of the lesson I have worksheets and exercises about it. It is quite structured. For the topic on dissolving I use the CD-ROM to show the models, to show visual pictures of how sodium chloride dissolves.

*Lesson objective*

Then after that they go onto write the equations. It is visual presentation, to show the meaning of dissolving, how the water works, how the water comes into the picture.

*Evaluative statement*

so it is very difficult to describe without animation...shows what happens and delivers commentaries so they are seeing the process and theory at the same time. I use that to develop an idea of how dissolving occurs. Well with the interactivity provided by the computer technology I can stop and explain or students join in asking questions.
Academic task/Action

Usually I make them predict what is going to happen next. You get their conceptions out. From there we move on, so that is sodium chloride dissolving, what about the rest like aluminium chloride? So they have the practice of writing that equation using visuals from dissolving sodium chloride to show how ionic solids dissolve.

(Anthony, Verification of coding interview, 02/04/99).

By using the basic narrative constructs (temporal, logical, goals, actions, intentions, evaluative statements and arguments) and the theoretical framework, a dialectical relationship was built to analyse the narratives, as shown in the aforementioned example. This also allowed for the interpretations to be tied directly to the data and enabled collaborative analysis to be undertaken.

3.8.4 Analysis of participant observation data

The field notes derived from participant observation were also analysed in a dialectical fashion against theoretical framework. The main purpose of this analysis was to deduce the microcosms or communities of practice that had developed through participants' construction of classroom meaning. As stated in Chapter 3: section 3.5.3 the sensitising framework oriented and highlighted the importance of: participant's movements in the classroom; student interest; general classroom tone; teacher actions; student actions; use of computer technology by teacher and/or students; and classroom physical structures (refer to Appendix B). Through the dialectical relationship between data obtained through this sensitising framework and theoretical framework, the researcher identified and labeled the phenomenon in terms of its basic components: academic tasks and social participation structures (activity structures). Next, patterns and relationships among the identified and labeled components were consolidated with participants' anecdotal data, and with participants themselves during member checking and focus group interviews. This enabled discernible patterns/inconsistencies/ambiguities to be deduced. Components arising from this stage were compared
and contrasted to further clarify/identify the categories resulting in theme formation and to capture the academic tasks and the social participation structures present when teaching and learning with the integration of computer technology.

3.8.5 Analysis of focus group interview data

The aim of the analysis of the focus group interview data was to discern the signs and symbols (Moallem, 1994) that were culturally patterned and were part of the meaning making or meaning systems of participants. Focus group interviews served as a social context to view findings from preliminary analysis of the verbatim verbal data, field notes and narratives. All the data were reviewed holistically – transcripts of audiotapes, and the summary reports – regularities, patterns, and themes were noted by the researcher. The inductive search for patterns was guided in large part by the way in which the findings were to be used. This analysis enabled the researcher to identify, corroborate and gain further insights into the findings that were culturally sanctioned: signs and symbols common to participants due to the institutional and cultural context they were situated in.

3.8.6 Analysis of beliefs

The semi-structured interviews were the method of choice for ascertaining participants’ beliefs, especially Interview 3 (Appendix D). This interview followed the convention of Kagan and Tippins (1991) in deriving participants’ beliefs. Together with this convention and the historical issues in studying and analysing teachers’ beliefs (Section 3.1.2), participants’ beliefs were put through an analysis sieve. This analysis sieve consisted of three simultaneous levels. Relationships were obtained between participants’ stated beliefs and self-reported accounts of teaching actions integrating computer technology (semi-structured interviews, focus group interviews, and narratives). For instance the propositional statements found in narratives were used for this purpose (Clark & Peterson, 1986; Oliver & Koballa, 1992 in Lumpe, Honey & Czerniak, 1998; Tobin &
Tippins, 1996). At the same time, relationships were obtained between participants' stated beliefs and observed classroom teaching actions: this reflected some modicum of relationships between what participants believed in and what they say they will do. Also at the same time the relationships were considered between self-reported accounts of teaching and observed actions. This helped the researcher not only to verify participants stated beliefs but also to build up the knowledge domain of participants' beliefs from the knowledge expressed in teaching actions, narratives and semi-structured interviews.

3.9. Summary of the methodology and analysis

The choice of a qualitative context of inquiry enabled the researcher to collect data that was pertinent to the investigation of the phenomenon under study and the theoretical framework articulated to explain it. This qualitative context of inquiry was oriented to a multimethod approach where, semi-structured interviews, participant observations and narratives captured participants' descriptions and interpretations of their construction of classroom meaning integrating computer technology. Furthermore, the use of focus group interviews substantiated these descriptions and interpretations within the larger context: the cultural context in which participants were situated. Table 8 summarizes how the data were generated, collected and analyzed in this study. This table, lists what were the data, the nature of the data (quantitative, anthropological or narratives), how the data were gathered, how the data were analysed (declarative, participatory or, linear and iterative) and interpreted (guided by the theoretical framework).

The choice of a predominantly qualitative context of inquiry raises issues about the trustworthiness and authenticity of this study that are commonly raised for any qualitative research. Therefore, before going to the next chapter, findings, a few words about the trustworthiness and authenticity of qualitative research to bring forth the general framework of ideas about validity within this study.
### TABLE 8

Summary of data collection and analysis

<table>
<thead>
<tr>
<th>Data source</th>
<th>How the data was gathered</th>
<th>How the data was analysed</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Relation of researcher to data</td>
<td>Nature of gathering data</td>
</tr>
<tr>
<td>------------------------------------</td>
<td>----------------------------</td>
<td>----------------------------</td>
</tr>
<tr>
<td><strong>Quantitative</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Attitudes About Reality scale</td>
<td>Declarative</td>
<td>Ex post facto</td>
</tr>
<tr>
<td><strong>Anthropological traditions</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Field notes</td>
<td>Declarative</td>
<td>Real-time</td>
</tr>
<tr>
<td>Interviews</td>
<td>Declarative</td>
<td>Ex post facto</td>
</tr>
<tr>
<td>Focus group interviews</td>
<td>Collaborative</td>
<td>Ex post facto</td>
</tr>
<tr>
<td><strong>Narratives</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Metaphorical statements</td>
<td>Self-generated</td>
<td>Real-time</td>
</tr>
<tr>
<td>Metaphorical narratives</td>
<td>Collaborative</td>
<td>Ex post facto</td>
</tr>
<tr>
<td>“The teacher as…” metaphor</td>
<td>Collaborative*</td>
<td>Ex post facto</td>
</tr>
<tr>
<td>Classroom cases</td>
<td>Collaborative*</td>
<td>Ex post facto</td>
</tr>
</tbody>
</table>

Key:
- Collaborative: Participants and researcher as a group generate data
- Collaborative*: Mutual researcher-participants reconstruction of data
- Declarative: Researcher documents participants thinking and/or actions
- Declarative*: Researcher handles the analysis with little or no further input from the teacher
- Iterative: Researcher breaks down the data, assembles the meanings and then returns to the data to verify and extend these meanings and so forth
- Linear: Researcher progressively breaks down the data, analyses and arrives at the findings
- Participatory: Researcher includes participants as co-analysts of data
3.10 Validity

This section gives an account of the issues related to the utilisation of a predominantly qualitative approach and the battle for validity (trustworthiness and authenticity) that consumes any qualitative approach to data collection, analysis, interpretations and conclusions.

3.10.1 Battling to achieve validity in qualitative research: ensuring trustworthiness (rigor) and allocating authenticity (quality).

The choice of a qualitative context of inquiry raises important issues about the validity of the study - aspects that seem to haunt and taunt any qualitative study. Since the qualitative paradigm adopted in this study emphasised the intentionalistic force to capture and encapsulate the intentions and meanings akin to the situational contexts and subjectivities of humans the claim for objectivity became an issue. A rational way to look at validity of the findings from this study could have shaped the beginning of this section in a statement like: Given the “minefield of inaccurate interpretation” (Krahn, Hohn & Kime, 1995:207) that might result from a qualitative methodology prior elimination of threats had to be planned”. However this portrays the existence of some absolute truth to be compared with or subjugating to satisfy some advocacy-laced protocol. Furthermore, this pertains to notions of structural validity where a correct and safe proof design circumscribed by standard/generalised rules, abstract rules and methods of validation produces definite conclusions (Behrens & Smith, 1996): the application of a “formal algorithm” (Mishler, 1990: 418).

Amongst the literature on validity in educational research a plethora of legitimisation of knowledge discourses (Lather, 1993: 673) are cited: naturalistic and constructivist (Lincoln & Guba, 1985; Guba & Lincoln, 1989; Miles & Huberman, 1984a; 1984b); discourse theory (Mishler, 1990); ethnographic authority (Clifford, 1983; Gordon, 1990); poststructuralism (Kvale, 1989); realist typology (Maxwell, 1992); “as an incitement to discourse” (Lather, 1993);
“enlightened eye approach” (Eisner, 1991b); postpositivist/epistemological approach (Hammersly, 1990; Brown & McIntyre, 1993; Fernsternacher, 1994) and multimethod approaches (Brannen, 1992; Brewer & Hunter, 1989; Moallem, 1994; Patton, 1990; Yinger, 1986). These seem to overwhelmingly deal with the issue of judging the rigor of naturalistic inquiry by specifically looking at the process of the inquiry or inference process of the inquiry or the end product of the inquiry or through the use of multimethod approach to inquiry: assessing trustworthiness across varying contexts of the inquiry. While other researchers have simply stated that “... concern for paradigmatic congruence goes beyond methodological proficiency (trustworthiness) and involves an approach to the research (authenticity)” - quality (Manning, 1997: 95; Lincoln, 1995). This refers to the ability of a reflexive researcher to be aware of the mutually evolving contexts of the study as it goes through the contexts of data collection, inference and conclusions and thereby bring about meaningfulness, usefulness and social change (Manning, 1997) to the study within these contexts. The validity of knowledge is not only an inherent property of methodological proficiency but also relates to relational context between researcher and participants that simultaneously parallels the mutually evolving contexts of the study. The researcher and participants’ positions, voices, critical subjectivities, reciprocities and shared meanings in relation to the data collection, data analysis and interpretations had to be considered (Lincoln, 1995).

This re-articulation of validity cohered with the researcher’s stand on using a predominantly qualitative method which was inductive and focussed on comprehending particulars rather than generalising to universals. That is, human phenomenon is threaded together by intentions, meanings, situations, structured subjectivities that are riven, extenuated and accreted through human beings vacillating knowledge and emotions. It also cohered with Maxwell’s (1992) contention that “any account of validity in qualitative research, in order to be productive, should begin with an understanding of how qualitative researchers think about validity” (p. 282). Therefore, the researcher’s working definition of validity in this study is stated as a progressive process where the relational context
between researcher and participants, within the mutually evolving context of the study, enables the researcher and participants to make reflexive judgements of the methodological proficiencies, experiences and interpretations that arise out of the interactions between researcher and participants as they investigate the phenomenon (refer to Table 10).

This definition re-articulated the researcher's senses away from validity as a perfunctory exercise to one that materialised in accordance with the researcher's perceptions and/or participants' responses. That is, data collection and preliminary analysis in due course or at “different moments”: (Republic of Singapore - field site - January 1999 to June 1999); data reduction and analysis (New Zealand June 1999 to June 2000); data display, interpretations and conclusion drawing/verification (June 2000 to August 2000).

Thus, this set the tone of validity within this study but this had to transcend, and materialise within the issues of trustworthiness and authenticity. The discussion now shifts to these perspectives.

3.10.2 Trustworthiness: triangulation, addition, negative case analysis and the multimethod approach

Trustworthiness, from the review of literature was marked by a list of procedures aided by a considerable number of prescriptive literature: trustworthiness protocols themselves seemed sceptical! (Hammersley, 1990; Martin & Sugarman, 1993; Phillips, 1987). On the other hand, trustworthiness is manifested as techniques applicable across the contexts of the research and as a result of applying multiple methods (qualitative and quantitative or different qualitative/quantitative approaches) within the study of a single phenomenon. Table 9 represents the researcher’s articulation of trustworthiness from an analysis of the literature pertaining to trustworthiness. Table 9 lists how the issue of trustworthiness is conceived in different ways focussing at different contexts of a study. Trustworthiness techniques that apply to each of the different contexts are
**TABLE 9**

**Researcher's articulation of trustworthiness: An analysis of the literature on trustworthiness**

<table>
<thead>
<tr>
<th>Prior to study</th>
<th>Procedures of gathering and coding data</th>
<th>Inference process</th>
<th>End product</th>
</tr>
</thead>
</table>

**Trustworthiness Techniques**

| Correct design: predetermined rules and techniques | Use of addition, negative case analysis, triangulation (sources, methods, investigators); peer debriefing; member check, thick description; respondent validation. Used during data collection, analysis and interpretation: methodological proficiency | Use of addition, negative case analysis, triangulation (of sources); peer debriefing; member check, and/or respondent validation. Used in regards to the different levels of evidence gathering when deriving claims from the data. | Use of structural corroboration; referential adequacy and multiplicative replication. Used to see gestalt of classrooms/phenomenon. |

<table>
<thead>
<tr>
<th>Advantage</th>
<th>Primacy of method</th>
<th>Primacy of judgements/claims over methods</th>
</tr>
</thead>
<tbody>
<tr>
<td>Caveats</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Preoccupation with methods: methodological (Martin &amp; Sugarman, 1993). Mimics quantitative research especially in relation to validity and reliability (Heap, 1995; Lincoln, 1995; Manning, 1997).</td>
<td>Reflects a postpositivist perspective (Seale, 1999).</td>
<td>Coherence not correlated to truth. That is, seeing features of classroom does not make it true, only consensual validation (Phillips, 1987).</td>
</tr>
</tbody>
</table>
also listed. Table 9 includes the advantages that trustworthiness techniques proffer on these different contexts of a study. Table 9 also lists the caveats that are prevalent when applying these trustworthiness techniques. It is obvious that trustworthiness at each context of any study has an entourage of techniques (addition, negative case analysis, triangulation of data sources, methods and investigators, peer debriefing, member checks, thick description, respondent validation, prolonged engagement and persistent observation; structural corroboration, referential adequacy and multiplicative replication) and is decorated with caveats. Furthermore it is also obvious that it is beyond any study to physically and/or systematically (and/or financially) apply every single technique. The techniques were kept in mind by the researcher as “guidelines” (Seale, 1999a: 471) to be applied when the context suggested: during the process of data collection and analysis; the inference process and/or the end product based on the researcher’s judgements and reflexivity.

Table 10 shows the various stages of this study; and it captures where and how techniques were utilised to ensure trustworthiness. That is, Table 10 lists where and how trustworthiness techniques like triangulation, tracking of negative cases and addition were utilised within the different contexts of the study. The attempts at trustworthiness was not a simple application of techniques by blindly accepting the epistemologies behind the techniques, instead the application involved a review of the literature to tighten the researcher’s skilful and epistemological application of techniques as well. Each of the techniques, utilised in this study, is briefly discussed to demonstrate their epistemological position within the study.

**Triangulation**

Triangulation in this study was a technique to access different versions of the phenomenon: to detect untoward situational influences (Flick, 1992; Hammersley & Atkins, 1983 in Fielding & Fielding, 1986; Seale, 1999a; 1999b); and to explain how accounts and actions in one setting are influenced and constrained by those in
TABLE 10
Trustworthiness at different contexts of this study
Multimethod approach applied throughout the contexts of study

<table>
<thead>
<tr>
<th>Procedures of gathering and coding data</th>
<th>Inference process</th>
<th>End product</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Contexts of the study</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Triangulation of:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Data sources</td>
<td>Evidence, claims, explanations, evaluations, predictions and codes with data from Observation, Interviews and Narratives from Metaphorical Statements, participants themselves and participants and researcher as a group.</td>
<td>Use of qualitative models within a image/text balance context.</td>
</tr>
<tr>
<td>(Observation, Interviews and Narratives from Metaphorical Statements): Triangulation within methods Different contexts, times and places</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Tracking of negative cases</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tracking of negative cases based on the criteria of participants’ identification, perception and explanation of negative case</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>By addition</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Repeated instances of similar actions and verbal accounts: continuity across data, time, contexts, participant, and participants and researcher as a group.</td>
<td></td>
<td></td>
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</tbody>
</table>
another (Dingwall, 1997). Also, triangulation was formulated to help increase the scope and depth of findings through convergence, inconsistency and contradiction (Bloor, 1997; Mathison, 1988; Seale, 1999a; 1999b). These qualitative data sources were independent data sources that captured the phenomenon under study in a concurrent fashion whereby various viewpoints of the phenomenon could be accessed.

**Addition**

What counted as evidence, for example, the coherence of cultural tools (supporting, developing, visualising, and equipping), emerging out of the analysis of language and metaphoric language from lesson transcripts, could be seen often in classroom observations, mentioned in semi-structured interviews, focus group interviews, or narratives. One instance was not sufficient, repeated instances of these cultural tools in verbatim verbal transcripts or as observed in classroom teaching actions augmented the epistemic status of these evidences. Plus the continuity of these cultural tools expressed as interpretations of how participants constructed classroom meaning integrating computer technology across temporal and spatial contexts further strengthened these evidences.

**Negative case analysis**

Negative case analysis in this study was utilised as the tracking for the existence or non-existence of aberrations that seemed to locate participants outside the claims and conclusions made (Seale, 1999b; Silverman, 1985). This led to the identification of alternative realities (Patton, 1990; Seale, 1999b); modification of ideas and prevented a lapse into unconfident solipsism (Seale, 1999b; Silverman, 1985). The existence of negative cases was based on the criteria of not only locating them but also on whether these identified negative cases were explainable from the participants' viewpoint.
Multimethod approach to trustworthiness

A multimethod approach utilising, different anthropological traditions (Jacob, 1987; 1988; 1989) (section 3.1.3) and; other genres of research like narratives (section 3.1.3) provided access to the ecology of the classroom context. Since participants’ construction of classroom meaning, when integrating computer technology into teaching, was the aim of this study, this construction of classroom meaning was approached from research methods that provided access to three different structures: academic task structure; social participation structure (Erickson, 1982) and the cognitive structure of the participants. This cohered with Yinger’s (1986) convention for investigating teaching as an interactional construct and with the researcher’s articulation for the need to examine both participants’ cognition and the associated actions: open process of interaction and deliberation leading to a community of practice.

The multimethod approach was used to gain accounts and additional insights of the same situation to deepen the understanding of the phenomenon. For example, the researcher used qualitative methods of participant observation, individual and focus group interviews, to investigate the phenomenon under investigation while participants concurrently investigated the same phenomenon using qualitative methods like metaphorical statements. The multimethod approach was not a naïve task of using several methods alongside one another to achieve proliferation/aggregation of perspectives on a phenomenon. This extenuates the chances of error, propounds and warrants the view that proliferation and aggregation of data result in a complete/holistic account of the phenomenon (Fielding & Fielding, 1986).

3.10.3 Authenticity: Member checking, qualitative models and peer debriefing

So far the discussion has been on trustworthiness as a parallel to the empiricist concepts of internal and external validity, reliability and objectivity which
addressed if the research process had been carried out correctly (Manning, 1997). The adoption of authenticity on the other hand, enabled the researcher to set in motion a democratic and humanistic perspective to the study as a crucial counterpart to trustworthiness in the battle for validity. Member checking was used as a technique to uphold authenticity within the study. This occurred during data collection and after data collection. Other techniques like the use of qualitative models and peer debriefing were also applied.

**Member checking**

During the data collection period member checks were used consistently (refer to calendar of research section 3.7) to check for intentionality and errors made by the researcher or participants (Guba & Lincoln, 1989; Munby, 1982; Patton, 1990; Tobin & McRobbie, 1997). This allowed the reviewing of data and interpretations with participants for elaboration rather than the mere reliance on corroboration. For example, participants were provided with copies of the all field notes, transcripts, codes, coding systems, concept maps and interpretations to which participants responded. This helped to alleviate any variance of interpretation between researcher and participants. Any variance was examined with the participants, their corrections and amplifications were taken into consideration, to gain further insights. Member checking also enabled the researcher's choice of participants' quotations to represent and support major themes be acknowledged and subject to further inquiry. Thus, member checking helped to shape this choice of quotations through interaction with the participants. This prevented researcher bias and the use of the researcher's personal intuitive theories to embellish the interpretations (Briscoe, 1996; Pope & Denicolo, 1986) and paved the way for further participant inputs.

**Qualitative models for authenticity**

The researcher also used qualitative models (Radnofsky, 1996) as a member checking technique the purpose of which was to provide an image/text balance
(Harper, 1994; Radnofsky, 1996); and to transcend the linguistic barricades of communication to enable other qualitative forms of interaction between researcher, interpretations and participants. For example, the qualitative models allowed participants to draw/redraw the qualitative models based on reflexivity and reinterpretation: a reflective tool that allowed participants to freely move from a one dimensional perspective to a multidimensional perspective of their own accounts. That is, linguistically based analysis was coupled with cognitive instruments of envisioning information and acting on it: drawing/redrawing. Furthermore it exposed and echoed the meanings of the phenomenon in the researcher’s mind to be laid out for the participants. The premise is that this form of communication depicted the “things, places and people” and made the inherent relationships much clearer to the participants (Eisner, 1997: 5). Participants’ own verbal verbatim comments framed these pictures, diagrams and maps, thus illuminating participants’ empathy. The researcher was aware that qualitative models might succumb to the Roscharch syndrome (Eisner, 1997): models as precision instruments depicting classroom situations. Thus, care was taken to always frame these qualitative models within a text/image balance.

Authenticity was not reduced to nor equated with peer-debriefing nor respondent validation/member endorsement of findings. The researcher understood that corroboration was too problematic since the context in which data were gathered was different from that of contexts in which member checking occurred (Bloor, 1997, Emerson, 1981; Emerson & Pollner, 1988): circumstances that shape initial participant accounts may have been problematized by frailties of methodologies and circumstances. During member checking, interpretation of claims may be problematized by frailties of methodologies and circumstances at that point in time.

Peer-debriefing

The period of data display, interpretations and conclusion drawing/verification was marked by peer debriefing (NECC 2000 conference) (Subramaniam, 2000)
that allowed "alternative voices" to "judge the openness, engagement, and problematic nature" (Lincoln, 1995: 283) of the data display, interpretation and conclusion drawing/verification.

In summation, the researcher's task to achieve validity involved approaches that capitalised on methodological proficiencies (trustworthiness techniques) and a relational context (authenticity) as the study evolved from data gathering, analysis and interpretations.

3.11 Validity and the limitations of this study

This section reviews the study undertaken so far as a research process by advancing and building upon some thoughts that were introduced earlier in section 3.10 about validity in qualitative research: ensuring trustworthiness and allocating authenticity. It appears here because the reader must be re-informed about the strengths and the limitations of the findings and claims that this discussion is heading towards in chapter 4, 5, and 6 respectively. The researcher is aware that validity is relative to purposes and circumstances of the study and that data cannot themselves be valid or invalid. Furthermore validity is not an inherent property of a particular method (Maxwell, 1992). Although member checking, throughout data collection and after data collection, was practised, the researcher did not rely on respondent validation as a sole means of final interpretations. As stated in Section 3.2.6, 'intersubjective validation' (Salnar, 1986 in Kvale, 1989:86) was not the aim of the researcher. Building on this perspective a number of additional resources from the theoretical and pragmatic viewpoints support this aim of the researcher.

Theoretically, a number of researchers (Bloor, 1997; Dingwall, 1997; Emerson, 1981; Emerson & Pollner, 1988) claim that respondent validation lapses into a quagmire of validation processes. First, respondent validation might reflect the interpretations of a sympathetic observer. Second, it might result in mutual consent and endorsing of interpretations rather than an elaboration or reflexive
critique of interpretations. As stated in Section 3.10.3 it may be that the context, in which respondent validation or member checking occurred, might be different from the context in which data were gathered. It could also be the case that participants' interpretations changed over time.

The discussion now shifts to the other means of corroboration, which the researcher undertook in order to strengthen the epistemic claims made in Chapter 4, 5, and 6. Rather than merely stating that different means used to ensure validity in this qualitative study, Figure 10 captures the validation process that was taking place throughout the mutually evolving contexts of this study. Figure 10 shows how the claims made in chapter 4, 5, and 6 were not only substantiated by the researcher’s analysis of the corpus of data (outsider perspective); they were also substantiated through participants (insider perspectives) and through groups - researcher and participant (interactive perspectives).

![Figure 10]

**FIGURE 10**

**Validity within a relational context**

It is obvious that the triangulation metaphor is used to portray this validation process. This implies that three different observers were "looking at" the same phenomenon from three vantage-points: researcher, participants and researcher and participants as a group. Each point of the triangle stands in a unique
epistemological position with respect to the phenomenon under study. This perspective gave the researcher opportunities to compare one account with accounts from other standpoints leading to the testing, revising, falsifying and elaborating the interpretations on the basis of more sufficient and relevant data. It is also obvious that this allowed the assessments of observations to see if they were representative of other behaviours or beliefs at the research site. This also gave a real sense of the range of behaviours and beliefs that were actually present: an opportunity to “test” emerging hypothesis by the active, systematic collection of further data. For example, in this study, researcher’s interpretations were triangulated with the metaphorical statements that were a result of participants themselves studying their classroom teaching actions with computer technology. Interpretations were also corroborated with the interpretations arising from the focus group interviews. This allowed not only the corroboration of interpretations but also the reformulation of interpretations in light of further insights and the tracking of negative cases. Furthermore, participants were empowered as co-researchers (narratives) and as researchers in their own right (metaphorical statements) and this allowed heterodoxy of voices and perceptions to be heard and interpreted in this study.

The use of observations gave the researcher no choice but to see and listen to what the phenomenon at hand was telling him. Furthermore, the use of critical incident techniques like, observer comment and the gathering of anecdotal data immediately following observations gave a more naturalistic evidence with higher ecological validity (Hofer & Pintrich, 1997). The researcher was aware that interviews afforded him the choice to pick up messages that the researcher hears and elicits (Dingwell, 1997). But this was avoided by presenting the researcher’s choice of participants’ quotes to the participants themselves during member checking to further elicit insights in reference to participants’ understanding of the theme that was supported by those quotes (Briscoe, 1996; Pope & Denicolo, 1986). Codes arising from the analysis were jointly analysed with participants (refer to section 3.8). This provided a particularity to the specific context that
participants were working in and it was also the least imperialistic, since participants were involved in nominating the codes (Constas, 1992).

Woo’s resistance to be observed presented a severe blow to the application of anthropological traditions like holistic ethnographic traditions, microethnographic traditions and cognitive anthropological traditions to her classroom teaching by the researcher. This limited the application of these qualitative traditions only to the interview phase and not the observation of the phenomenon at hand. But through the application of the multimethod approaches (metaphorical statements, narratives and interviews), the researcher was able to gain an assessment of Woo’s classroom practices. In further defence, these multiple data sources enabled triangulation, member checking and tracking of negative cases.

It must be noted that the findings from the Attitudes About Reality scale were not factored into the discussion chapter, Chapter 5. The participants’ beliefs arising from the analysis of qualitative data provided richer sources of interpretations than this scale.

On a final note, participants agreed that the researcher’s explanation of their construction of classroom meaning did represent an accurate portrait of their teaching actions in the particular context. This accuracy can be attributed to the fact that the researcher is an experienced science teacher, a former colleague in the same school, and one who shares similar cultural values. The researcher could serve as the best informant or cultural source (Wolcott, 1980) for this particular study.

In this study, the concluding claims are the researcher’s, built from the multiple voices, perceptions, insights and dialogic interactions that occurred as the study progressed throughout its multiple stages of data collection, analysis and member checking. The thesis now moves towards the findings of this study, chapter 4. The claims are presented in chapter 5 and 6.
Chapter 4

Findings

4.0 Introduction

Analysis of the data illuminated three crucial findings. First, the contexts in which the teaching actions integrating computer technology took place were revealed. Second, how participants constructed classroom meaning integrating computer technology was revealed: the negotiations for action, cognitive guides and structures and strictures. Finally, participants’ beliefs, which were influencing their construction of classroom meaning, were also made explicit. The researcher strongly felt that the first two sets of findings, the context and participants’ construction of classroom meaning could be encapsulated as communities of practice.

The findings of this study are presented in four sections. Section 4.1 makes explicit the profiles of the participants who were involved in this study. Section 4.2 presents the cultural context in which participants were located and the common goals that were present within this context. Section 4.3 and 4.4 deal with communities of practices that encapsulate the participants’ context and construction of classroom meaning integrating computer technology.

4.1 Profiles of the participants

This profile captures a number of crucial components of participants’ views of teaching and learning in general and within the context of teaching and learning integrating computer technology. The purpose is to bring about “consciousness raising” (Bruner, 1996: 6) of the main characters in this study. That is, to provide
a background of the humans who are intimately involved in the meaning making process that this study is concerned with.

This profile includes four major components, as expressed by participants throughout the five month study: their philosophy of teaching; their views of the subject they were teaching; how they view students' learning; and the pedagogical practices that follow. This profile was built up from the semi-structured interviews, metaphorical statements, narratives and classroom observations. These profiles were also built up in a relational context with the participants. Participants were involved in the process of writing up the profile themselves. This profile does not include a personal biography of participants as suggested by a number of researchers (Goodson, & Mangan, 1995; 1996; Kelchtermans & Vandenberghhe, 1994; Woods, 1981). Since the study was conducted in an Asian context, this proved difficult, as personal biographies were considered to be intrusions into the personal lives of participants. A profile of each individual participant is presented next.

**Sundari**

Sundari's philosophy of teaching centred on her view of being a modern teacher versatile in her teaching actions. This included the ability to incorporate new skills of teaching and ways of bringing about conceptual change in students. Sundari states:

The most important thing I can give as a teacher to students are the skills to learn... skills you teach to process knowledge, and to acquire knowledge; these are more important in a student... rewilding their concepts by presenting situations where their concepts become explicit...

In other words what I am saying is that it clears misconception, because when you show a process with clarity they tend to understand better. In teaching, we, the students and me, reconnect... clear misconceptions...

(Interview 3, 25/03/99).
Sundari sees teaching as an active effort where there is a conscious involvement on part of the teacher and students. Sundari views scientific knowledge that she transmits as cultural templates in her classes as commodities. This view is not to be confused with static facts or figures. As Sundari states in her metaphorical statement: “Teaching is like re-wiring so that right connections take place in the minds of the pupils”. Thus, Sundari views knowledge construction as processes where her teaching acts as commodities that she and her students use to bring about conceptual change. This also revealed her view about how she thought about her students and students’ minds. She did not view science teaching as a process of filling students with facts and figures. Sundari remarked that her use of computer technology centred on its ability to bring about biology concepts “alive” (animation or simulations). But she strongly cautioned that it had to play a role in helping her and her students to move away from the misconceptions about biology. That is, it helped her to show students what their misconceptions are or to draw out their misconceptions.

Anthony

Anthony's philosophy of teaching and learning centred on his religious beliefs. He viewed teaching as a calling. That is, to build something meaningful with his pupils that they could use in their lives and in society. Thus, chemistry, the subject he taught, was seen as knowledge that was to be shared and built upon by the interaction between students and himself. Anthony expressed this as:

Well you need to get everyone to participate. You see if you are the captain of the ship, then you need to get everyone involved and get everyone to work together. No doubt the work comes from you but then the captain can delegate all duties what he wants others to do. He can delegate whatever duties but he must be in charge yet able to actually gather all of them together as one…

(Narrative, 08/05/99)
There seemed to be a heavy reliance on the social context in which chemistry teaching and learning occurred. Anthony explained that this was necessary as it allowed for rapport to be built up between his students and himself and brought about a joint effort in teaching and learning chemistry. This joint activity also opened up connections that exposed each other’s knowledge of chemistry. This provided an atmosphere to share with each other their conceptions of the topic. Anthony also explained that this allowed him to get to the ideas about chemistry held by his students and for him to set up tasks that could help them remedy their misconceptions. This, he said cohered with his view of teacher as captain and students as crew, both were on a journey to a common destination, but that journey involved co-operation between the two parties involved.

The use of computer technology in Anthony’s class was sanctioned by a number of boundaries. First, Anthony remarked that it should help in bringing about an atmosphere where students could examine and visualise their misconceptions and see chemistry content in action (simulation or animations of chemistry concepts like electron transfer). Second, its use had to bring about an atmosphere of shared ambience, something that Anthony felt brought about the rapport conducive for meaningful teaching and learning to occur.

**Ning**

Ning’s philosophy of teaching was intimately linked to her love for physics and teaching. Ning expressed physics teaching as:

... it is put together by observation that is made in our everyday life. The only way to make it meaningful in learning is to make that link to everyday life examples. To illustrate the physics principle as close to the students daily life experiences, that is the link. Something, that is more real life. Anything beyond that will be applied...where they have to do the extension.

(Narrative, 28/04/99).
To enable this teaching and learning to occur, physics teaching had to involve a lot of demonstrations and laboratory activities. She claimed that this enabled her and her students to make physics "alive". Students were not to be passive onlookers or mere note takers. Although she viewed that students had to keep notes, these notes had to come out of their own experiences in the classroom, where she and her students had engaged in activities that involved physics concepts.

Just like the preceding two participants, her teaching integrating computer technology involved a range and scope that captured its purpose and use in the classroom. She expressed this range as:

it must be different from the traditional type of teaching...I don't use it just because it is useful or is a requirement. It must allow me and my students to actively do physics... not just picking up information

(Interview 3, 25/03/99)

**Angela**

Angela, like Ning is also a physics teacher, but she also taught general science. Her philosophy of teaching centred on the "growth" construct. That is, she perceived herself as tireless farmer enabling her students, whom she considered as plants with much growth potential, to excel in physics. As she expressed:

I want them to explore on their own, like roots, to find out something on their own...make linkages able to learn further...develop an inquisitive mind...but I will be there with them playing my part...guiding them...not forcing them with notes... I don’t think physics teaching is like that...they grow as they explore...

(Narrative, 14/05/99).
Her view of physics itself was centred on the view that physics content had to be built up from the experience of actively doing physics. Although she considered her notes for students as crucial, she strongly felt that they would be meaningless without students and herself participating in the very process of building physics content.

With this view of teacher being crucial to teaching, as the aforementioned quote signified, Angela’s range and scope of teaching physics with computer technology was very clear cut. She stated that it provided an atmosphere where physics content was “alive”: it provided visualisation and hands on activities. But she was clear that what happened within that context was also a joint activity where her students and she worked together on the physics content. She said that she preferred not to use the computer technology to gather information or to provide novelty effects of physics content.

Tan

For Tan her philosophy of teaching and learning was captured in her metaphorical statement: “Teaching is like a magic show. You create something unexpected to arouse the curiosity of your pupils”. She felt that she had to create a teaching and learning contexts in which her students were able to identify and face their misconceptions. Through interactive teaching and learning activities these misconceptions are laid out and examined by both teacher and students as a learning group. This meant that teaching and learning were more than knowing the content, as she explains:

I like to teach because I want to see that everyone is able to contribute...apply the concepts they are learning. I like to see my students apply what they have learnt... this gets them to be independent learners...they must know where to look out for information, how to interpret it, analyse it and build it up into their own... I am there to help them to do this... (Interview 3, 26/03/99).
For Tan, chemistry was not a static content to be transferred, it had to be taught such that students came face to face with their conceptions of it - the conceptions held by the larger scientific community. For Tan, her students' minds were to be continuously at work: constructing, contributing and applying their knowledge to the learning environment. She perceived her lessons to being stimuli which trigger the aforementioned events that contribute to students' learning.

The range in which Tan perceived her use of computer technology centred on its ability to provide for the aforementioned teaching and learning approaches she mentioned. This range was further highlighted as computer technology provided explorative contexts where students could explore their misconceptions and reconstruct them into concepts that cohere to the scientific community at large.

**Woo**

For Woo her main philosophy of teaching and learning centred on helping students consolidate the concepts that had been taught by her. She added that it was her duty to also motivate her students to like the subject and help them see the relevance of the subject to their daily lives rather than just an examinable subject. Woo perceived her students' knowledge of concepts to be learnt as incomplete: students held misconstrued or unconsolidated conceptual frameworks of the biology concepts they had to learn. Woo felt that this had to be remedied, "make this incomplete knowledge complete". Thus, her pedagogical practice centred on transferring knowledge to students to make it complete. She strongly felt that it was the teachers' duty to do so.

Woo was confident that her use of computer technology reflected her philosophy of teaching: "The computer technology had served its purpose so far...I still hold them back". This was reasoned as a precaution, which she stated as:

I cannot foresee myself doing that (referring to the use of computer technology within her context of teaching) what will happen if the computer hangs
This “style” of teaching was centred on Woo delivering the content, followed by the use of computer technology that closely matched her previous teaching. The purpose of which was to consolidate her teaching: “...you need the teacher there to provide the education, the computer technology is just a tool, the teacher utilises it to give a quality education.” This perception framed Woo’s range and scope for the use of computer technology for teaching and learning.

4.2 Cultural context and participants goals

As the data were analysed, it emerged that the participants' thinking was strongly centred around the cultural context as illustrated in Figure 11. Figure 11 represents how teachers’ roles, teachers’ beliefs, the role of computer technology, and accountability are related to students’ conceptual change (instructional and classroom foci) and to the GCE “O” level examinations (institutional focus). This culture constituted the "standards" (Patton, 1990) through which teaching and learning actions, with the integration of computer technology took place it included behaviour patterns and beliefs. For example the GCE "O" level exams and preparations for this exam seemed to form one of the standards, serving as an institutional focus. This standard formed the "institutional culture" which created the cognitive frameworks for thinking about their specific teaching actions and learning actions.

Participants' role, accountability, the role of the computer technology, images and beliefs made up the other parts of this cultural context. These standards, which the participants brought to their classroom teaching with computer technology shaped overall planning approaches, the selection of content, and the forms of interaction which participants believed should characterise their classrooms: classroom focus. These standards enveloped and gave "life" to the instructional focus. That is, the
specific forms of instruction, teacher and student tasks during lessons, decisions underpinning these tasks, resources and materials and participants’ roles in managing classroom interactions. Together these focussed on the students’ roles and students’ conceptual change. Participants in this study seemed to draw upon this cultural context and the way they did it reflected an interdependence, interrelation and intertwining between the institutional culture, classroom focus and instructional focus. Although all participants mentioned these standards, how these standards were connected, leading to teaching and learning, actions varied considerably between Woo and the rest of the participants.
4.2.1 Participants’ goals: Why they use computer technology

The participants’ data revealed two distinct types of goals for their teaching and learning environments with the integration of computer technology. One set of goals dealt with the creation of educative performances and experiences within the context of students’ conceptual change. The other set of goals was more self-referential: acquiring personal competence in the use of computer technology for educative purposes. These goals revealed how this group of participants interpreted and comprehended their experiences within this particular cultural context of teaching with computer technology.

The following extract of focus group interview transcript captured the two specific goals that participants had for teaching actions integrating computer technology: creating educative performances and experiences; and, gaining competence in the use of computer technology.

Ning: A certain topic delivered with the integration of computer technology captures the students' attention more, but it also allows for easier engagement with them... easier to achieve your lesson objectives... but it doesn't mean that a second method or strategy may not be good, that method may still achieve what you want to do in class, I think it is one of the many ways...

Sundari: I think it is the quality that it gives us, that is why we focus on its use in lessons... yes it brings us closer to bringing about change in the concepts that they have...

Anthony: It must do something that we cannot do otherwise! That is the quality. [Everybody agreed in unison to Anthony's remark]. Like experiments essential to the topic the flow of the topic... where you can project it on the spot it makes it
more lively. Like the metals and water chemical reactions, with the computer technology you can show the gradation how as we go down the group the reactivity increases or decreases, you can show them on the spot...it adds value gives them the chance to predict outcomes with visuals...rather than we talk and talk about the reactions between metals and water....

Tan: Like using the data loggers they get to do experiments in class, this unites the theory and the experiments on the spot...We can be there to see how they do that application, we can show them...correct the terms that they use...well sort of guiding them along...

Angela: True it is just like one of the tools, just one of the different ways of giving a lesson, but a lot of teachers use it for animation you show them something or say the Internet it provides information...it must be something more like what Anthony and Tan said it should do those things in class, not show stuff, pick up things...

[Everybody agrees in unison, but Woo interjects]

Woo: I still think that you need the teacher there to provide the education, the computer technology is just a tool, the teacher utilises to give a quality education.

(Focus group interview, 1, 12/02/99)

4.2.2 Creating educative performances and experiences

Listening and focussing on the interactional data above, it was clear that participants wanted to create teaching and learning environments that gave
opportunities for interactions. This, they suggested catered for both teacher-student interactive educative performances and self-regulated student learning. Participants felt that the use of computer technology allowed them to set up and sustain these teacher-student-curriculum interactions. Although Woo seemed to agree with the rest, she still felt that this goal was to come after the teacher had taught the concepts or content.

4.2.3 Self-referential goals: Competence

Apart from the aforementioned student-centred goal, participants wanted to become more competent in their use of computer technology for teaching and learning purposes. Comments from participants indicated that this goal was related to and interpreted from actual classroom experiences. The following comment by Ning was typical of all the participants' reason for using computer technology:

...to bring variation, making my lesson interesting and if possible to use the computer technology to replace some of the lab apparatus that don't work or we don't have in the school's physics lab...improvising teaching situations...I would like to learn more about what computer technology can do for my teaching and lessons, more of that personal gain. Whatever I pick up I can use to enhance my teaching and my students can learn to pick up too from my teaching and integration into lessons...

(Interview 2, 26/02/99)

Participants' goals of gaining competence in the use of computer technology were related to achieving students' conceptual change. They viewed gaining personal competence in relation to how it would help the processes that shaped their instruction leading to students' conceptual change. Also, this view correlated to how this competence and teaching actions would help their students' learning. On the other hand, Woo used computer technology, "... to motivate the students to learn more...to hold their interest...find additional resources... any interesting
things to share with the class." Woo's goal for gaining competence was geared towards making her lessons and the topic being taught more interesting for her students. Interestingly, the scope of this goal was within the larger cultural context but also focussed on students' conceptual change.

In summary, Angela's, Anthony's, Ning's, Sundari's and Tan's goals for the integration of computer technology into teaching and learning actions were interrelated. Participants' goals for creating educative performances and experiences were related to their self-referential goals to enhance teaching and learning actions geared towards the process of students' conceptual change, coupled with the goals of making lessons varied and interesting. Woo on the other hand, positioned her goals in such a way that it was aimed at tapping onto students' interest/motivation. She claimed that this enabled students to be engaged in her teaching and the taught content.

Having considered the cultural context (Section 4.2) and the profiles of participants (Section 4.1), the focus now shifts towards the communities of practice, which were extant within this cultural context. This section presents the findings that reflected the test of the researcher's articulated theory to explain the research question in this study. That is, how the participants in this study constructed classroom meaning integrating computer technology.

4.3 The communities of practice

As was mentioned in chapter 2: section 2.5.3, the concept of community of practice pertaining to the teaching profession and classrooms in general, was defined as practice that involved negotiations, access, and engagement that resulted in legitimate peripheral participation and membership. Based on these constructs and the concept of community of practice adopted in this thesis (chapter 2: section 2.5.3: p. 77-78) two distinct types of communities of practice emerged from the analysis of the data. First, community of practice I (CP I) in which the computer technology was designated as an integral part of participants'
instructional processes. Students were active members and contributors within the instructional processes that occurred in this type of community of practice. Second, community of practice II (CP II) in which the computer technology was used to reinforce what participants had already taught in the classroom. That is, participants taught the relevant and suggested content by traditional methods first, than used the computer technology to substantiate their instruction. Angela’s, Anthony’s, Ning’s, Sundari’s and Tan’s classroom teaching reflected CP I. On the other hand, Woo’s classroom teaching only contained CP II.

Next, the two types of communities of practices are illustrated. First, the features of the activity structures and the teaching actions within them are presented. This gives the reader an idea of what constitutes an activity structure within these communities of practices. Then, the participants’ negotiations that constituted the construction of these activity structures are presented. Following this, the mediation by psychological tools that brought together these negotiations, within the activity structures, are presented. The extant and functioning beliefs are presented after the presentation of each community of practice.

4.3.1 Community of practice I: Journeying together towards a destination

Community of practice I was organised around the imagery of a journey. 24% of the participants’ (Angela’s, Anthony’s, Ning’s, Sundari’s and Tan’s) metaphoric language (from verbatim verbal data, classroom discourse, and narratives) captured this imagery. The imagery of classroom lessons as journeys depicted participants and their students, together with the computer technology, moving towards a destination: the fulfilment of lesson objectives leading to students’ conceptual change. Thus, this journey, like any other, required landmarks that guided the participants towards that destination.

These landmarks were the apparent result of the negotiations that took place within the CP I. These landmarks sustained the journey by enabling participants to focus on the very act of teaching actions pertaining to the transfer of cultural
templates leading to students’ conceptual change. Unique to this imagery of journey was the recurrent image of a “pitstop” among participants’ verbatim verbal data. This pitstop imagery depicted a stop along the journey towards the destination. This pitstop imagery brought about a change in participants’ roles as well: from that of a facilitator to that of a guide, as participants and students moved along the journey.

The participants’ imagery of classroom lessons integrating computer technology as journeys characterised the participants’ construction of classroom meaning. This imagery mediated a number of negotiations: acquiring a facilitator role; designating roles for the computer technology; and positioning students – all within the classroom context. These negotiations provided the structures and strictures, and cognitive guides that collectively took the form of activity structures. Two reasons can be cited for this association: First, acquiring a facilitator role; designating roles for the computer technology; and positioning students, all paralleled the academic task structures of activity structures. That is, the participants selected the relevant and prescribed content, organised the content and related it to what their student audience already knew. This selection, organisation and transfer of content was done taking note that the computer technology was being integrated into teaching actions. Second, acquiring a facilitator role; designating roles for the computer technology; and positioning students, all paralleled the social participation structures present within activity structures. That is, participants enabled themselves and their students to gain access to learning and to demonstrate social academic competence. The use of computer technology featured as an integral component in these social participation structures.

These activity structures in turn were mediated by the participants’ psychological tools which extended the negotiated landmarks within the activity structures towards teaching and learning actions. These psychological tools carried the perceptions of supporting, developing, equipping and visualising. Mediation by these psychological tools, together with the negotiated activity structures, enabled
participants to bring about teaching actions leading to students' conceptual change rather than teaching actions pertaining solely to the computer technology: educational computing as teaching. This also reflected aspects of the zone of proximal development. This is further elaborated on in section 4.3.1.7.

Within this community of practice, the journey towards the destination the transfer of cultural templates leading to students' conceptual change, involved a joint partnership between participants and students where the designated roles for computer technology played integral roles within this joint activity. Data showed that CP I consisted of three key events: setting the stage for interactive teaching and learning; the joint activity; and maintaining accountability. First, setting the stage for interactive teaching and learning actions. In this event participants stated the lesson objectives, the lesson format and the purpose/role of the computer technology. This event also included the participants' verbal cues for social participation. Event one led to event two the interactive participant-student instruction-cum-learning phase. This event closely matched the lesson objectives. This event was not a mere lecture format that incorporated powerful imageries, provided by the computer technology, to sustain the lecture. It was more a case of using the computer technology to initiate joint participant-student tasks that revolved around the academic task.

Data revealed that students were exposed to a multitude of tasks that related to the lesson objectives. These tasks provided participants and their students support and guidance structures that allowed students to interact with the concepts being presented. In CP I, these usually involved the computer technology providing a platform for participants to stimulate their students with content that was animated or had interactive attributes. This situation also gave participants a platform to listen to and diagnose students' cognitive activities and relate them to further instructional actions. Students were seen as partners in this community of practice, as Anthony stated, "like participants in a workshop...we are co-learners discussing with each other...." Participants seemed to favour this because they felt that it provided an atmosphere in which they were at a "closer range" to students'
understanding. The following comment captured the aforementioned structural features of CP I:

...there are a lot of group discussions and the students and me are involved in the activities...the use of computer technology widens the scope for these activities...not the teacher just doing the activities...now we are finding out the content together and you get to know about things...like what they learn...from there you can guide them on and clarify...of course you cannot do without the teacher definitely...
(Angela, Interview 1, 15/01/99).

Table 11 captures some of the features of CP I classrooms and the role of computer technology in the teaching and learning processes: activities involving computer technology and the aspects of computer technology that were covered. It also captures the student, teacher, computer technology, the teaching and learning activities and the science topics covered.

Participants' contributions to the CP I were characterised by a distinct set of ideas: patterns of teaching, patterns of learning and orchestration of legitimate tasks. Their participation was further dependent on maintaining natural communicative routes between themselves and their participants. The computer technology seemed to mediate these natural communicative routes by opening up avenues through which students' knowledge was exposed to participants. But participants' psychological tools were mediating the whole teaching and learning activity within the context of teaching with computer technology.

Event three, maintaining accountability within this community of practice did not follow any recipe and was sought through a number of measures, which were characterised by a partnership attribute. Accountability focussed on how the students' made sense of the tasks they were involved in. This plenary phase was a "wrapping up" session where participants or sometimes students summarised what
<table>
<thead>
<tr>
<th>Content</th>
<th>Science covered</th>
<th>Activities involving computer technology: Role of computer technology</th>
<th>Aspects of computer technology covered</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Angela</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acids and Alkalis</td>
<td>Properties of acids and alkalis, Neutralization</td>
<td>Use of data-logging probes (pH sensors) to measure pH changes Data collection, plotting graphs and analysis</td>
<td>Data-logging</td>
</tr>
<tr>
<td>Speed, time and velocity</td>
<td>Interpreting speed time, velocity and acceleration graphs</td>
<td>Use of data-logging probes (motion sensors) to measure motion changes Data collection, plotting graphs and analysis</td>
<td>Data-logging</td>
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<tr>
<td><strong>Anthony</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chemical Bonding</td>
<td>Identify and name covalent and ionic compounds</td>
<td>CD-ROM based activity Provided 3D structures of chemical compounds which students could rotate and have closer views of chemical bonding types</td>
<td>Modeling Animation</td>
</tr>
<tr>
<td><strong>Ning</strong></td>
<td></td>
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</tr>
<tr>
<td>Sound</td>
<td>Reflection of sound and sound waves, Properties of sound waves</td>
<td>CD-ROM based simulation of experiment to measure the speed of sound Use of data-logging probes (sound sensor) to measure sound and present them as sound waves</td>
<td>Data-logging</td>
</tr>
</tbody>
</table>
Table 11 (continued)

The science subject content, role of computer technology and activities for observed classroom teaching

<table>
<thead>
<tr>
<th>Content</th>
<th>Science covered</th>
<th>Activities involving computer technology: Role of computer technology</th>
<th>Aspects of computer technology covered</th>
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</thead>
<tbody>
<tr>
<td><strong>Ning</strong></td>
<td></td>
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<tr>
<td>Acceleration due to</td>
<td>Experimental determination of acceleration due to gravity: calculating “g”</td>
<td>Use of data-logging probes (motion sensors) to measure motion changes</td>
<td>Data-logging</td>
</tr>
<tr>
<td>gravity</td>
<td></td>
<td>Data collection, plotting graphs and analysis</td>
<td></td>
</tr>
<tr>
<td><strong>Sundari</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cell Structure</td>
<td>Factors that affect diffusion rate in cells: Cell surface area to volume ratio</td>
<td>Interactive simulation: enabling the manipulation of cell size and features of cell. Change in size/feature animates diffusion rate</td>
<td>Simulation Modeling Animation</td>
</tr>
<tr>
<td><strong>Nutrients</strong></td>
<td>Measuring caloric values of common foods</td>
<td>PowerPoint presentation of bomb calorimeter</td>
<td>Simulation Modeling Animation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Designing a laboratory apparatus for measuring caloric values using PowerPoint icons</td>
<td></td>
</tr>
<tr>
<td><strong>Reproduction</strong></td>
<td>Exploring the human female reproductive tract in relation to structure, function and fertilization</td>
<td>CD-ROM based activity Provided interactive journey into the female reproductive tract</td>
<td>Interactivity Animation</td>
</tr>
<tr>
<td><strong>Tan</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chemical Bonding</td>
<td>Identify and name covalent and ionic compounds</td>
<td>CD-ROM based activity Provided 3D structures of chemical compounds which students could rotate and have closer views of chemical bonding types</td>
<td>Modeling Animation</td>
</tr>
</tbody>
</table>
educative performances had taken place during the instruction cum learning phase: a "pitstop". Participants drew correlation to lesson objectives.

As stated before, Section 4.3, CP I was a product of three interrelated negotiations: acquiring a facilitator role; designating roles for the computer technology; and positioning students. Through these negotiations the computer technology was designated as an integral part of participants' instructional process. These negotiations did not occur in any prescribed order but were interactive leading to the creation of activity structures. These negotiations set up the landmarks that guided participants towards their destination.

4.3.1.1 Positioning students

Positioning students centred on the participants' perspectives of how to enable students to be part of the instructional processes: to be part of the journey towards the destination rather than mere passengers in the journey. Students had to be part of the journey, to reach the destination on their own accord as well. Two perspectives enunciated how participants positioned their students within the journey: the mutual investment perspective and the interest/motivation perspective. Both involve an interaction with the other negotiations of acquiring a facilitator role and designating roles for the computer technology.

4.3.1.2 Mutual investment perspective

This mutual investment perspective played a crucial part in participants' construction of classroom meaning integrating computer technology. This mutual investment perspective held the common understanding that both participants and their students had to be partners within the instructional processes that led to the transfer of cultural templates: instruction was a two way process, both parties had to be involved. Students had to be part of an "on going" instructional process that enabled them to build or make meaning and not just "pick up" concepts from participants or from the computer technology. Participants' adoption of this
mutual investment perspective involved a number of features. The following narrative signified some of these features.

Sometimes I just present a lesson using computer technology, just a small part of the lesson I have worksheets and exercises about it. It is quite structured. For the topic on dissolving I use the CD-ROM to show the models, to show visual pictures of how sodium chloride dissolves. Then after that they go onto write the equations. It is visual presentation, to show the meaning of dissolving, how the water works, how the water comes into the picture, so it is very difficult to describe without animation...shows what happens and delivers commentaries so they are seeing the process and theory at the same time. I use that to develop an idea of how dissolving occurs. Well with the interactivity provided by the computer technology I can stop and explain or students join in asking questions. Usually I make them predict what is going to happen next. You get their conceptions out. From there we move on, so that is sodium chloride dissolving, what about the rest like aluminium chloride? So they have the practice of writing that equation using visuals from dissolving sodium chloride to show how ionic solids dissolve.

(Anthony, Verification of coding interview, 02/04/99)

This mutual investment perspective was a crucial component in the negotiations involving the positioning of students. Data revealed that participants interpreted the importance of this perspective on the basis that it allowed students not only to be part of the instructional processes but also enabled them to contribute to the instructional processes. For example, in the aforementioned quote, students were to "predict", "join in the questioning" and "write the equations". That is, the computer technology was factored in as an integral component because it enabled the participants to accomplish these joint instructional activities.
Negotiations for positioning students were also based on feedback gained from past teaching experiences with the integration of computer technology. The following focus group interview transcript illustrated this negotiation.

Anthony: There might be some students who might not be open to teaching and learning...to be active contributors or geared towards independent learning or group work...

Ning: Yes, some students might be rigid in their own thinking, we might lose a few...

Sundari: Some of them are passive no matter what approach you take! These are those few.

Angela: These are the ones who just come in and go off in some lessons.

Ning: ...you cannot possibly change to suit every class! Making the content more tangible with the use of computer technology; they see it they tend to understand better.

(Focus group interview 2, 14/05/99)

Participants seemed to resolve this issue by suggesting that the powerful visual imageries and interactivity that the computer technology provided was a strong impetus for engaging students. Second, data revealed that participants also held the supposition that their use of student worksheets made students more involved in the instructional processes.
My worksheet...that's one way of finding out if they really understood. How the students are involved, whether they are learning...you can see if they are following...if they are on the right track...
(Sundari, Interview 1, 12/01/99)

Thus, the mutual investment perspective seemed to play a crucial role in positioning students. It provided a focus to situate students in a position that enabled them to be contributors to the teaching and learning processes and to gain cultural templates from these processes. The factoring in of the computer technology as an integral factor was based on this mutual investment perspective. Participants also held the notion that mutual investment could also be achieved by the use of student worksheets and the powerful visual imageries and interactivity provided by the computer technology. This notion was underpinned by the understanding that this was an extreme form of mutual investment; it was to enable students to be part of the teaching and learning, especially those students who were only interested in gaining from the teaching and learning processes and not to be contributors to them.

4.3.1.3 Interest/Motivation perspective

Positioning of students was also negotiated in consideration of the interest/motivation perspective. This perspective reflected the conception that the integration of computer technology into teaching actions resulted in student motivation and interest towards the content being taught. Participants related this conception to the attributes of interactivity, animations, and simulations that the computer technology afforded the classroom context. The interest/motivation perspective was however channelled towards the process of transferring cultural templates. The following narrative illustrated this perspective held by the participants in this study.

I chose to use the sound file. It is very sensitive so it responds very well. The girls sort of enjoy it, more fun but at the same time they are creating
the sound waves, the sound or noise they make gets detected and the sound file picks it up and the sound wave forms on the screen. They can spot the difference between waves, ...the rarefaction and compression... that's good. I guide them along, sometimes we compare sounds and I ask them to predict the type of wave... I realise that since they are enjoying and learning at the same time I actually allocated more time although this lesson could be finished in twenty minutes or less. I actually let them play with it more.
(Ning, Classroom Case, 27/04/99)

This interest/motivation perspective was interpreted by participants as helping them to position students within the classroom context based on the attributes of the computer technology. This group of participants used this motivation as a platform to enable the transfer of cultural templates.

4.3.1.4 Designating an integral role for computer technology

Participants designated the computer technology as a tool for visualisation and as a tool for interactivity. In the following lesson extract, Sundari first introduced the bomb calorimeter used commercially in science and food chemistry laboratories through a slide show presentation (PowerPoint). Then, Sundari and her students, in a joint activity, used the computer technology for visualisation and as a tool for interactivity to design an apparatus to measure caloric values of common food items in the biology laboratory.

Sundari: What is the common link among carbohydrates... other than the elements... they contain?

Students: Energy?

Sundari: Be specific! Remember food can labels at the supermarket or at home?
Students: Caloric values?

Sundari: Yes. That's good! Let's talk about caloric values. What is it and how can it be measured.

[Sundari shows a scanned image of a bomb calorimeter and explains how it works].

Sundari: Give me another apparatus you can use to measure caloric values in the lab. You tell me and I will try to design it with PowerPoint.

Students: ...test-tubes, beakers, bunsen burners, thermometers...

[Sundari uses the shape icons to design the apparatus that the students are giving. She then uses the animation icons to visually move the icons. Students respond by giving her directions to move the icons to simulate the experiment].

Sundari: Let's compare both apparatus, can you tell me the experimental errors you might get?

(Field note, 12/02/99; 19/02/99; 0103/99, Biology Classroom-Appendix B)

I am just trying to draw the knowledge out of them by using the computer technology, attract their attention, connect it to their prior knowledge...the students seem to assume that the bomb calorimeter is the only way to measure caloric values of foods, by first showing them how the bomb calorimeter works, they get to know the essential features, combustion of the food, measuring the heat given off...they then use these features to help them design a simple version of the bomb calorimeter that they can use in the lab... After all, the topic of nutrients is something close to them (points to her stomach and laughs). It has a lasting impression on them...
because they have seen the animation...it reminds them of the process...sometimes they are able to recall what they have seen rather than what they have heard...

(Anecdotal data accompanying Field note, 19/02/99).

Participants adopted these designations for the computer technology because of three interrelated perceptions derived from interpretations of the mutual investment perspective and from past teaching experiences that had integrated computer technology into teaching.

First, it supported the mutual investment perspective that participants explained was essential in teaching and learning environments. That is, the attributes of visualisation and interactivity, allowed, students to be part of the instructional processes together with the participants. Assigning these designations to the use of computer technology allowed for mutual investment because participants and their students were involved in the ongoing instructional processes that articulated subject matter not as a static transferable content but into constructs that students had to gain through teaching and learning actions with participants. The following comment highlights this perception held by participants.

My students and me are able to manipulate, increase the percentage of villi and at the same time the surface area to volume ratio gets calculated and they are able to connect much faster...students were able to figure out themselves...the students told me what are the features of the cell that aids diffusion...

(Sundari, Classroom Case, 12/01/99)

Angela's, Anthony's, Ning's, Sundari's and Tan's verbatim verbal data, classroom discourse and classroom practice contained further perceptions and interpretations that illuminated this landmark. These perceptions tended to demarcate the designations assigned to the computer technology in the classroom. First, they did not favour using computer technology as a textbook resource. As Tan explained "I
don't like to use CD-ROMs where there are a lot of text like the textbook. It must be something the students can benefit from". Second, they also did not favour designating computer technology as a powerful visual medium that transferred content stipulated by the curriculum.

Participants reported that they were aware, from past experiences, of the added value afforded by integrating computer technology into their lessons. But they indicated that integrating computer technology alone was not the answer to all teaching and learning situations. First, all participants agreed that computer technology simulations/animations of science experiments were good in some cases when laboratory conditions and tools were inefficient or unavailable. But this did not mean that computer technology was to replace all experiments. The following extract from a focus group interview illustrates and supports this notion.

Angela: Yes, it (computer technology) makes the experiments tangible (all participants)...but will they (students) feel the force...

Ning: Will they get a feel for circular motion...

Tan: Nothing like smelling the gases produced when mixing chemicals

[Everybody laughs]

Anthony: The immediate colour changes from their (students) own mixing of chemicals...

Sundari: For biology it is different, some processes occur inside the cell or human body... how to show them (students)...

(Focus group interview 1, 12/02/99)
The dialogue demonstrated that the participants' view of computer technology as a tool that enabled impossible teaching and learning actions to be possible actions in the classroom, had its limitations. They also felt that students needed a "hands on" feel for science. This was derived from their own perceptions of the need for students to plan and do experiments themselves and not just rely on simulations and animations.

The negotiations involved in designating roles for the computer technology was also made evident in a often recurring theme of "back ups." Participants articulated these “back ups” as teaching actions that would replace teaching actions hampered by the possible malfunctioning of computer technology during class. The “back ups” were included to maintain the flow of the lesson and flow of thought that accompanied the lessons. The following extract from a focus group interview transcript illustrated this point.

Sundari: There's no continuity!...when you come back to the lesson after troubleshooting the problem with the computer technology...

Ning: Yes! after all that fixing, connecting and starting up again, you come back to the topic, but the students are already distracted ...

Angela: Actually I had that experience...tried setting up the CD-ROM...it didn't work...in the end had to ask the students to do reading on their own. After that when I finally got it working I had already lost the students interest!

Anthony: They (students) tend to go off at a tangent if we start to troubleshoot the problem or have to call in the technician...
"Back ups" were considered a necessity for the integration of computer technology into lessons for two key reasons. First, to maintain the "momentum of the lesson." Second, to maintain the students' ongoing focus onto the teaching and learning situation. Thus, participants interpreted their designation of roles for the computer technology as a means to focus their students onto instructional processes and also to keep students in tune with the instructional processes. This interpretation showed that participants were not designating the computer technology in a peripheral fashion. That is, computer technology was an integral part of the teaching and learning actions and not outside these teaching and learning actions.

Thus, the participants' designated roles for the computer technology in the teaching and learning activities involved a lot of negotiations. Most of these negotiations tended to designate the computer technology as an integral component of the participants-students joint activities.

### 4.3.1.5 Acquiring a facilitator role

The imagery of a journey assumed a teacher's role that sustained participants' efforts towards the destination. To achieve this, participants fashioned and enacted the facilitator role. This facilitator role itself was underscored by two striking characteristics: a functional aspect and a cognitive aspect. Both functioned to produce and maintain a social system, where participants and students could be involved in joint activities. These two aspects seemed to be the central focus in the participants' negotiating processes in acquiring the facilitator role. The following comment illustrated this negotiation process responsible for the facilitator role.

> The teacher puts it all together so that the students know what to do...we don't want the students to be fumbling ...you must know what the computer is doing in the class for this particular lesson...make adjustments as well...sometimes students go off tangent...

(Anthony, Interview 2, 27/02/99).
...a facilitator for students’ learning rather than a person who provides information, or delivers facts using the computer technology. I see myself as a person who facilitates learning in the classroom...

(Sundari, Interview 2, 19/02/99).

The functional aspect of the facilitator role performed several functions. First, as facilitators, participants provided the lesson objectives. Second, they provided guidelines for students' utilisation of computer technology or how it was going to be used for that particular lesson. The cognitive aspect of the facilitator, within CP I, was closely linked to the designations afforded to the computer technology and the positioning of students. For example, how the computer technology was going to function within the instructional processes: what was it going to contribute and what was the relationship to the academic task. These aforementioned elements were factored into the creation of the facilitator role that shaped and gave meaning to teaching integrating computer technology. Experiences from prior practices influenced how the participants enacted the facilitator role. For example data from classroom observations revealed that the participants’ need to wrap up lessons was based on previous experiences.

It is important to wrap up the lesson to reiterate the objectives of the lesson. So I don't think the use of computer technology can replace the teacher in that way. It can't be done with the computer technology, I don't think it is intelligent enough...well you can use those self assessing software but students are always curious or they may have misconceptions I think we are the ones who need to find these...the computer technology can do all those things to build up the knowledge ...but we still need to check.

(Sundari, Interview 2, 19/02/99).

...when we get down to the solid stuff like writing chemical equations and all that I have to be there to make sure it is correct and monitor this. They will tell me as they write it out...
Data revealed that participants held the perception that some teaching functions were impossible or inefficient when integrating computer technology into teaching. They reinforced their need to maintain accountability for their teaching actions, in light of the cultural context in which participants were situated. Central to this context was the presence of the GCE "O" level exams.

Of course one very important thing right now is preparing the students for their GCE "O" level exams and so we are bound by the syllabus so I always make sure that they understand the objectives of the lesson before they leave; otherwise sometimes they lose focus and really don't know what they have done for the day...

(Tan, Interview 1, 15/01/99).

4.3.1.6 Recasting as a guide

During the journey towards achieving lesson objectives, there seemed to be a temporal recasting of participants' role as a facilitator to that of a guide. Narratives, "The teacher as..." metaphors and metaphoric language, classroom observation revealed the lesson as a moving object slowing down in tune with the recasting of participants into guides. The slowing down was captured as a "pit stop" where the participants as guides reconnoitred the steps taken by students through: checking for students' understanding; reinstating the relevance of the topic at hand; and wrapping up. The social context in which this “pitstop” occurred was marked by the assertion of the participants' roles as teachers who were making sure that what had been done by their students was in accordance with objectives. This revealed the influence of the institutional focus.

Participants checked for student understanding: "get down to the solid stuff" and "focus them back" were the key classroom discourse terms prevalent within these "pitstops". It must be noted that this “pitstop” did not materialise into participants
directing students to the procedures that they had in their minds all along: there was no evidence of imposing the traditional or official solutions for the students to learn. The following comment captures this recasting:

The teacher's role now shifts, before the lesson the teacher does the planning, the background that makes them do the learning themselves...but now the guiding comes along...is like the summary part where I have to make sure that the students, after going through all those CD-ROMs, Internet sites or simulations, are able to...know what they are supposed to learn...because sometimes they become too out of focus and so the teacher has to focus them onto the main things again.
(Angela, Interview 3, 31/03/99)

This recasting occurred in response to actual feedback from classroom actions and experience. First, participants claimed that there was always a possibility of students "going off at a tangent". The computer technology's attributes of animation, simulation and interactivity or the use of Internet itself encouraged this perception. Participants stated that sometimes students might be overwhelmed by these attributes and move away from the lesson at hand. The need to "wrap up" the lesson was also cited as a crucial reason for this change. As the following comments from participants’ lesson extracts signalled, the role of guide was more in tune with maintaining the relevance to the topic being covered.

Let's clarify the molecular structure again with that depicted on the screen and on your worksheet...Let's summarise what we have done, look at the ionic bond...refer to the software...are there any problems...let's look at the structure again...
(Anthony, Field note, 06/04/99)
Since you are the experts now in your designs of finding out "g", please share it with the other groups. Pick up from one another...what are the factors that you chose or the other group chose (Ning, Field note, 11/05/99)

...have you considered all the recommendations given to you by the website? As a scientist you have considered many factors for the design of the fire alarm or the thermometer...you have to consider other factors as well...Lets discuss together what we have done so far. Remember you also have to present your answers...
(Tan, Field note. 13/01/99)

The predominant function of the role of guide was to ensure that students were able to account for their learning. The guide role was cast within a social context to maintain the social relations between students and participants.

So far, the participants' negotiations leading to the creation of activity structures have been presented. Now the focus shifts towards the psychological tools that mediated these activity structures (and the inherent landmarks) towards teaching actions.

4.3.1.7 Psychological tools: Supporting, developing, equipping and visualising

A number of psychological tools seemed to be the key mediators of teaching and learning with the use of computer technology. They did this by extending the three landmarks (positioning students, designating roles for the computer technology and acquiring a facilitator role) set within the activity structures towards teaching actions. These psychological tools enabled the activity structures and three landmarks, within them, to function towards the destination by extending the three landmarks towards a common social act. These psychological tools mediated the teaching and learning processes including the mediating role of the computer technology. The analysis of participants' language (including metaphorical)
within teaching actions (classroom observations and classroom discourse) narratives and interviews enabled the researcher to deduce these psychological tools. The analysis of metaphoric language (Chapter 3: Section 3.8.2.2) also played a crucial role in the identification and interpretation of the metaphoric language that formed a large part of participants’ language of instruction. These four key psychological mediators were supporting, developing, visualising and equipping. Although, supporting (26%), developing (22%), equipping (15%), and visualising (13%) had different frequencies within the participants’ verbatim verbal data, it must be noted that these psychological tools were not separate entities functioning independently. Instead they functioned in unison with other psychological tools to mediate activity structures towards teaching actions. Each of the psychological tools carried its own notion of how classroom meaning was to be achieved with the integration of computer technology. This was evident, as the mediating role of computer technology, as designated by its roles, was itself mediated by the psychological tools.

Figure 12 captures this understanding of how these particular psychological tools work within this cultural context, thus contributing to the participants’ construction of classroom meaning. This figure shows how the participants’ facilitator role, participants’ positioning of students, and their designation of roles for computer technology are mediated by participants’ psychological tools when they are involved in the transfer of cultural templates leading to students’ conceptual change. Furthermore, the zone of proximal development, was a prominent occurrence within activity structures as the psychological tools brought together the three negotiations, which were involved in constructing classroom meaning. Most of the classroom teaching actions observed and the participants’ narratives captured this zone of proximal development. Next, each of the psychological tools is presented. To recap: Psychological tools were not separate entities but occurred in an interactive way within teaching actions. For the sake of clarity, each psychological tool is presented separately.
Facilitator Role

Psychological tools

Transfer of cultural templates leading
to students' conceptual change

Psychological tools

Designating roles
for the computer technology

Psychological tools

Positioning students

FIGURE 12

The role of psychological tools within activity structures

Supporting

The psychological tool of supporting carried the notion of participants supporting students' conceptual change. This cohered with the negotiations for the positioning of students, acquiring a facilitator role and designating roles for the computer technology. The following narrative captured the very essence of what this psychological tool meant for participants. For instance, the following narrative gives a glimpse into a lesson on human reproduction.

The use of the CD-ROM (9 month miracle) enabled me to show the actual movement of the ovum and the sperm...how the ovum is fertilised...the path that the sperm takes...how it fertilises the ovum and how the fertilised ovum moves down the fallopian tube towards the uterus and how the embryo is formed. It had a lasting impression on them because we actually manoeuvred down the female reproductive tract together...the CD-ROM gave us the opportunity...I am sure they are able to recall what they had seen...they become part of the movement they told me when to stop...and sometimes they manoeuvred in the wrong direction... I stopped and they ask me why...they give me explanations...sometimes it is funny but the
questions really help...I can reinforce like a pointer...they understand the process not just the textbook diagram...
(Sundari, Classroom case, 13/05/99)

The narrative above clearly depicted the participants’ perception and notion of this psychological tool. Participants supported students’ conceptual change with the help of the designated role of the computer technology. The facilitator role was negotiated towards the joint activity and the negotiated role for computer technology enabled students to approach a concept through questioning it, comprehending the explanations that surround it and to showcase the concept’s relationships with other concepts: supporting knowledge construction rather than transmitting. For example, how fertilisation was related to embryo development. The computer technology mediated these approaches through its attributes of animation, simulation and interactivity. But the participants captured this perspective and reflected this through the coherent way in which this was turned into educative opportunity. They did not just depend on the attributes of the computer technology, instead they used it to support their facilitator role. Through the use of the psychological tool of supporting, the mediation process by the computer technology enabled the potential for teaching and learning within the zone of proximal development. Participants’ facilitator role was using the computer technology to support students’ knowledge construction as supportive actions as they traversed through a scientific phenomenon. In the above example, this involved questioning, and making relationships between constructs of fertilisation and embryo development.

Developing

Developing, reflected closely the "manufacturing metaphor" (Munby, 1986: 384). This depicted teaching actions as being enhanced to present the concepts within the content in multiple ways: as images that were constructed from many concepts; as images that were linked to many other related concepts; and as images that were able to stimulate and make students connect these concepts. The
participants' classroom discourse carried the common conception of "connecting", "linking", "constructing", "making", and semantic opposites like "breaking down" and "igniting into". For example, the lesson extract below illustrates Angela's teaching a topic on acids, alkalis and neutralisation. The computer technology's purpose within this topic was that of data logging and graph plotting.

Angela: I am going to put the pH probe into each of the beakers...

[Angela places the pH probe into beaker A, removes it, washes it and re-calibrates it in the pH 7 buffer and then places it again into the beaker B]

Students: pH 10! pH 5!
[Students shout out the readings from the overhead screen connected to the computer terminal]

Angela: Which beaker has the Ammonium Hydroxide?

Students: Beaker A!

Angela: Look at the graph and see the pH change over time. As we go along, look at the trend!

[Angela adds alkali in beaker A to a burette which dispenses the alkali into beaker B which has the pH probe in it]

Angela: What do you think is happening? Let me repeat the experiment and this time look at the graph that is produced, tell me what is going on.

[Later on in the same lesson, students are measuring the pH of the solutions they had brought from home]
Angela: Now this group is measuring the pH of soft drinks. How does the gas in the soft drinks affect the pH...what is the pH measurement when you first open the can and measuring the pH over time reveal?

[Another group of students voice their answers]

Students: Is it the loss of gas? Well the fizzing stops and the pH seems to change...it seems to increase slightly...

Angela: Well how did you all come to that conclusion?

Students: We compared our pH graphs to that plotted before (students refer to the plotted graphs) but we added nothing to it, when we opened the can there was only the fizzing...May be the gas that is escaping could be the reason for the slight change in the pH (students show the plotted graph to Angela) Let's look at the can label, maybe it contains something that causes the change in pH when you open it...

Angela: That's good you are on the right track, now the pH increased slightly, refer to the graph again...

Students: On the can label it says sugar...lots of it ...carbonic acid, hey don't they pump carbon dioxide into canned drinks? Okay there is the acid, but we didn't add any alkali in to neutralise the drink, so why did the pH increase slightly?

Angela: That's good, it is not neutralisation, since there was no addition of alkali...looks like you are building up to a solution...

Students: Can we check up on the ingredients on the can label...
Students use the Internet to do a web search, some of the students use the textbooks to do an index search.

Students: It says carbonic acid...it breaks down to carbon dioxide...
Angela: Why?

I always first show them how to use it then after that I carry on with the discussion on acids, alkalis and neutralisation...the students can join in asking questions...continue the discussion. I let them try, they use the probe, it is a type of building which is part of project based learning...within the lesson we set up simple experiments just try to get a lot of graphs or tabulate results make then relate to the topic...they extend this to future experiment...will set them to relate what they learn...well, like the groups that were measuring the pH of soft drinks.

(Angela, Field note and accompanying anecdotal data, 12/04/99)

I may show them something first before we get into the discussion, in this case the computer technology enabled me to break down the topic on acids and alkalis...it enabled me to teach a certain concept...follow through with another example neutralisation... I bring in that part through and all that...

(Angela, Interview 5, 14/05/99)

This lesson extract and anecdotal data illustrate participants’ common conception of this psychological tool. Participants as facilitators, through this psychological tool of developing, were mediating the designated function of computer technology to provide the necessary interactivity. In the above example, the facilitator role was able to present the concept of acids and alkalis, by using the interactivity provided by the pH sensor and the graphs. A zone of proximal development was created when the participants used the pH sensor and the graphs to introduce the concept of neutralisation and the concept of weak acids (Carbonic acid as unstable and its dissociation into carbon dioxide and water). The pH sensors and graphs were used as thinking triggers by Angela, in this case, to
enable students to develop the concept of neutralisation by building connections between the graphs and the experiments performed. This was repeated in the second activity where students had to correlate their own experiments with graphs. Students were developing their own concepts, but the facilitator was developing the social context, through the facilitator roles and designation of roles for computer technology.

Equipping

The psychological tool of equipping mediated the process of using the computer technology for knowledge transmission/knowledge acquisition. Students gained the necessary concepts and content through using the computer technology. Participants encapsulated this psychological tool of equipping in a pluralistic way of mediating learning and teaching through powerful visual imageries or content delivered via computer technology. The following narrative illuminated the how participants engaged in “equipping”.

I don't like to use CD-ROMs where there are a lot of texts like the textbook. It must be something the students can benefit from. For example the Chemistry set CD-ROM which includes learning about the reactivity of metals. You see I can tell the students about the metals in the groups as you go down the group the metal becomes very reactive. But I cannot carry out the experiment because it is too expensive and dangerous. With the CD-ROM you can show them each metal one by one. As you move down the groups you make them predict what is going to happen. Different groups take turns to answer them. If you just explain the chemistry concepts you have to hope that your students can imagine what you are explaining, but with the CD-ROM or Internet they can make a "big picture". This helps them to imagine. I can also get the concepts across better and see how they grasp it. The big picture they form I usually ask them to sketch it or make notes, like the concept-mapping they like to do...I get to grasp what they know now and from there I move on...And
when you go down to caesium in the group of the Periodic table the students can figure out what is going to happen...
(Tan, Interview 4, 03/04/99).

Thus, the use of computer technology enabled participants to gain insights into the misconceptions or conceptions that students held. It also enabled the participants to correct misconceptions or to sustain correct student insights of concepts. Thus, the notion of equipping allowed participants to move beyond knowledge transmission to that of gaining insights through a partnership that was possible through the use of computer technology. As Tan explained above, this tool of equipping was not to be focussed onto gaining content or concepts only, but included teaching and learning activities that provided a social context where cognitive tasks and cognitive products could be displayed.

**Visualising**

Visualising as a psychological tool mediated a "vision and intellection" parallelism (Sweetser, 1991: 38) within the zone of proximal development. Visualising as a psychological tool mediated an environment that positioned vision, as provided by the computer technology, as a stimulus bringing about cognitive engagement or understanding of the surrounding environment. Participants were constructing teaching and learning environments where the computer technology was performing two crucial functions. First, the integration of computer technology was mediating the teaching and learning environment through animation or simulations of science concepts. Second, the use of computer technology fostered collaborative inquiry through scientific ways of observation and acting on the observation. Participants channelled the powerful imageries that the computer technology afforded into cognitive actions that made these powerful imageries plausible in the context of memorable and meaningful learning experiences. Furthermore, they captured this mediation by computer technology as multiple images of "capturing students attention", "focussing" and correlated to multiple images of "figuring out", responding to a "big picture" and
"manipulation". The following classroom case revealed how this psychological tool of visualising, leads to a partnership that fostered clearer visions of how students were gaining conceptual change. In this classroom case Sundari was using the computer technology to teach the topic on cell size and diffusion rate: surface area to volume ratio. Instead of just showing them the animation, the whole lesson was transformed into a lesson where that vision attribute of the computer technology was extended to a cognitive activity: "let them play around...manipulate...were able to figure out...the students told me what are the features..."

I was showing the students the cell size and how the cell size affects the surface area to volume ratio, which in turn affects the diffusion rate.... It was a software where I could play around with the size of the cells, at the same time as I changed these variables, the surface area to volume ratio values come up and the diffusion rate changes accordingly. So the students were able to see as I changed all these variables. From this animation they were able to figure out that in order for a cell to carry out diffusion at a maximum rate it had to have all these qualities. They could see the changes instantly, that is the best part of it; you change the variables and they can see it. I got the students into groups and let them play around. At the end of the lesson the students told me what are the features of a cell that makes diffusion efficient.

When you talk about surface area versus volume ratio, sometimes students are confused. Now! My students and me are able to manipulate, increase the percentage of villi and at the same time the surface area to volume ratio gets calculated and they are able to connect much faster.

(Sundari, Classroom case, 12/01/99)

Participants explained that visualising (that was prevalent within CP I) enabled them to co-ordinate activities that required students to externalise their conceptions or misconceptions. They performed tasks that captured and revealed
these conceptions and misconceptions to themselves and to their teachers. Activities were not to be reduced to just showing science concepts.

So far, the mediation of activity structures by psychological tools towards students' conceptual change was presented. The aforementioned presentation of findings illustrated how Angela, Anthony, Ning, Sundari and Tan constructed classroom meaning integrating computer technology. The focus now shifts towards the belief systems and the beliefs which were extant, encapsulating, enshrining and evoking the participants negotiations and mediations within this community of practice.

4.3.2 Participants' general belief systems and beliefs within CP I

4.3.2.1 Belief systems

Using the Attitudes About Reality scale (Chapter 3: Section 3.5) the researcher was able to reveal the participants' broader belief systems. Four participants, Anthony, Ning, Sundari and Tan reflected a social constructionist personal belief paradigm. This belief paradigm suggests that these participants viewed reality as being changeable and defined by historical and cultural factors. Furthermore they believed that social problems were a result of environmental causes and viewed control by factors outside oneself as a vital part of how society works. These participants were also less content with status quo and most likely viewed individual efforts toward social change negatively.

Angela, in contrast, showed a tendency towards the logical positivist personal belief paradigm. That is, she viewed reality as stable, irreversible and deterministic. Furthermore her perceptions of the world were taken from an internal or biological position and not a societal or environmental one. She was content with status quo and believed in individualistic determination of power and status rather than a societal determination.
It was also clear that most of these five participants were clustered around the midpoint range (112). There was no marked degree of any of these five participants being identified as having had a very strong personal belief paradigm that geared towards the extremes of the social constructionist-logical positivist continuum.

Next, these five participants’ beliefs distilled from the qualitative data are presented.

4.3.2.2 Participants’ beliefs

Five categories of beliefs emerged from the analysis of the data. This categorisation followed the convention set by Calderhead (1996). These categories included beliefs about:

- teaching
- students and learning
- teaching with computer technology
- students and learning with computer technology
- self as teacher

Each category of beliefs is explained next to reveal the intentions, action components and the context under which they operated.

4.3.2.3 Beliefs about teaching

For Angela, Anthony, Ning, Sundari, and Tan, the structuring of teaching actions: setting up of objectives; planning and managing of teacher-student/student-student activities; and accounting for the teaching and learning actions; were the focal units or action components of the beliefs about teaching. As Angela stated:
Good teaching has to be structured...so that students at the end of the lesson learn something not only from me but from their own experience as well, like experiments or activities they engage in...poor teaching is teaching where students go through the lesson, no feedback from them...teacher just used chalk and talk..

(Interview 3, 31/03/99)

Participants also made recurring references as to why these teaching actions were relevant to their students. They constantly related this relevancy to the institutional focus. As Sundari stated:

... of course one very important thing is preparing the students for their "O" level exams and so we are bound by the syllabus. So I always make sure that they understand the objectives of the lesson before they leave. Otherwise, they might lose focus and really don't know what they have done for the day...

(Interview 1, 12/01/99)

The dimensions of these beliefs about teaching emerged in connection with their views of students and their learning. Participants suggested that by structuring teaching, teaching was open to students. As Ning elaborated

... the only way to make lessons meaningful is to link the lesson to students’ everyday life examples...something that is real life, something they can relate to...provision of examples from me and the students...this teaching strategy in general gives the ability to assess how and what they have learnt and of course make means available to correct misconceptions...

(Ning, Interview 3, 25/03/99)

Students became active contributors and members to both teaching and learning actions. They also suggested that this enabled students’ educative performance:
constructing their own knowledge and meaning. To participants this opening up of teaching also enabled them to gain insights into their students' learning.

Overall, the five participants' beliefs about teaching carried the conception of teaching as a mutual investment for both themselves and their students. That is, the structuring of teaching gave opportunities to make provisions within teaching actions to accommodate students as partners.

4.3.2.4 Beliefs about students and learning

In shaping their comprehension of what was to be planned and enacted in their classrooms, participants alluded frequently to the characteristics of their students. Their beliefs about students were also located within the overarching context of students' conceptual change in relation to the national exams.

...students as groups or pairs can discuss and communicate ideas and think about the concepts they are learning with me and themselves...you should also bring them back and show them that these are the objectives that have been covered so that when they leave the classroom they know exactly what has been done...Sometimes during their self-learning activities like discussion, they tend to go astray, so wrapping up the lesson is essential (Sundari, Interview 3, 25/03/99)

The comment above was typical of five of the participants' expressions of this belief about students (Angela, Ning, Anthony, Sundari and Ning). Students had to be actively involved in the teaching and learning processes by assuming the roles of active contributors or as active members. This quote also illustrated the nature of accountability that was sought by participants especially during self-learning activities.

Related to participants' beliefs about students were the beliefs about learning: the nature of learning; nature of learning roles and responsibilities students had to
adopt. For, Angela, Anthony, Ning, Sundari, and Tan, their desired approaches were either self-regulated learning and/or teacher-student interactive learning and/or group learning or a combination of two or three of these approaches. These were closely correlated to their beliefs of students as active contributors and members. As Anthony explained,

Well you need to get everyone involved to participate...involved...work together. No doubt the work comes from you but then like a captain of a ship you delegate duties to your students but he must be in charge yet able to gather all of them together...

(Narrative from metaphorical statement, 08/05/99)

These beliefs about students and learning were reflected in participants' teaching approaches as well. The following excerpts from interview transcripts and narrative data were evidence of this. (This was a crucial link as no observations of participants’ classroom teaching without the integration of computer technology were done by the researcher). As Tan and Sundari elaborated:

I always like to demonstrate chemistry concepts that my students have to learn. To me this is like creating magic shows. I am the magician and they the audience. Then I will want them to think about what I am teaching, the magic show. They get involved in the demonstrations, they try to figure out the magic behind the magic show. Now chemistry is a lot of fun. They enjoy it and at the same time they are figuring out asking me how I did it... they try it out and they tell me...relating it. That's good they get an experience of doing chemistry...

(Tan, Narrative derived form metaphorical statement, 17/04/99)

To me poor teaching is where the teacher goes into the class just teaches and walks out without drawing any student conceptions or misconceptions. Not having activities, that get students going into the topic, discussing among themselves...questioning the teacher or themselves...Communicate
their ideas, think about the concepts taught, discuss it with me or themselves...
(Sundari, Interview 3, 25/03/99)

Overall, Angela's, Anthony's, Ning's, Sundari's and Tan's beliefs about students and learning carried the conception of learning as a student activity involving self-regulated learning and/or active contribution and membership within teaching and learning actions leading to the personal construction of knowledge.

4.3.2.5 Beliefs about teaching with the integration of computer technology

The participants' beliefs about teaching with the integration of computer technology paralleled their beliefs about teaching. Most participants' responses suggested that the computer technology was a multipurpose tool that enhanced their teaching actions and this was related as providing interest/motivation dimension to teaching and learning actions: the mutual investment perspective. Angela, Anthony, Ning, Sundari and Tan also suggested that they were able to include actions like gaining immediate insights into their teaching actions and students' learning actions. As Tan stated,

If you just explain the chemistry concepts you have to hope that your students can imagine what you are explaining, but with the CD-ROM or Internet they can make a "big picture". This helps them to imagine. I can also get the concepts across better and see how they grasped it. ...I usually ask them to sketch it or make notes, like the concept-mapping they like to do...I get to grasp what they know now and from there I move on...
(Interview 4, 03/04/99)

Participants made explicit references to how the specific actions and intentions were related closely to students' conceptual change. Furthermore, reference was also made to the use of computer technology and its relevance to the content being
taught. That is, how it was related to a teaching action or learning action conducive to the process of students' conceptual change.

All five participants located in community of practice I expressed the need for precautionary measures to check students' learning in lessons that used computer technology. There were usually worksheets to be completed up by students as they participated in lessons with the integration of computer technology. All participants reported that teacher questioning and teacher-student discussions were "part and parcel" of the teaching and learning actions taking place in lessons with the integration of computer technology. The participants appeared to have the need for a shared responsibility towards learning actions. This shared responsibility was expressed as enabling the participants to account for students' learning and for students to account for their own learning. It also allowed the participants to check on students' learning by listening and commenting on worksheet answers. This precautionary measure was reportedly a necessity as participants stated that students might get side-tracked by the attributes of the computer technology and worksheets, for example, were a way of keeping them focussed. Precautionary measures were highly context specific and were observed in action whenever participants had created learning situations. The focus group interview revealed the participants' beliefs about the need for such precautionary measures.

Anthony: In the real exam they have to express it in words, yes the computer technology helps to make learning easy, but whether they can put it down in paper is a concern that we always look into...

Angela: Yes! We need them to show us concrete work that they have done...like a follow up...
Tan: Where they put down key points, so that they have something to take home, those things that they grasped during the lesson...we can be sure they have got it down...

Sundari: A kind of reinforcement goes with any kind of lesson, not just with computer technology, even traditional teaching...in order to check to see if they have learnt the right things we always accompany our lessons with a worksheet to check understanding....

[Everybody agrees in unison]

(Focus group interview 1, 12/02/99)

The emphasis lay within past experiences of teaching as well as the need to provide a sense of accountability for learning to have taken place on their part as well as on the students’ part.

4.3.2.6 Beliefs about students and learning with the integration of computer technology

Participants’ beliefs about their students in a teaching and learning environment with computer technology were closely aligned to their beliefs about students in general: active contributors and members of teaching and learning actions. Participants suggested that the use of computer technology in teaching and learning situations stimulated students to use their cognitive abilities. They stated that students’ learning processes were transformed with the integration of computer technology. Ning and Tan expressed that their students' use of computer technology, especially in the process of acquiring information from the CD-ROM or Internet, gained them the cognitive ability to "screen off" information that was irrelevant to the lesson. Sundari elaborated on how her use of computer technology and students use resulted in students creating their own learning skills.
Participants suggested that the use of computer technology meant that students participated more in their learning leading to critical thinking and learning situations where they were being challenged to go beyond the concepts they had learnt or the concepts they held. They also perceived that the integration of computer technology provided students with opportunities to visualise and better understand the concepts to be learnt. It also made them independent learners as they were now able to access information and discover the content for themselves. These perceptions captured by Tan's and Angela's comments were typical of the participants.

With the computer technology you can get across a lot of abstract chemistry concepts. If you just explain and explain, you have to hope that the pupils can imagine the explanation. But with the computer technology, using the Internet or the CD-ROM they can see and make a big picture and this helps in their imagining of the chemistry concepts. I think I can get the chemistry concepts across better and the students should be able to grasp the concepts better. For example when you talk about molecules or atoms moving, in the past I had to get the students to imagine the process. But now with the animation they can see the process. Pictures of electrons jumping from one shell to another so at least you can get the chemistry concepts across better...

(Tan, Interview 2, 22/02/99)

With the use of computer technology it is not the teacher doing all the activities. The students themselves are doing the activities, they are the ones who find out the content. Well I can let the students explore more about pH using the data loggers, they measure the changes and they come up with the conclusions for the changes...

(Angela, Interview 4, 29/04/99)
4.3.2.7 Beliefs about self and teaching role

The personal belief that was most commonly projected was the need to share their love (Anthony and Ning) or interest (Angela, Sundari, and Tan) of their teaching subjects with their students. They felt that this sharing would instil in students a similar passion for the subject as well as lead them to become inquisitive and delve deeper into the subject. Participants felt that by using the attributes of the computer technology, like its interactivity and its ability to portray animations and simulations of scientific concepts and processes to their students, they would transfer their interest or love of their teaching subjects to their students. This belief was also shaped by the intention that since computer technology afforded these attributes, participants were able to bring about conceptual change in students’ naïve conceptions of scientific theory. They saw the attributes not only as evoking interest in students, but becoming part of their teaching role; an extension of teaching actions not possible before. As Ning expressed:

Now I can reach out to students and give them the desire to know more about the subject, reaching out to love the subject, to get interested and along the way they can communicate and demonstrate the...extend it to daily life in what they see and do.
(Interview 3, 25/03/99)

Normally before it is just touch and go, but this time around with the use of computer technology they get to do the Physics experiments on the spot and I am able to do it as well students are actively doing it... with the data loggers they are not just seeing the experiments they do it, collect data, evaluate the data and they are making the meaning by themselves, making links going beyond...I am there as the teacher who provides these settings but it is more than that I can actually see their learning I am actively doing it...the teaching...not I give they pick up...
(Interview 4, 27/04/99)
Typically the participants' view of their facilitator role rested on their need to provide a teaching or learning environment that enabled them to bring about educative moments that enabled students to be active contributors and members.

Next, the focus shifts to the community of practice II, the negotiations, mediations and beliefs extant within this community of practice

4.4 Community of practice II

CP II was different from CP I in a number of ways, but shared some common aspects with CP I. First, CP II, was not organised by an imagery of lesson as a moving object. Instead, CP II was conceived as a teaching practice based on the need to consolidate and reinforce instruction taught by traditional methods. The use of computer technology provided this substantiation of instruction taught by traditional methods. The evolution of this community of practice, just like CP I involved a number of negotiations: acquiring a facilitator role; designating a role/roles for the computer technology; and positioning students within the classroom context. Woo's focus and the interpretations for these negotiations differed significantly from the rest of the participants. These negotiations like in CP I, provided the structures and strictures/cognitive guides that collectively took the form of activity structures. In this activity structure, the use of computer technology had to cohere with the instruction taught by traditional methods. Furthermore, Woo designated the computer technology with roles that enabled her to reinforce and consolidate students' social academic competence, the competence gained through instruction by traditional methods. These designated roles assigned to the computer technology in CP II, differed from designated roles for the computer technology in CP I, where the designated roles for computer technology were correlated with the social participation structures and the academic tasks. Another major difference that distinguished CP II from CP I was found in the psychological tools that mediated the activity structures within CP II. These psychological tools carried the perception of consolidation and maintenance.
CP II was predominant in Woo's classroom teaching with the use of computer technology. This community of practice materialised as an adjunct to teacher-centred approach. This community of practice was a follow-up to the Woo's teaching actions and involved the students' using computer technology to consolidate what was taught by Woo. This community of practice was unlike CP I where computer technology was a part of the teaching and learning actions. Furthermore, the researcher cannot claim to make inferences about the activities that had occurred before the use of computer technology. Thus, this presentation of community of practice centres only on Woo's use of computer technology.

Data revealed that students faced a number of tasks within this community of practice. First, students were exposed to powerful visual imageries that Woo now showcased with the use of computer technology. Second, students were to consolidate their learning by looking at these visuals or through revision exercises that the computer technology afforded. Another task that students had to follow was the adherence to the guidelines and frameworks that Woo had given out as instructions. This was especially so when students used the computer technology on their own. This gave a sense of proceduralised/routinised format that involved teacher scaffolding of every learning moment for students.

The use of computer technology signalled a change in the social structure, and marked the occurrence of CP II. Students were to be on task following the guidelines and frameworks that Woo had set up for them. This social participation structure catered solely for the reinforcement of academic demand covered by teacher-centred teaching. Students were to gain content and consolidate their knowledge.

Woo's contribution throughout this community of practice was to maintain the academic demand structure by providing the physical materials through which students accomplished educative experiences like gaining the content. The cues she utilised towards achieving these educative experiences seemed not to be related to the content. They focussed more on students being on task to gain the
content. Woo practised a form of social gate keeping that brought about a patterned set of interactional rights and obligations. Functional slots with the use of computer technology were sequenced and timed by her during the lesson. There was a high recurrence of actions that centred on Woo. Students' actions were restricted to that of following guidelines and frameworks.

Accountability within this community of practice was conveyed in the form of worksheets. These worksheets were the ones that contained the very guidelines and frameworks that students had to follow. Worksheets were proposed as a good recipe for preventing student distraction, digression from the subject at hand and served as a measurement of students' content gain from the computer technology. Lastly and most importantly this worksheet enabled the student performance of consolidating the content taught by Woo.

### 4.4.1 Positioning students

Woo embedded the interest/motivation dimension away from her framework of teaching and learning. It existed as a reinforcement of what was taught, thereby maintaining students' interest in her teaching, the topic taught and for the consolidation of student learning. As Woo stated,

I show the students photographs (downloaded from the Internet) of tropism and I ask the students what is the stimulus. Why is the plant behaving this way...I think it is basically good, it adds interest to the lesson...I actually use it as a question and answer session like after teaching a certain concept or topic. I will show animation or simulations using the computer technology and ask the students questions... it will be meant to be a revision of what they have learnt (Classroom Case, 25/05/99).

Woo expressed that this interest/motivation dimension imparted a novelty effect that maintained continued interest in both her teaching and the topic. This was
marked by her recurring reference to the "novelty wearing off". Her use of computer technology within CP II was demarcated and delimited by this strong philosophy. The following comment further substantiated Woo's perception of the interest/motivation dimension and its impact on her positioning of her students within the community of practice she was socialising them into.

Teacher teaching is more effective than if you were to let students explore on their own, it is because self-exploration is good only if the students are very motivated. Computer technology helps as a tool...it opens up new things students can explore things they cannot find in textbooks...It is best used after the concept is attained rather than during the process of attaining it. It is more consolidation rather then the teaching part.

(Interview 3, 30/03/99)

4.4.2 Designating a role for the computer technology

The designation of computer technology within this community of practice was basically geared towards computer technology serving as a tool to provide variety and as a tool for visualisation. Although this designation reflected Woo's conception of computer technology as a multipurpose tool, she did not associate this attribute within the processes of students' conceptual change. Data revealed that the designation functioned as a proceduralised process: visualisation adds variety and both lead to interest and reinforcement of taught concepts.

...if the students have already understood the concepts I can show them how the concepts are applied using the computer technology, this consolidates their understanding...with the help of the animation...

(Interview 1, 25/01/99)

After I teach a certain topic, my students can explore the CD-ROM or Internet where an interactive program might be available. Through
practising the interactive software they can discover more content on their own.

(Interview 2, 26/02/99)

The designation itself was cemented by two conceptions that did not juxtapose the computer technology within the students' process of conceptual change. First, the designation was weighted by its novelty effect. That is, its attributes like the powerful imageries it provided were related to maintain interest and motivation onto the content. The relevance to students' conceptual change was not referred to.

I actually use it as a question and answer session. After teaching a certain topic then I will show the movie clips or show the photos (downloaded from the Internet) and I will ask them questions which are meant to be a revision of what they have learnt.

It was also evident that computer technology was utilised for topics which were perceived as boring. But Woo also believed that prolonged use of computer technology would result in the novelty wearing off. The use of computer technology was also clearly demarcated and delimited by this philosophy that Woo held.

Woo's designation of the computer technology was highly structured and confined to her use only. The students were seen as passive recipients and the computer technology an 'add on' to their learning activities. If lessons involved students using computer technology, it entailed detailed guidelines and frameworks. These guidelines and frameworks cohered with the content already taught.

I would end up saying that it is a good means of consolidating what the students have already learnt, the concepts they have attained. For example, a concept in photosynthesis...But first you must know what the meaning of photosynthesis, like what are the reactions involved. But if the students use
the computer technology from scratch without having any knowledge of the lesson, I don't know how effective that lesson would be.

From the above comment it was also obvious that Woo's designation of a role for computer technology was highly structured by her own experience of not seeing any plausibility for computer technology to aid student learning other than consolidation and providing interest/motivation.

4.4.3 Acquiring a facilitator role

Woo's facilitator role functioned to maintain the interest/motivation dimension and consolidate aspects of her teaching. This role was far removed from the processes of students' conceptual change. In fact it was more in tune to making sure that the computer technology was providing powerful visual imageries or attributes that enabled students to consolidate the content taught by Woo. The facilitator role did not derive its functions from positioning of students nor the designation of roles for the computer technology.

4.4.4 Psychological tools: Maintenance and consolidation

Woo also held multiple psychological tools that seemed to mediate her teaching with the use of computer technology. The common denominator that linked these psychological tools was the mediation of students' learning through consolidation and maintenance of content taught by instructional processes prior to the use of computer technology.

Maintenance

This psychological tool of maintenance seemed to be predominant in Woo's teaching with computer technology. Woo used the computer technology to maintain students' interest/motivation in her teaching. The common genre of
metaphoric language that Woo used to describe the role of computer technology was that of "hold their interest" and "hold their attention".

Consolidation

Woo's use of computer technology sought to consolidate learning. Students were to gain from the computer technology powerful visual imageries that would enable them to consolidate their learning.

In keeping with the images of maintenance and consolidation was Woo's "The teacher as..." metaphor for her teaching actions with the use of computer technology, head chef. The head chef encapsulated the image of Woo as a teacher being in complete charge of the teaching and learning actions that occurred with the use of computer technology. As Woo stated:

I give the outline...the skeleton...like where to go but the details along the way they will fill it up by using the computer technology...So if they have a fat skeleton I mean one that has lots of meat on it that means the students have a greater amount of knowledge...if it is a thin one that means they have not looked hard enough or they were distracted along the way, distracted by a lot of other things...that is not productive time spent...
(Narrative from metaphorical statement, 14/05/99)

The above narrative pointed out that Woo was delegating tasks to her students to accomplish this with strict regulations as accountability seemed to be placed on high stakes in this setting. Furthermore every step that students took seemed to be monitored. This image of teaching with computer technology was underpinned by the perception of computer technology being visualised as a novelty. That is, something that needed to be controlled and used not too often, as using it too many times would lead to the novelty wearing off.
4.4.5 Woo’s general belief system and beliefs

4.4.5.1 Belief System

Woo had a balanced viewpoint (a score of 112), that is her personal belief paradigm centred between social constructionism and logical positivism.

4.4.5.2 Beliefs about teaching

For Woo there was an overarching reference to her structuring of teaching in relation to students’ conceptual change. As Woo stated:

Teacher is the heart and the students the arteries, knowledge is the blood. The heart pumps blood into the arteries. (Metaphor for teaching, 16/04/99)

From the above comment, it was obvious that Woo’s beliefs about teaching encapsulated a teacher-centred approach. All teaching actions and learning actions were planned and directed by Woo. This belief was connected to the need to structure the lesson that she was going to present to meet the students’ needs.

4.4.5.3 Beliefs about students and learning

Woo alluded frequently to her belief of students' knowledge being incomplete. She also explained that students' prior knowledge had to be deduced by teachers as students held misconceptions that had to be corrected by teaching actions. This belief about students interacted with her notions of what student learning entailed. For Woo, this meant that student learning had to be completely controlled by the teacher. The process of learning was seen as students gaining the content that she was transferring. Woo’s beliefs about teaching, students and learning were reflected in the accompanying narrative.
Basically here I am trying to say that the students' knowledge is incomplete. ... teacher is like the heart, without the teacher the students' knowledge cannot flow. Thus, the teacher feeds the knowledge to students. The teacher will be the giver and provider of knowledge, students like arteries receive blood or the knowledge directly from the heart, the teacher.

(Narrative derived from metaphorical statement, 25/05/99).

Woo's conception of learning had a strong dimension that related to the teacher as the sole purveyor and transmitter of knowledge and the one who constructed meaning for students.

4.4.5.4 Beliefs about teaching with the integration of computer technology

Woo's belief with respect to teaching with the integration of computer technology varied considerably from the rest of the participants.

I think there must be a lot of structure...if you don't tell the students exactly what they are looking for they will become distracted...They must know what they exactly have to do. If you don't structure the work for them, in the end they might all go around looking at this and that, and in the end not gaining anything substantial...If the students have already understood the concept I proceed to show them how the concepts are applied using computer technology, this consolidates their understanding...

(Interview 3, 25/03/99)

I give the students a brief outline to explain a particular concept, a concept is just a concept but if they don't know how it is applied or what are some examples of it. It is likely that the students will not remember or understand very well. But if you can show it visually what it looks like maybe the students can understand better. Like for example when I did the eye topic, showing accommodation. How the eye accommodates to
viewing near and far objects. I found this movie clip from the Internet that shows what happens when an object is brought close to the eye. It showed the ciliary muscles contracting then it shows the suspensory ligaments and lens changing shape ...that was quite good ... students could see it. ... I find that with the Internet it is easy to start and stop; it is faster... I can just tell them the definition of accommodation and what happens when you look near or far objects. But these are just words and pictures in the textbook. But with the Internet you show the students visually it is clearer in the sense that it actually shows how accommodation happens...
( Classrroom Cases, 25/01/99).

Woo’s conceptual orientation, as depicted by the above comments, revealed that she evaluated her teaching with the use of computer technology with her beliefs about teaching. The emphasis on her use of computer technology showcased this perspective. There seemed to be an exclusive emphasis on her use of the computer technology in the classroom rather than that of her students. Interestingly, her beliefs about computer technology were not interdependent, interrelated or intertwined with her beliefs about teaching with the use of computer technology, like the rest of the participants. She believed that the computer technology provided the interest/motivation dimension like her colleagues but this was conceptualised differently. Her perception revealed that this dimension was to maintain students’ interest in her teaching and the content taught. She also believed that the computer technology was a tool that enabled students to consolidate what they had learnt. Use of powerful imageries, possible with the computer technology, were alluded to constantly by Woo as actions that seemed to consolidate student learning of what she had taught. In contrast to the rest of the participants, her beliefs about computer technology were not intercontextualized with beliefs about teaching and learning. They seemed to occur outside the realm of her teaching and learning actions.

For Woo, the need to have precautionary measures stemmed from the necessity to keep students focussed onto the task at hand with the use of computer technology.
Strict guidelines were implemented and were printed onto students' worksheets for students to follow.

You have to have a well-defined worksheet that tells the students specifically what to do. If there are no guidelines to follow, the whole lesson is wasted. They are using the computer technology to build up the "skeleton", but the framework is already there and I am the one who provides the framework...

(Interview 3, 30/03/99)

Her perception for using precautionary measure was situated in a different context from that of the other five participants. Her view was that the main purpose of the worksheets was to maintain the teacher-centredness of the learning process. That is, it was closely related to her perception that the teacher had to be the only one to deliver content to the students.

4.4.5.5 Beliefs about students and learning with the integration of computer technology

Woo on the other hand revealed her beliefs about computer technology as a tool that stimulated student interest and motivation in the prescribed content.

Actually although it is basically very helpful in terms of teaching and learning. It will be very good if we have a lot of time to go out and source out all the best photographs and movie clips. Giving the students to explore on CD-ROMs, which we have very little time for. But actually I can incorporate computer technology into every lesson but maybe one or two minutes at the end of the lesson after we have learnt a certain concept I show them a photograph of tropism and I ask the students what is the stimulus. Why is it behaving in this way at least there are photographs to help them see what tropism is.
I think it is basically good, it adds interest to the lesson if it is used for the right purposes and not for the sake of using the computer technology and the whole lesson is based on the computer technology.

After a while the novelty wears off...you should use it here and there and only bits of it...But let's say if I want to show some pictures or movie clip from the internet I actually use the computer technology during question and answer sessions for example after teaching a certain topic. I will show the movie clips or show this photos I will ask them questions it will be meant to be like a revision of what they have learnt.

(Classroom Case, 25/01/99)

Thus, Woo perceived that students had to be kept interested in her teaching and the topic and the use of computer technology assisted in doing this. This cohered with her belief that it was teachers who made students' incomplete knowledge complete. Thus, learning with the use of computer technology was relegated to seeing imageries of taught content and consolidating taught content.

4.4.5.6 Beliefs about self and teaching role

Typically the participants' view of their facilitator role rested on their need to provide a teaching or learning environment that enabled them to bring about educative moments that enabled students to be active contributors and members. Interestingly Woo expressed this belief about self as;

I think it is to instil in my students an interest in the subject so that it goes beyond just answering exam questions...to instil an interest...to such an extent that they will look up information on their own...read beyond the textbook even though they know it is not in the syllabus,

and substantiated it with intention in relation to computer technology use as;
...opens up new things...they can explore things they cannot find in the textbook...pictures, photographs, experiments...learn a lot of things and experience a lot of things....

Thus, Woo's belief about being a facilitator not only involved utilising the computer technology to consolidate and maintain content taught by instruction prior to the use of computer technology, but also to bring about an interest beyond what had been taught. In this way she was seeking to encourage ongoing learning.

4.5 Summary

This chapter has attempted to capture the teaching actions that were extant within the cultural context studied. These teaching actions with the use of computer technology were captured as two distinct communities of practice: created by negotiations and mediated by psychological tools. Firstly, the findings reflect the various negotiations of meanings leading to negotiations for actions among participants who make up the community leading to actions that reflect the practices of that community (Lave & Wenger, 1991; Wenger, 1998). Secondly, findings provided a focal point for the study of participants' teaching practice (Davis & Sumara, 1998; Erickson, 1991; Mitchell, 1994) which parallels the importance of communities of practice within educational research. Findings, within this study also revealed that participants' construction of classroom meaning centred on interpretations that characterised the thinking of participants. This paralleled the characteristics of thinking within communities of practice which provide the structures and strictures for the functioning of the communities of practice (Stewart, 1996). Finally, the analysis of data revealed that findings were encapsulated by the culture and customs which depicted the institutional, instructional and classroom foci of the phenomenon under investigation. Thus, this paralleled the characteristic of communities of practice being shaped by culture and customs that develop concurrently as the communities of practice function around a value. Participants' beliefs were presented after the presentation of the extant communities of practice, to show how they influence the structures.
and strictures and negotiations for actions responsible for the communities of practice.

The next chapter aims to frame these findings within the theoretical framework derived in Chapter 2 of this study.
Chapter 5

Interpretation of findings

5.0 Introduction

The findings of the previous chapter constitute an attempt to reconstruct how participants in this study construct classroom meaning integrating computer technology into teaching. This presentation of the constructive process was organised along two dimensions: first, the negotiations and the mediations which were inherent within the communities of practice in which participants were situated; second, the beliefs that structured these communities of practices and the inherent negotiations and mediations within these communities of practices.

Thus, the previous chapter was used to present how participants in this study construct classroom meaning within the extant communities of practices they built with their students and the computer technology and how their beliefs influenced the construction of these communities of practices. Now, in this chapter, the researcher revisits the initially articulated theoretical endeavour stated in chapter 2 of this study.

5.1 Discussion

Data showed that five out of the six participants, Angela, Anthony, Ning, Sundari, and Tan showed an integrated approach to teaching with the computer technology, while Woo showed a supplementary approach (Doornekamp & Carleer, 1993) to teaching with computer technology. This interpretation was agreed upon consultation with the review of the literature (Chapter 2: Section 2.1.2), where the indicators of integration (p.25-26) and the spectrum of teachers' approaches to the use of computer technology in the classroom were reviewed and stated (Section
2.1.2: p. 23). Angela, Anthony, Ning, Sundari and Tan had incorporated the computer technology into teaching actions, the computer technology as an integral part of the instructional processes that they had constructed to bring about students' conceptual change. Woo's teaching actions are also included. This is because, both Woo and the five participants showed common elements that contributed to their construction of classroom meaning with the use of computer technology. Furthermore, this comparison also substantiates the findings by better locating how each type of construction of meaning occurs. Table 12 captures the salient similarities and differences between the two types of teaching approaches that emerged from the findings. Table 12 lists the similarities that existed between Woo's supplementary approach and the rest of the five participants' integrated approach in terms of the negotiations that led to their respective teaching approaches with computer technology. This table also lists the fundamental differences that existed between the two teaching approaches in terms of the characteristics of the psychological tools, the nature of lessons, the presence of the zone of proximal development and the beliefs held by participants. The focus now shifts towards the discussion proper.

5.1.1 Mindset

Findings showed that participants did have a mindset (Bigum, 1997; Lankshear & Snyder, 2000)/a way of thinking (Morton, 1996; Muffoletto, 1994; 1996; Saloman, 1998)/cognitive empathy (Carter, 2000; Mandinach & Cline, 1994; 1996; Perkins, 1985; Perkins, Crismond, Simmons & Unger, 1995) towards the construction of classroom meaning with the use of computer technology. This mindset/way of thinking/cognitive empathy took the form of negotiations involving positioning students; designating roles for computer technology; and acquiring a facilitator role. All of which took into account the computer technology within the social and cultural context. These negotiations themselves were made up of contributing elements.
### TABLE 12

**Salient features: similarities and differences between two approaches to construction of classroom meaning**

<table>
<thead>
<tr>
<th>Angela, Anthony, Ning, Sundari and Tan</th>
<th>Woo</th>
</tr>
</thead>
<tbody>
<tr>
<td>Integrated approach</td>
<td>Supplementary approach</td>
</tr>
</tbody>
</table>

#### Similarities

- **Negotiations:** Positioning students, designating roles for computer technology; acquiring a facilitator role

#### Differences

- **Psychological tools:**
  - Supporting
  - Developing
  - Equipping
  - Visualising
  - Consolidation
  - Maintenance

- **Lessons as journeys:**
  - Lessons were not depicted as journeys

- **Zone of proximal development:**
  - No zone of proximal development

#### Beliefs

Positioning of students involved two elements: mutual investment perspective and the interest/motivation perspective. These constituted the participants’ need to position students into joint participant and student activities such that both were part of the instructional processes. Although participants did have interpretations that alluded to the notion that this positioning was also to get students interested in the instructional processes. For Woo, this interpretation seemed to be dominant. The rest of the participants did allude to this interpretation but seemed to channel it towards the working of the joint instructional processes. This was usually based on the notion that it brought students closer to the content.

The designation of roles for the computer technology involved an interaction with the above two perspectives present within the positioning of students. It also
included participants’ perceptions of how the computer technology should function within the classroom context: in the very process of transferring cultural templates. This included the need for the computer technology as a tool for interactivity and as a tool for visualisation. This designation of roles for computer technology was demarcated and delimited by the participants’ perception that this role should not just harbour the prospect of students “picking up” content. This interpretation was solidly grounded on the notion that it reflected prior traditional forms of teaching which centred on transmission of content and lacked joint activity of instructional processes that their designations of computer technology now provided. But participants did hold perceptions that contributed to this negotiation in other ways as well. They stated that they were not sure if using computer technology would enable them to bring about students’ conceptual change in all their students and hoped that the interactivity and visualisation might be able to achieve this together with the joint participant and student activities of instruction.

Woo’s designation of roles for the computer technology on the other hand, centred on the prospect of it reflecting her instruction, done prior to teaching using computer technology. Furthermore, her designation centred on the perception of computer technology as a novelty effect. This novelty effect, though not explicitly mentioned by the rest of the participants, was to maintain the students’ interest on the content. Unlike the rest of the participants, who used this aspect as one of their reasons for the designation of computer technology to position students, Woo seemed to rely on this novelty aspect alone. Furthermore, she stated that her decision to use computer technology was based on this novelty effect as well.

The facilitator role itself took into account the need to perform teaching actions like wrapping up the lesson. Participants claimed that no matter what the computer technology could do or not do and no matter how well the students were involved in the joint participant and students’ activities of instruction, the participants had to bring the students back to the lesson’s objectives. This was a direct consequence of the cultural context, where students were preparing for
national exams. But this was also interpreted as acts of accountability that teachers perform in any classroom context. These interpretations strongly correlated to the recasting of the facilitator role into the guide role. Again, it was not the sole imperative of using the computer technology by the participants that caused these role acquisitions. These roles were evident because they took into account the social context capturing students, computer technology and participants: the interactivity of the negotiations for positioning students and designating roles for the computer technology (Mandinach & Cline, 1994; Scrimshaw, 1997). In stark contrast to the rest of the participants, Woo's facilitator role was based on using the computer technology to reflect her previous instruction. Positioning students was not factored into this negotiation for a facilitator role, although she did mention that she was a facilitator when using the computer technology. This was interpretation cohered with the functional aspect of the facilitator's role: providing guidelines for students' utilisation of computer technology.

Thus, participants (except Woo) in this study did not demarcate and delimit the computer technology as a sole imperative for teaching or learning: educational computing as teaching (Bowers, 1988). Instead, the use of computer technology was factored and sieved through the other elements within the social and cultural context in which they were situated. It reflected a way of thinking (Kerr, 1991; Marton, 1996; Mufolletto, 1994; 1996; Saloman, 1998) that the computer technology was more than a tool because it was factored into the human elements of the social context and the values they were trying to accomplish. The participants' mindsets also cohered with Saloman's (1998) contention that computer technology provided the needed tools for novel teaching and learning actions. But, the features inherent within the negotiations made these novel teaching and learning actions materialise. In this study, novel teaching and learning actions were not attributed solely to the computer technology but how the computer technology was factored interactively with the other negotiations.
5.1.2 Negotiations: Programs of actions/Balancing of incentives and disincentives/Amplifications and/or reductions

As the above discussion has shown, the inherent negotiations within participants’ mindset showed that they were not static constructs that participants picked and chose. The negotiations themselves acted like programs of actions (Bigum, 1997; Bromley, 1997; Bromley & Apple, 1998; Lankshear, & Ball, 2000). As the findings have shown, negotiations were interactive: elements within the designation of roles for the computer technology, acquiring a facilitator role, and positioning of students were all interactive. These negotiations took into account the perception of the roles and the modes of operation of the other integral agents in the classroom context. The designated roles for computer technology were balanced with that of the facilitator role and the positioning of students such that a social context of interaction with the cultural templates was maintained, rather than a context of gearing towards the computer technology (Knupfer, 1993). Thus, the balancing of incentives and disincentives is centred on the human elements of the classroom context and does not just pertain to the computer technology. In this study, this interpretation was built up from participants’ need to maintain the joint activity of instructional processes.

The interactive nature of the negotiations was also indicative of the amplifications and/or reductions that Bowers (1988b; 1998a; 1998b) claimed as marking the cultural transmission process when computer technology becomes part of this process. The negotiations for designating roles for computer technology were amplified and/or reduced by the negotiations for positioning students and acquiring a facilitator role. The computer technology’s attributes of animation, simulation and interactivity were directed towards joint activities of instructional processes instead of the computer technology running the whole teaching and learning process. These selective attributes of the computer technology, animations, simulations and interactivity, were themselves mediated by the other negotiations in this cultural context.
On the other hand, Woo's negotiations did show these programs of actions, balancing of incentives and disincentives, amplifications and/or reductions however the inherent features of the negotiations seem to determine the course of the teaching and learning. For example, the designation of computer technology was determined on its novelty effect. This seemed to be the overriding concern in the way the negotiations led to an activity structure that did not reflect teaching actions integrating computer technology.

Finally, the mindset and the negotiations (programs of actions/balancing of incentives and disincentives/amplifications and reductions) showed open processes of interactions and deliberations that led to the creation of communities of practices (Lauzon, 1999; Olson, 1997). The findings indicated that human negotiations that factored the computer technology into the very processes of teaching and learning were the key determinants for the construction of these communities of practices. The academic demand structures and the social participation structures were a result of participants' negotiations. This concurs with Lave and Wenger's (1991; 1999) perception of what constitutes a community of practice: legitimate peripheral participation, learning activities and the role of the teacher in organising communities of practice. That is, negotiations, access, and engagement are crucial to the perception of a community of practice. On the other hand, Woo's factoring of the computer technology to perform teaching acts of consolidation and maintenance of instruction created communities of practices that reflected the computer technology's role as a determinant.

So far, the discussion has revealed that participants' construction of classroom meaning involves a multitude of interactive components that set up the activity structures in which teaching and learning actions occur. These negotiations and activity structures support the contention that teachers subscribe to both instructional and learning paradigms (Lasley, 1998). In this study the negotiations leading to CP I included both paradigms, while CP II included only the instructional paradigm. Furthermore, the facilitator role was more than temporal and, spatial (Linn, 2000; Linn & Slotta, 2000); more than a provider of stimuli
(Forcheri & Molfini, 2000) instead it contained obligatory and orientational (Buchman, 1986) functions that sustained teaching and learning actions. The activity structure contained the academic demand structures and social participation structures that took in account the computer technology as an integral component and conveyed roles for participants within the social context of transferring cultural templates. One unique issue that had appeared within this study is that participants (except Woo) seemed to negotiate meanings that ensure that student learning lies within the context of the cultural templates that have to transmitted. This took the form of a social cue/social arrangement/interaction (Merrill, Drake & Pratt, 1996; Scott, Cole & Engel, 1992) that participants negotiated: the pitstop. This pitstop did not contain the thoughts or actions that the psychological tools proffered. Instead they involved participants (except Woo) taking account of accountability for their instructional processes and students' learning: checking for student understanding.

But it must be mentioned that these negotiations were also being mediated by the participants' psychological tools. On their own these aforementioned negotiations set the context for the transfer of cultural templates but the participants' psychological tools seemed to mediate negotiations. This mediation occurred by extending the negotiations towards the very acts of instruction as a social act, rather than an act performed by the computer technology. The psychological tools also provided an additional level: the zone of proximal development. Woo's mediation of computer technology was strikingly different from the rest of the participants. The psychological tools of maintenance and consolidation seemed to mark the mediating process of the computer technology. These tools were the yard-stick that Woo used to measure the utility of the computer technology in the classroom.

5.1.3 The influence of beliefs

The role of participants' beliefs were also determinants that influenced the mediating roles of the psychological tools and the negotiations within the
communities of practice (Briscoe, 1996; Becker, 1991; Ladewski, Krajcik & Harvey, 1994; Robin & Harris, 1998; Sigel, 1992). Five of the participants had beliefs that were characteristic of teaching and learning as a social process. Furthermore, these five participants professed profiles that suggested that the knowledge was to be constructed rather than reproduced. And within the context of teaching and learning with computer technology, their beliefs professed knowledge domains that constrained the use of computer technology to certain roles. These sets of teachers’ beliefs, with a strong socialisation characteristic, were proffering the very acts of negotiations, and were also apparently involved in the teachers’ roles and the modes of operation of all the agents (teachers, students, computer technology and curriculum) in the classroom (Robin & Harris, 1998). Furthermore, these teachers’ beliefs were also influencing the applicability of the psychological tools within the classroom context. This also cohered with Briscoe’s (1996) contention that teachers have constructed mental images of teaching actions. It could be argued that participants were reconstructing the computer technology’s role in line with their beliefs, thus factoring computer technology into the acquiring of facilitator roles and positioning students. Both these negotiations were very social in nature, as they contained elements like human motivation, mutual investment and joint activities.

These findings also paint a picture that participants’ beliefs that influence their integration of computer technology are strongly correlated to the social context. The presence of psychological tools further supports the view, since psychological tools are active within social contexts (Sigel, 1992).

On the other hand, Woo’s beliefs were very teacher centred and the socialisation process was seen as teacher controlled. She also viewed students’ knowledge construction as a process that the teacher had to perform by herself. Thus, her beliefs seemed to be strongly advocating the mediation through psychological tools that carried the conception of maintenance and consolidation which cohered with her beliefs about teacher being in control of student learning and knowledge construction.
To interpret the aforementioned discussion, the researcher offers the reader a diagrammatic representation of his interpretation of the participants' construction of classroom meaning integrating computer technology. This qualitative model was developed by the researcher collaboratively with participants, but the final representation, Figure 13, is the researcher's. The researcher presented preliminary copies of Figure 13 to the participants and this allowed participants to draw/redraw the qualitative model represented by Figure 13. Participants' comments of these preliminary copies of Figure 13 were also taken into account. Participants' interpretations and drawings/redrawings resulting from their reflexivity and interpretation of the preliminary copies of Figure 13 were used as further insights by the researcher to further refine Figure 13. This process is also discussed in Chapter 3: section 3.10.3. This qualitative model is not representative of Woo's use of computer technology. Figure 13 shows what were the key determinants (participants, computer technology, cultural context) that influenced the negotiations that took place and how these negotiations in turn lead to key aspects of acquiring a facilitator role, positioning students and designating roles for computer technology within the classroom integrating computer technology. This figure also shows how construction of classroom meaning included participants' psychological tools that mediated the aforementioned negotiations within the zone of proximal development leading to students' conceptual change. The activity structure is a result of this construction of classroom meaning.

The construction of classroom meaning seems to be controlled by participants' negotiations, and psychological tools taking into account the beliefs that also seem to be present in the social context in which these negotiations and mediations are extant. These negotiations and mediation by psychological tools led to the construction of classroom meaning that integrated computer technology as an integral component integral to the transmission of cultural templates but not the sole purveyor of the transmission.
Participants, computer technology, and cultural context

Lead to

Negotiations

Lead to

Psychological tools

Lead to

Students as mutual partners

Students’ conceptual change

Facilitator role

Designated roles for computer technology

Mediation

Zone of proximal development

Activity Structure

FIGURE 13

Diagrammatic representation of participants’ construction of classroom meaning
Chapter 6

Conclusion

The function of this chapter is to draw together the major insights of this study. To recap, teachers' construction of classroom meaning with the integration of computer technology was articulated by the researcher as: The teachers' role in negotiating personal transformations in students of cultural templates, through constructive activity structures, is shaped by teachers' interpretations of how to present the cultural templates within a social context/community of practice. These interpretations are the teachers' conceptual underpinnings of the social context in which teaching integrating computer technology occurs.

Thus, to bring about this construction:


2. This mediator role involves a mindset (Bigum, 1997; Carter, 2000; Lankshear & Snyder, 2000; Mandinach & Cline, 1994; 1996;Morton, 1996; Muffolletto, 1994; 1996; Perkins; 1985; Perkins, Crismond, Simmons & Unger, 1995 Saloman, 1998)

3. This mindset carries out negotiations: programs of actions (Bigum, 1997; Bromley, 1997; Bromely & Apple, 1998; Lankshear, & Ball, 2000); balancing of incentives and disincentives (Knupfer, 1993); and amplifications and/or reductions (Bowers, 1988b; 1998a; 1998b). These are open processes of interaction and deliberation (Lave & Wenger, 1991; Westheimer & Kahne,

4. Through these negotiations for actions/structures and strictures/cognitive guides, teachers, as mediators, create microcosms (Olson, 1997)/communities of practice (Lauzon, 1999; Lave & Wenger, 1991; 1999) in which the roles of all the components of the social milieu including the computer technology are defined. This allows the enculturation process to take place, significant to the cultural templates rather than pertaining solely to the computer technology. Collectively these result in the zone of proximal development where social interaction enables joint activity in accomplishing academic tasks resulting in intersubjectivity between teachers and students.

5. These negotiations for actions/structures and strictures/cognitive guides are reflected in the language (including metaphorical), culture, thought, images of teachers who undergo these open processes of interaction and deliberation within the social context of the classroom teaching integrating computer technology.

6. These negotiations of actions/cognitive guides and structures and strictures are in turn influenced by the interlocking sets of teachers' beliefs that act within the microcosms/communities of practice (Apple & Jungck, 1990; Bigum, 1998; Blacker, 1993; Briscoe, 1996; Becker, 1991; Buchman, 1986; Campoy, 1992; Ladewski, Krajcik & Harvey, 1994; Robin & Harris, 1998; Sigel, 1992). These influence the negotiated actions/structures and strictures/cognitive
guides that constitute the community of practice. These influence the negotiated actions/structures and strictures/cognitive guides that constitute the community of practice.

And now the researcher asks what is the contribution of this study? What are the new meanings that the researcher claims to insert within the educational computing research?

The theoretical challenge of this thesis was to demonstrate how teachers construct classroom meaning integrating computer technology. The utilisation of researcher-participant mutual collaboration, researcher-participants as groups and participant as researcher enabled the generation of data that demonstrated the multiple meaning making processes that were present within the phenomenon under study. This study has also demonstrated that researcher, researcher-participant mutual collaboration, researcher-participants as groups and participant as researcher served as a mutually evolving context in which validity became a process of reflexive and relational articulation of claims.

In this research, images of participants' teaching actions with computer technology derived through metaphors (metaphorical statements and metaphoric language) served as a crucial data that enabled an intimate view of how construction of classroom meaning occurred within the classroom context. These images served the researcher and the participants as connotative descriptions of the very practices that were being investigated. This occurred through a qualitative image/text balance. It framed the meaning making process in words as well as qualitative models through which both researcher and participants were able to manipulate and draw out further insights.

Finally, the research design provided a "socially, culturally and politically reflective approach" (Smyth, 1992: 294) to the study. Through the generation of metaphorical statements and the generation of narratives from these metaphorical statements, participants were able to describe and inform about their teaching
actions. Through qualitative models and the presentation of findings as communities of practice, participants were able to confront and reconstruct their own work of teaching within their very communities of practice. By doing so participants themselves were reflective upon their teaching, and their theories in use in consideration of their cultural context.

In reference to the knowledge gains from this study, the first contribution to be discussed is in reference to the state of teachers' roles in the field of educational computing research. This study has shown that teachers' roles are more than spatial and temporal movements, or a utilitarian, unprofessional and associated model of teaching. This study has demonstrated that teachers teaching with computer technology work at different and complex levels within the classroom social contexts: roles are intimately and interactively involved in the communities of practice. The activity structures themselves represent one of these levels. Furthermore, the concept of community of practice provides a lens to view how teachers construct classroom meaning through their own perspectives of negotiations, access and engagement. That is, how their negotiations reflect the structure and strictures of their classroom teaching with the integration of computer technology and the membership of their students and themselves as defined by the community of practice. Teachers' roles thus, cannot be reduced to prescribed labels. These simplistic and monolithic labels do not fathom the different levels that teachers traverse within the social context to bring about the transfer of cultural templates. Spatial and temporal movements cannot account for these different and interactive levels or zones that teachers traverse.

This study has shown that teachers' use of computer technology has got to do with more than acquiring skills. Looking at teachers' use of computer technology within the framework of transmission of cultural templates, has revealed that it is a complex process. Teachers possess mindsets that undergo negotiations and set up negotiated activity structures which function as effective transmitters of cultural templates through the influence of psychological tools. These psychological tools serve a dialectic function, mediating the activity structures for
pragmatic purposes of teaching (Woo's use of computer technology for teaching) or expressive and instrumental purposes of teaching (Angela's, Anthony's, Ning's, Sundari's and Tan's use of computer technology for teaching).

Another contribution of this study is that it has furthered our understanding of teachers' use of computer technology for teaching. This teaching action itself is a complex interaction with human actions of negotiations and mediations, and teacher beliefs thrown in to make this teaching action a complex process. From this study, it was apparent that these negotiations and mediations within a social context were working towards a value. In the case of this study, this was framed by the cultural context in which the study was located: students' conceptual change and preparing students for the GCE "O" level exams. What is apparent is that these negotiations and mediations take into account values that professional activities espouse and to seek to accomplish. This perception further marshalls against the ever-present notions of teachers as technicians who fall back on computer technology to deal with teaching actions.

Teachers' negotiations seem to be imperatives in teachers' use of computer technology. As this study has shown, these negotiations take place within the social context where the integral components of teachers, students and the computer technology, are captured by teachers' thinking and become part of complex and interrelated processes of negotiations. Negotiations in turn are influenced by the beliefs that are extant and functioning within the very same social contexts in which these negotiations occur.

Taking into account of the aforementioned contributions, it can be stated that teachers are the primary agents in the use of computer technology for teaching and learning actions. As this study has shown, teachers' beliefs, negotiations and mediations, encapsulated within a social context, are the main determinants of teachers' use of computer technology. Furthermore, this study has shown that teachers, as primary agents, in the use of computer technology, have a strong humanistic perspective: negotiations, mediations and beliefs are human
interpretations, part and parcel of every cultural activity. Thus, this study supports the person-centred vision of technology for education (Kerr, 1996b, Budin, 1999) as it captures basic human interpretations as the main determinants for teachers' use of computer technology, rather than educational computing as teaching (Bowers, 1988a).

On the other hand this study contributes also to the skills training literature. That is, skills training should not just look into the cultural building process as a sole imperative for changes in skills training protocols. Instead the negotiations, and psychological tools that grace the culture building process and the beliefs that are "part and parcel" of these cultural template transfer processes need to be identified. There is a need to capture this culture building process as a set of negotiations, beliefs and psychological tools rather than falling into the trap of seeing it as a single entity. Furthermore the magnitude of the psychological tools needs to be identified as this study has shown that not all psychological tools are conducive to effective use of computer technology in the classroom. There is a need to capture teachers' psychological tools together with the negotiations and beliefs before skills training can take root within the teachers' teaching agenda.

Implications for further research

The data this research disclosed and the meanings extracted from it suggest a few areas of further inquiry. Although this study examined science teaching, academic disciplines like biology, chemistry, physics, geography, history or other academic subjects do have differing knowledge structures and epistemological assumptions and thus need to be considered in further research. For example, in this study, the physics teachers (Angela and Ning) seemed to emphasize the importance of hands on activities (data loggers) rather than use of animations or simulations by computer technology. They both stated that physics is a subject that is learnt through doing activities rather than solely looking at animations. What sorts of task are most suitable in different academic disciplines that are taught with the use of computer technology?
Using the Vygotskian framework to examine the psychological tools used in science classrooms that have integrated computer technology has the potential to provide insights into the mediation power that teachers exert as mediators of students’ cognitive development. In reference to science education research, recent phenomenological theorizing has attacked the sociocultural perspectives on students’ construction of knowledge as being influenced by undemocratic pursuits (Bencze, 2000). As this study has shown, teachers’ psychological tools mediate activity structures resulting in teaching and learning actions. These psychological tools can focus on identifying practices that seem to be democratic or undemocratic in light of the negotiations that set up the activity structures.

Since this study has examined the teachers’ role and the psychological tools that sanction thought and actions within the context of teaching with computer technology, a parallel study of inservice educators may be pertinent. How does the “trainer as model teacher” scenario cohere with or challenge the psychological tools that teachers possess? Do inservice educators take account of the relevance of the psychological tools that teachers use to mediate teaching and learning? Inservice educators need to consider these psychological tools and derive plans that do not just emphasize the mediating role of the computer technology. Are inservice educators aware of their own cultural tools that amplify or reduce the mediating role of computer technology or the culture building processes of teachers they train? What are the activity structures that inservice educators perceive? How are inservice trainers activity structures mediated by their psychological tools? These need to be made explicit and theorised.

On the other hand, this study has also attempted to bridge research on teachers’ construction of classroom meaning integrating computer technology, with Vygotskian and neo-Vygotskian perspectives on teaching. In so doing it offers new insights about the process of teaching with computer technology. The study also offers new insights about the processes of teaching which could be further understood through a model of participation in a culture of skills training. Within
this cultural perspective, an analysis of the interactions between inservice teachers and inservice educators would highlight the co-construction of shared meaning and how it relates with practices and events in the classroom. How do inservice educators and inservice teachers interact? What are the areas on which they agree and disagree? How do these agreements-disagreements impact skills training? How do they manage to build common goals and to establish a zone of proximal development?

This study has illustrated that teachers may possess sets of psychological tools that mediate their thoughts and actions in the classroom setting with the use of computer technology. There needs to be a correlational investigation of the psychological tools that exist in classroom settings that do not involve the use of computer technology for teaching. A comparative analysis of the psychological tools found within these two settings may shed light on the relative values that these psychological tools may hold for teachers. Is there an overlap between the psychological tools that mediate teaching and learning in both settings?

This study has shown the importance of collaborative research, through researcher-participant collaboration (narratives) and researcher-participants as collaborative groups (focus group interview). These collaborative research agenda in some ways alleviated the need for respondent validation as the sole validity instrument for the claims in this study. Although this represented an empowering of participants as co-researchers, further research is needed to capture the epistemologies of methods that participants bring into the contexts of the study. As in this research, participants generated metaphorical statements individually, and co-constructed narratives in mutual collaboration with the researcher. The researcher’s understanding of the method may be different from that of the participants. Research is needed to find out if these collaborative research strategies are also dependent on the methods and the epistemologies that participants espouse. Empowerment may be a side effect of the method or utilising the method rather than just empowering the participant as a co-researcher.
Implications for teacher education

Finally, the findings of this study offer interesting landmarks for teacher education and skills training. Firstly, attending to classroom structures, through activity structures, for example, is a relevant theoretical perspective to understand teachers' construction of classroom meaning within the context of teaching with computer technology. This study had shown that these activity structures lead to authentic tasks in the classroom mediated by the teachers' psychological tools rather than being mediated solely by the computer technology.

Secondly, the findings have shown that teachers' construction of classroom meaning is very specific and context dependent. The concept of zone of proximal development, identified in the findings, suggests that teachers' mediate teaching and learning towards this zone. The psychological tools, the facilitator role, the designation of roles for the computer technology and the positioning of students all indicate the relevance of this zone and its specificity in constructing classroom meaning. Teacher education and skills training need to instill practices that enable teachers to identify this zone. Furthermore, there is a need to identify tasks that cohere with this zone of proximal development for potential teaching and learning interactions.

Teacher educators have to consider the psychological tools that (in service and preservice) teachers use to mediate teaching and learning with the use of computer technology. These tools seem to be the tools that directly influence the computer technology's amplification or reducing power in classrooms. Furthermore construction of classroom meaning with the integration of computer technology is not just the use of computer technology nor is it just the mediation of the computer technology. Teachers, through these psychological tools, develop tasks which lead to cognitive activities in a social milieu. Thus, empowering inservice or preservice teachers with the use of computer technology requires an interactive and intertwined perception of beliefs, psychological tools, academic tasks and the
social participation structures that follow. This moves away from the perception of educational computing as a skills based approach and reflects the complexity and multidimensionality of classroom contexts.

Mediation as a mindset needs to be examined not only from the viewpoint of psychological tools but also from the viewpoints of positioning of students, teachers' roles and designation of computer technology's role in the classrooms. Mediation of computer technology in the classroom is dependent on these factors as well as the psychological tools.

Teacher educators need to expose how teachers construct classroom meaning with the integration of computer technology, and to reveal the aforementioned factors. As this study has shown that the nature of psychological tools vary and that the impact of these tools are also varies. For example, some of the psychological tools carried the notions of consolidation and/or maintenance while others carried the notions of supporting, developing, visualising or equipping. The perception of teachers psychological tools need to examined.

Teacher educators have to view teachers’ beliefs as more than context dependent. They have to see the relevance of these beliefs in light of the psychological tools that exist in the contexts in which beliefs themselves exist. This study has shown that psychological tools are influenced by teachers’ beliefs, especially those that seem to be involved in the socialization process of the classroom. Teacher beliefs and the knowledge domains of these beliefs have to be explored within social contexts in which they operate.

In summation, this thesis is about how teachers construct classroom meaning integrating computer technology into teaching. Its main conclusion is that teachers' construction of classroom meaning integrating computer technology into teaching involves a complex process of negotiations and mediations of these negotiations by psychological tools enacted within social contexts. Teachers' negotiations create activity structures that are mediated by teachers' psychological
tools such that the negotiated components within the activity structures, including the computer technology, all converge onto the transfer of cultural templates. These negotiations and mediations are in turn influenced by the teachers' beliefs, extant and functioning within these social contexts.


_Educational Researcher, 22_(7), 5-11.


Miller, L., & Olson, J. (1994). Teaching with technology: Putting the computer in its place, a study of teaching with technology. *Journal of Curriculum Studies, 26*(2), 121-141.


Russell, T., & Johnston, P. (1988b). Teachers learning from experiences of teaching: Analyses based on metaphor and reflection. Faculty of Education, Queen's University, Kingston, Ontario, Canada.


Appendix A:

Information sheets, consent forms, and letter formats approved by the University of Otago Ethics Committee (November 17, 1998)

INFORMATION SHEET FOR TEACHERS

Thank you for showing an interest in this project. Please read this information sheet carefully before deciding whether or not to participate. If you decide to participate we thank you. If you decide not to take part there will be no disadvantage to you of any kind and we thank you for considering our request.

Researcher Information:

I am a qualified secondary school science teacher, with approximately four years of teaching. I have a particular interest in the integration of computer technology into teaching practice. I am currently studying towards a PhD at the University of Otago.

What is the Aim of the Project?

This project is an investigation of teachers' construction of meaning and purpose in the integration of computer technology into their teaching.

The research project aims to describe the thoughts, personal intentions and rationales of teachers who are examining the potentials of integrating computer technology into their teaching. The project is being undertaken to examine teaching with computer technology and how it is shaped by teachers' perceptions, perspectives, judgements, beliefs and negotiated meanings.

It is critical that research is informed by the very people who are involved in the use of this technology and adopting it into their pedagogical practice, that is the classroom teacher.

Together with the participants, the researcher would like to explore the meaning and purpose that participants construct as they integrate computer technology into their teaching.

What Type of Participants are being sought?

Participants being sought will be Science Teachers (Biology, Chemistry, General Science, or Physics) or any subject teachers who plan to or will be using computer technology in their teaching for the new school year, 1999. Teachers who are interested in working with the researcher and their colleagues to develop enhanced approaches to integrate computer technology into their classes.

What will Participants be Asked to Do?

Should you agree to take part in this project, we will meet regularly, both individually and as a group, with other participants of the project. In these meetings I would like to explore how you integrate computer technology into your teaching. Thus working collaboratively to develop an enhanced teaching practice with computer technology in the classroom.

Can Participants Change their Mind and Withdraw from the Project?

You may withdraw from participation in the project at any time and without any disadvantage to yourself of any kind.

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What Data or Information will be Collected and What Use will be Made of it?

Data will take the form of lesson plans of computer technology integrated lessons; video recordings of classroom lessons; metaphors of teaching with computer technology; stimulated recall interviews; group interviews and notes of observations in the classrooms.

Your interviews will be audio taped and transcribed. The group interviews will be audio taped and transcribed in a group report. Your transcribed individual interviews, and metaphors along with the group interview reports will be used to answer the research question; how teachers construct meaning and purpose in the integration of computer technology into their teaching. The results of the project will be used in the writing up of my PhD thesis, and also in any academic publications that arise from that. At the completion of the study I will give you a summary of the findings of the research.

The data collected will be securely stored in such a way that only the researcher, Karthigeyan Subramaniam, and his supervisors Dr. R. G. Ethell and Dr. Bruce McMillan have access to it. At the end of the study any personal information will be destroyed immediately except that, as required by the University’s research policy, any raw data which the results of the project depend will be retained in secure storage for five years, after which it will be destroyed.

What if Participants have any Questions?

If you have any questions about our project, either now or in the future, please feel free to contact either:

**Researcher**
Mr. Karthigeyan Subramaniam  
Department of Education  
University Telephone Number: 479 8894

**Supervisors**
Dr. R. G. Ethell  
Higher Education Development Centre  
University Telephone Number: 479 5139
Dr. Bruce McMillan  
Department of Education  
University Telephone Number: 479 8818

Thank you for taking the time to consider your involvement in my project.

This project has been reviewed and approved by the Ethics Committee of the University of Otago.
Appendix A:

CONSENT FORM FOR STUDENTS' PARENTS

In order to examine how teachers approach the use of computer technology in their classroom it is necessary to videotape some key lessons. The focus of this research is on the teaching methods and not on individual students.

I know that:

1. my son’s/daughter’s* NAME: ______________________________________________________________________ participation in the classroom videotaping is entirely voluntary;

2. I am free to withdraw my son/daughter* from the videotaping at any time without any disadvantage;

3. the videotapes will be destroyed at the conclusion of the project but any raw data on which the results of the videotaping depend will be retained in secure storage for five years, after which it will be destroyed;

4. there will be no harm or discomfort to the students during the duration of the videotaping of classroom teaching.

5. no payment or reward will be offered.

I agree to allow my son/daughter* to be videotaped for the purpose of the researcher’s investigation of teachers’ construction of meaning and purpose in the integration of computer technology into their teaching.

..................................................................................................................  ..............
(Signature of Parent/Guardian*) (Date)

* Delete whichever is inapplicable

This project has been reviewed and approved by the Ethics Committee of the University of Otago
Appendix A:

CONSENT FORM FOR TEACHERS

I have read the Information Sheet concerning this project and understand what it involves. All my questions have been answered to my satisfaction. I understand that I am free to request further information at any stage.

I know that:

1. my participation in the study is entirely voluntary;

2. I am free to withdraw from the study at any time without any disadvantage;

3. the videotapes will be destroyed at the conclusion of the project but any interview transcripts, transcribed metaphors, group interview reports and participation observation notes on which the results of the project depend will be retained in secure storage for five years, after which it will be destroyed;

4. that this project involves open-questioning technique where the precise nature of the questions which will be asked have not been determined in advance, but will depend on the way in which the interview develops. In the event that the line of questioning develops in such a way that I feel hesitant or uncomfortable I may decline to answer any question(s) and/or may withdraw from the project without any disadvantage of any kind;

5. I am able to read the transcripts of my interviews/group interview reports, transcribed metaphors and field observation notes and delete any information I do not wish to have included in the project;

6. the results of the study will be treated in strict confidence and that I will remain anonymous. Within these restrictions, results of the study will be made available to me at my request;

7. any personal information gathered during the study will be confidential and will only be seen by the researcher's supervisors, Dr. Bruce McMillan and Dr. R. G. Ethell and the researcher, Mr. Karthigeyan Subramaniam;

8. the results of the project may be published, but my anonymity will be preserved in all cases.

I agree to take part in this project.

.................................................................
(Signature of participant)
(Date)

This project has been reviewed and approved by the Ethics Committee of the University of Otago
Appendix A:

Letter to Board of Trustees

The Chairperson
Board of Trustees
(Name of School)

(Date)

Dear Chairperson

I am writing to request permission for a teacher in your school (teacher’s name) to be involved in a research project entitled "Teachers’ construction of meaning and purpose in the integration of computer technology into their teaching". This project is being undertaken at an important time, as we witness a rapid introduction of computer technology into schools. This research will inform both preservice and inservice education with respect to the process of learning to teach with computer technology and it has the potential to contribute to the ongoing development of inservice skills training.

Teachers who agree to participate in this project will be sharing their valuable experience and viewpoints on teaching with computer technology. I have enclosed a copy of the information sheet and consent form which will be given to (teacher’s name). Formal consent forms will be completed only if we receive permission from you to proceed.

If you have any further questions relating to the research study please do not hesitate to contact me or my supervisors, Dr. R. G. Ethell and Dr. Bruce McMillan at the following locations:

Researcher or Supervisors

Mr. Karthigeyan Subramaniam
Department of Education
University Telephone Number: 479 8894

Dr. R. G. Ethell
Higher Education Development Centre
University Telephone Number: 479 5139

Dr. Bruce McMillan
Department of Education
University Telephone Number: 479 8818

Thank you for considering my request. I look forward to your reply.

Yours sincerely

Karthigeyan Subramaniam

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Appendix B

Classroom observations dates and time

<table>
<thead>
<tr>
<th>Participant</th>
<th>Topics</th>
<th>Dates</th>
<th>Duration</th>
<th>Location</th>
<th>Type of Software Utilized</th>
</tr>
</thead>
<tbody>
<tr>
<td>Angela</td>
<td>1. Measuring physical changes</td>
<td>02/04/99</td>
<td></td>
<td></td>
<td>Data loggers, temperature, motion, and light sensors.</td>
</tr>
<tr>
<td></td>
<td>2. Acids and Alkalis</td>
<td>09/04/99</td>
<td></td>
<td>Science Laboratory</td>
<td>Data loggers and pH meter</td>
</tr>
<tr>
<td></td>
<td>3. Acids and Alkalis</td>
<td>12/04/99</td>
<td>1h 30 min</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>4. Acids and Alkalis</td>
<td>13/04/99</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>5. Speed, time and velocity graphs</td>
<td>14/04/99</td>
<td></td>
<td>Physics Classroom</td>
<td>Data loggers and motion detectors/sensors</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anthony</td>
<td>1. Chromatography</td>
<td>02/03/99</td>
<td></td>
<td>Encounter Lab</td>
<td>Downloaded Internet website (<a href="http://genchem.chem.wisc.edu/labdocs/chromato/paper/paper.htm">http://genchem.chem.wisc.edu/labdocs/chromato/paper/paper.htm</a>)</td>
</tr>
<tr>
<td></td>
<td>2. Chromatography</td>
<td>11/03/99</td>
<td></td>
<td></td>
<td>CD-ROM - Chemical Structures (The Chemistry Set)</td>
</tr>
<tr>
<td></td>
<td>3. Chemical bonding</td>
<td>06/04/99</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## Classroom observations dates and time

<table>
<thead>
<tr>
<th>Participant</th>
<th>Topics</th>
<th>Dates</th>
<th>Duration</th>
<th>Location</th>
<th>Type of Software Utilized</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ning</td>
<td>1. Reflection of sound and sound waves</td>
<td>07/03/99</td>
<td></td>
<td>Physics Laboratory</td>
<td>CD-ROM – Reflection of sound Data logger, and sound sensor.</td>
</tr>
<tr>
<td>Ning</td>
<td>2. Reflection of sound and sound waves</td>
<td>25/03/99</td>
<td></td>
<td></td>
<td>Data loggers and motion detectors/sensors</td>
</tr>
<tr>
<td>Ning</td>
<td>3. Calculating “g”</td>
<td>11/05/99</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sundari</td>
<td>1. Cell Structure</td>
<td>12/01/99</td>
<td>1h 30min</td>
<td>Biology Classroom</td>
<td>CD-ROM – Cell structure</td>
</tr>
<tr>
<td>Sundari</td>
<td>2. Nutrients</td>
<td>12/02/99</td>
<td></td>
<td></td>
<td>Power Point presentation</td>
</tr>
<tr>
<td>Sundari</td>
<td>3. Nutrients</td>
<td>19/02/99</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sundari</td>
<td>4. Nutrients</td>
<td>01/03/99</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sundari</td>
<td>5. Reproduction</td>
<td>05/03/99</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sundari</td>
<td>6. Circulation in humans</td>
<td>06/05/99</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tan</td>
<td>1. Basic chemistry</td>
<td>07/01/99</td>
<td></td>
<td>Encounter Laboratory</td>
<td>CD-ROM - Nine month miracle</td>
</tr>
<tr>
<td>Tan</td>
<td>2. Basic chemistry</td>
<td>08/01/99</td>
<td></td>
<td>Encounter Laboratory</td>
<td>CD-ROM - Human Circulatory System</td>
</tr>
<tr>
<td>Tan</td>
<td>3. Basic chemistry</td>
<td>13/01/99</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Appendix B:

The innovative capacity of the school: Diagrammatic layouts of observed classrooms

Key:

- Computer Terminal

- Researcher

Science Laboratory used by Angela
Appendix B:

Physics Classroom used by Angela

Biology Classroom used by Sundari
Appendix B:

Physics Laboratory use by Ning

Encounter Laboratory used by Anthony Sundari and Tan respectively
Appendix C:

Attitudes About Reality Scale: Shorter version (Unger, Draper & Pendergrass, 1986:78)

<table>
<thead>
<tr>
<th>ATTITUDES ABOUT REALITY SCALE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tick Your Response</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Agree</th>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Neither Agree Nor Disagree</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
<th>Disagree Almost Completely</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>It is maladaptive to refuse to conform to the demands of society.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>If one works hard at solving a problem, one can usually find an answer.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td>If everyone learns what is important to them, the world would take care of itself.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td>Most sex differences have an evolutionary purpose.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.</td>
<td>People who achieve success usually deserve it.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6.</td>
<td>The saying &quot;You shall know the truth and the truth shall make you free&quot; is still valid today.</td>
<td></td>
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<tr>
<td>7.</td>
<td>The more technology we develop the better our science will be.</td>
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<tr>
<td>8.</td>
<td>Accidental solutions to problems are very rare</td>
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</tbody>
</table>
Appendix C:

<table>
<thead>
<tr>
<th></th>
<th>Agree</th>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Neither Agree Nor Disagree</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
<th>Disagree Almost Completely</th>
</tr>
</thead>
<tbody>
<tr>
<td>9.</td>
<td>At present time, people are recognised for their achievements regardless of their ethnicity, sex or social class.</td>
<td></td>
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<tr>
<td>10.</td>
<td>People cannot be trained to be creative – they are born that way or not.</td>
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<tr>
<td>11.</td>
<td>People who demand social change are usually those who have been ineffectual in present society.</td>
<td></td>
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<tr>
<td>12.</td>
<td>Once a scientific fact is discovered it remains part of that science.</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>13.</td>
<td>Personality characteristics account for most differences in human behaviour.</td>
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<tr>
<td>14.</td>
<td>Important ideas are most likely to originate from prestigious institutions.</td>
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<tr>
<td>15.</td>
<td>It is more important to be liked than to be powerful.</td>
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</tbody>
</table>
### Appendix C

<table>
<thead>
<tr>
<th></th>
<th>Agree</th>
<th>Strongly Agree</th>
<th>Agree</th>
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<th>Disagree</th>
<th>Strongly Disagree</th>
<th>Disagree Almost Completely</th>
</tr>
</thead>
<tbody>
<tr>
<td>17.</td>
<td>Most people would co-operate with each other if only they understood that everyone would benefit by such actions.</td>
<td></td>
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<tr>
<td>18.</td>
<td>Scientific merit is determined by the excellence of the work done.</td>
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<tr>
<td>19.</td>
<td>Those who are nonconformists during one period of history are often found to be innovators by future eras.</td>
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<tr>
<td>20.</td>
<td>It is better not to know too much about things that cannot be changed.</td>
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<tr>
<td>21.</td>
<td>Physiological differences limit the degree to which males and females can learn to be similar to each other.</td>
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<tr>
<td>22.</td>
<td>Most social problems are solved by very few qualified individuals.</td>
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<tr>
<td>23.</td>
<td>Science has underestimated the extent to which genes affect human behaviour.</td>
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<tr>
<td>24.</td>
<td>The way scientist choose to investigate problems is influenced by the values of their society.</td>
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</tr>
</tbody>
</table>


Appendix C

<table>
<thead>
<tr>
<th></th>
<th>Agree Almost Completely</th>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Neither Agree Nor Disagree</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
<th>Disagree Almost Completely</th>
</tr>
</thead>
<tbody>
<tr>
<td>25. Who has power is a central issue in understanding how society works.</td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>26. The facts of science change over time.</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>27. We communicate much more information to each other than we are aware of doing.</td>
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<tr>
<td>28. It is important to decrease the distance between the &quot;real world&quot; and the scientific laboratory.</td>
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</table>
## Appendix D

### Interview themes, dates and duration

<table>
<thead>
<tr>
<th>Participants</th>
<th>Profile</th>
<th>Teaching process with computer technology</th>
<th>Beliefs</th>
<th>Verification of first three interviews</th>
<th>Computer technology’s influence on teachers</th>
<th>Teachers’ thought processes</th>
<th>Overall verification of interview 1 to 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sundari</td>
<td>12/01/99 (1hr)</td>
<td>19/02/99 (1hr)</td>
<td>25/03/99 (1hr)</td>
<td>28/04/99 (45min)</td>
<td>28/04/99 (30min)</td>
<td>13/05/99 (1hr)</td>
<td>25/05/99 (45min)</td>
</tr>
<tr>
<td>Anthony</td>
<td>09/01/99 (1hr)</td>
<td>27/02/99 (1hr)</td>
<td>27/03/99 (1hr)</td>
<td>06/04/99 (45min)</td>
<td>06/04/99 (30min)</td>
<td>08/05/99 (1hr)</td>
<td>22/05/99 (45min)</td>
</tr>
<tr>
<td>Ning</td>
<td>16/01/99 (1hr)</td>
<td>26/02/99 (1hr)</td>
<td>25/03/99 (1hr)</td>
<td>27/04/99 (45min)</td>
<td>27/04/99 (30min)</td>
<td>15/05/99 (1hr)</td>
<td>22/05/99 (45min)</td>
</tr>
<tr>
<td>Angela</td>
<td>15/01/99 (1hr)</td>
<td>26/02/99 (1hr)</td>
<td>31/03/99 (1hr)</td>
<td>29/04/99 (45min)</td>
<td>29/04/99 (30min)</td>
<td>14/05/99 (1hr)</td>
<td>21/05/99 (45min)</td>
</tr>
<tr>
<td>Tan</td>
<td>26/01/99 (1hr)</td>
<td>22/02/99 (1hr)</td>
<td>26/03/99 (1hr)</td>
<td>03/05/99 (45min)</td>
<td>03/05/99 (30min)</td>
<td>03/05/99 (1hr)</td>
<td>17/05/99 (45min)</td>
</tr>
<tr>
<td>Woo</td>
<td>25/01/99 (1hr)</td>
<td>26/02/99 (1hr)</td>
<td>30/03/99 (1hr)</td>
<td>29/04/99 (45min)</td>
<td>29/04/99 (30min)</td>
<td>25/05/99 (1hr)</td>
<td>25/05/99 (45min)</td>
</tr>
</tbody>
</table>
Appendix D:

**Sample: Classification of questions for semi-structured and focus group interviews**

<table>
<thead>
<tr>
<th>DESCRIPTIVE</th>
<th>ANALYTICAL</th>
<th>EVALUATIVE</th>
</tr>
</thead>
<tbody>
<tr>
<td>How would you define your teaching practice with the integration of computer technology and of what importance is this integration to you?</td>
<td>How would you explain your personal philosophy of teaching and learning with computer technology?</td>
<td>How have your approaches to teaching been changed by the integration of computer technology into your teaching?</td>
</tr>
<tr>
<td>What is the crucial factor of this integration that had an effect on your teaching practice in class?</td>
<td>Describe an alternative teaching method if the integration of computer technology was not possible?</td>
<td>How happy are you about this computer technology integrated lesson?</td>
</tr>
<tr>
<td>How are students responding to your teaching practice with the integration of computer technology in the classroom?</td>
<td>Do you consider teaching with computer technology a developmental process?</td>
<td>What is the primary drive behind your efforts?</td>
</tr>
<tr>
<td>Are students required to contribute to this learning environment?</td>
<td>What benefits did you realise by using this technology?</td>
<td>Do you want your students to do things differently and think for themselves?</td>
</tr>
<tr>
<td>What would be your unique visions of what the learning environment should be?</td>
<td>What major obstacles did you encounter?</td>
<td>What did you hope to accomplish by teaching your course with this technology?</td>
</tr>
<tr>
<td>What motivated you to try teaching your course with the technology?</td>
<td>What obstacles do you think would hinder other teachers?</td>
<td>How did you develop the concept for your new way of teaching?</td>
</tr>
<tr>
<td>What communication interactions did you hope to capitalise on?</td>
<td>How would you describe this compatibility?</td>
<td>How does this teaching practice have an effect on your internalised sense of what the work of teaching is?</td>
</tr>
<tr>
<td>What is the analogy for your teaching tool with technology?</td>
<td>What do you think would be the central and dominant aim of education with computers?</td>
<td>Are you freed from those instructional tasks to conduct higher and more personal levels of pedagogic instruction?</td>
</tr>
<tr>
<td>Do you see a transition in your role as a teacher?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>What is the role you construct from this?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>How do you view your teaching practice in terms of relationship between student and computer technology?</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Appendix D

Semi-structured interview questions

First Interview : Profile of teacher using computer technology to teach

1. Can you tell me how you became acquainted with the use of computer technology for teaching and learning purposes?
   - Was it through skills training, university courses, and/or teacher training courses?
   - For how long have you been using technology in the classroom?

2. Tell me a bit about how you use computer technology in the classroom.
   - Can you give me some examples?

3. Can you tell me the most significant affect computer technology has had on your teaching practice in your classroom?
   - On what you do in the classroom?

4. What motivated you to try teaching your course with the technology?

5. Can you tell me how students respond to your use of technology as part of your classroom lessons?
   - Can you give examples?
   - How would you describe this compatibility?

6. How do you view your teaching practice in terms of relationship between student and computer technology?

7. Think about a recent lesson where you have used computer technology.
   - Describe for me some of the communication interactions that occurred.
   - Were you satisfied with the level of communication?
   - Do students talk with each other?

8. Think about a computer-based lesson and a text-based lesson.
   - Can you tell me some of the differences in students' responses?

9. What do you think would be the central and dominant aim of education with computers?
Appendix D

10. How would you explain your personal philosophy of teaching and learning with computer technology?

11. What would be your unique visions of what the learning environment should be?

Second Interview: Teaching process with computer technology

1. How would you define your teaching practice with the integration of computer technology?
   • What importance is this integration to you?
     • What benefits did you realise by using this technology?
     • What major obstacles did you encounter?
     • Why do you think some teachers do not use computer technology?

2. Can you tell me some of the questions you ask yourself before integrating computer technology into your lesson?

3. What is the crucial factor of this integration that had an affect on your teaching practice in class?

4. How are students responding to your teaching practice with the integration of computer technology in the classroom?
   • What communication interactions with students did you hope to capitalise on?

5. Describe an alternative teaching method if the integration of computer technology was not possible?

6. Think back on when you began to integrate computer technology into your teaching.
   • What was it that motivated you to explore their use?

7. What were your goals in using computer technology?
   • What are the short-term versus long term gains and objectives?

8. How happy are you about this computer technology integrated lesson?

9. Where do you see yourself going with computer technology?
Appendix D

Third Interview: Beliefs.
[adapted and modified from Kagan and Tippins, (1991)]

1. What are the elements of good teaching?
2. What are the elements of poor teaching?
3. With these elements you have just expressed to me in mind what do you see are the elements of good teaching with computer technology?
4. What role(s) should the teacher play in the classroom with computer technology?
5. What are your strengths as a teacher with computer technology?
6. What are your weakness as a teacher with computer technology?
7. What is the most important thing a teacher can give to his/her students?

Fourth Interview: Computer technology's influence on teacher

1. “Can't do anything with computer technology”. What is your response to this?
2. How is the “most important thing a teacher can give to students” achieved using computer technology?

Fifth Interview: Teachers' thought processes

1. Two aspects of teaching with computer technology are, individual beliefs about teaching and learning, and specific experience in the use of computer technology?
   • What are the contributions of these two aspects in teaching with computer technology?
   • With what you have expressed in mind, which do you think is crucial?
2. Computer technology can re-place not replace the teacher. Can you relate this to teaching with computer technology?
Appendix D

3. You will describe teaching with computer technology to a new/novice teacher as?
4. How does computer technology figure in your thoughts about teaching?
5. How does computer technology figure in your thoughts in planning instructional activities?
6. What are the expectations you look for in a computer technology integrated classroom?
7. What are the social relations you look for in a computer technology integrated classroom?
8. Do you follow a routine/script when you are teaching with computer technology?
   • Can you describe this routine/script?
Appendix E:

Focus group formats.

Field Note Reporting Form

Information About the Focus Group

<table>
<thead>
<tr>
<th>Date of Focus Group</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Location of Focus Group</td>
<td></td>
</tr>
<tr>
<td>Number and Description of Participants</td>
<td></td>
</tr>
<tr>
<td>Moderator Name</td>
<td></td>
</tr>
<tr>
<td>Assistant Moderator Name</td>
<td></td>
</tr>
</tbody>
</table>

Responses to Questions

Q1. The most important change you see in your teaching practice?

<table>
<thead>
<tr>
<th>Brief Summary/Key Points</th>
<th>Notable Quotes</th>
</tr>
</thead>
<tbody>
<tr>
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</table>
Appendix E:

Checklist for Focus Group Interviews

1. Advance Notice

| Contact Participants at least 1-2 weeks before the session. |
| Give the participants a reminder phone call prior to the session. |

2. Logistics

| The room should be satisfactory (sizes, tables, comfort, etc.) |
| The moderator should arrive early to make necessary changes. |
| Background noise should not interfere with the tape recording. |
| A remote microphone should be placed on the table. |
| Bring extra tapes and batteries. |
| Plan topics for small talk conversation. |
| Seat experts and loud participants next to the moderator. |
| Seat shy and quiet participants directly across from the moderator. |
| When having a meal, limit selections and stress fast service. |
| Bring enough copies of handouts and/or visual aids. |

3. Questions

| The introductory question should be answered quickly and not identify status. |
| Questions should flow in a logical sequence. |
| Key questions should focus on the critical issues of concern. |
| Consider probe or follow-up questions. |
| Limit the use of “why” questions. |
| Use “think back” questions as needed. |
| Provide a summary of the discussion and invite comments. |
Appendix E:

Checklist for Focus Group Interviews

4. Moderator Skills

| Be well rested and alert for the focus group sessions. |
| Practice the introduction without referring to notes. |
| Ask questions with minimal reference to notes. |
| Be careful to avoid head nodding. |
| Avoid comments that signal approval such as “Excellent,” “Great,” “Wonderful.” |
| Avoid giving personal opinions. |

5. Immediately After the Session

| Prepare a brief written summary of key points as soon as possible. |
| Check to see if the tape recorder captured the comments. |
Appendix E:

Moderator and Moderating Skills

Should
1. be comfortable and familiar with group processes
2. be able to carefully and subtly guide the conversation back on target. – make these transitions and maintain group enthusiasm and interest for the topic.
3. have a sense of timing – timing for the mood of the group and the appropriateness of discussion alternatives.
4. know when to wrap up the questioning and move on to the next issue, but not prematurely.
5. possess a curiosity about the topic and the participants.
6. truly believe that the participants have wisdom no matter what their level of education, experience, or background.
7. have adequate background knowledge on the critical areas of concern.
8. be able to communicate clearly and precisely both in writing and orally.
9. have an emotional detachment from the topic of study.
10. have a friendly manner and a sense of humour – but do not over do it.
11. be mentally alert and free from distractions, anxieties, or pressures that would limit participants ability to think quickly
12. plan schedule to minimise the risk of unexpected pressure that would limit their ability to concentrate
13. give full attention to the group.
14. discipline one to listen and not to talk.
15. limit the key questions to about two to five questions with possible subpoints within each question.
16. have a mastery of the question – valuable because the sequence of questions is sometimes modified during the interview.
17. be focussed on “What do you feel?” and not “What is your opinion?”
18. be able to anticipate the various directions the discussion as opposed to dead ends. - include a comment in the introduction about the scope of the study – all points of view – positive or negative – are needed and wanted.
Appendix E:

Moderator and Moderating Skills

19. be familiar with the technique of the 5-second pause, especially after a participant comment.

20. be familiar with the technique of probing. – best to use it in the beginning of the interview then use it sparingly in later discussion.


22. be encouraged to monitor their normal social interactions and become comfortable with “value neutral” gestures and comments.

Use
1. head nodding sparingly and consciously, such as in eliciting additional comments
2. verbal responses like – “Ok,” “Yes”, ”Uh huh”
3. name tents (5 x 8 cards folded in the middle, with first names printed).

Avoid
1. those that indicate accuracy or agreement – responses like “correct”, “that’s good”, Excellent”
2. avoid expressing personal points of view.
   - Participants must feel comfortable with the moderator and that the moderator is the appropriate person to ask the questions and that the answers can be openly offered and discussed.
   - Place shy and quiet participants immediately across from the moderator to facilitate maximum eye contact.
   - Give a second reminder when participants are simply “echoing” the same concept – to deter this ask, “Does anyone see it differently?” or “Are there any other points of view?”
   - Is primarily concerned with directing the discussion, keeping the conversation flowing, and taking a few notes.
   - Notes of the moderator are not so much to capture the total interview but rather to identify a few key ideas or future questions that need to be asked.
Appendix E:

Rules for Assistant Moderators

1. Take responsibility for all equipment.
   • *Ensure that it works and is complete.*
     - Tape recorder
     - Microphone
     - Blank tapes
     - Spare Batteries
     - Refreshments
     - Visuals or Handouts

2. Take responsibility for refreshments.
   • *Obtain the refreshments and set them up in the room.*

3. Arrange the room.
   • *Book the room in advance.*
   • *Rearrange chairs and table so everyone can see each other.*
   • *Be attentive to background noises that would affect the audio recording.*

4. Set up the equipment.
   • *Verify that it works properly.*

5. Welcome participants as they arrive.

6. Sit in the designated location.
   • *Sit outside the circle, opposite the moderator, and close to the door.*
   *If someone arrives after the session begins, meet the person at the door, take him/her outside the room, and give him/her a short briefing as to what has happened and the current topic of discussion. Then bring the late participant into the room and show him/her where to sit.*

7. Take notes throughout the discussion.
   • *Well said quotes.*
     - *Capture word for word as much of the statement as possible.*
     - *Listen for sentences/phrases that are particularly enlightening/eloquently express a particular point of view.*
     - *Place quotation marks around the statement/phrase and indicate the name/pseudonym of the speaker.*
     - *Place your opinions, thoughts, or ideas in parentheses to keep them separate from participant comments.*
Appendix E:

Rules for Assistant Moderators

➢ If a question occurs to you that you would like to ask at the end of the discussion, write it down in a circle/box.

• Note the nonverbal activity.

➢ Watch for head nods, physical excitement, eye contact between participants, or other clues that would indicate level of agreement, support or interest.

• Make a sketch of the seating arrangement.

8. Monitor recording equipment.
   • Occasionally glance at the tape recorder to see if the reels are moving.
   • Turn over the tape/insert another tape when appropriate.
   • Attempt to do this as smoothly as possible without drawing attention to the recording equipment.
   • Label the cassette tapes. Indicate date, location and number of each tape.

9. Do not participate in the discussion!
   • You talk only if invited by the moderator.
   • Control your nonverbal actions no matter how strongly you feel about an issue.

10. Ask questions when invited.
    • At the end of the discussion, the moderator will invite you to ask questions of amplification or clarification.

    • At the end of the discussion, the moderator or assistant should provide a brief summary (about 3 minutes) of responses to the important questions.
    • Invite participants to offer additions or corrections to the summary.

12. Thank the participants.

13. Debrief the session with the moderator.
    • Following the focus group, participate in the debriefing with the moderator.

14. Read and provide feedback on the analysis.
Appendix E

Focus Group Questions

Focus Group Session I : Issue discussed:
Teaching with computer technology – the characteristics, decisions, signals and boundaries.

1. What are the characteristics of a computer technology integrated lesson?

2. What are the teaching/learning decisions made when integrating computer technology into the classroom?

3. What are the information that you act upon in a computer technology integrated classroom?

4. Are there boundaries in the use of computer technology for teaching and learning purposes?

Focus Group Session II : Issue discussed:

Teaching with computer technology - Teacher Thoughts and Knowledge

1. Students are “critical reality definers” in a computer technology integrated lesson. What is your response to this? What do you think this term means? What does it say about the role of students in a technology classroom?

2. A computer technology integrated classroom serves as a symbol of the quality of education students are receiving. Do you think this is the case? In what ways can it be represented? Can you give examples of when this happens?
3. Teachers will not use computer technology to any noticeable extent if they do not feel there is some educational purpose to be furthered.
   What is this educational purpose?
   Can you give examples of lessons where this educational purpose has been achieved?

4. Teachers’ have a role in making learning meaningful.
   How does computer technology fit into this?
### Appendix F:

**Samples of participants hand written metaphors**

<table>
<thead>
<tr>
<th>Name</th>
<th>Metaphor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sundari</td>
<td>Computer technology is a tool I use to anchor my students so that they are focussed.</td>
</tr>
<tr>
<td>Anthony</td>
<td>To teach or learn with computers is like learning to drive a car. Once the basics are mastered, driving is easy. Like driving it can breakdown and cause frustrations.</td>
</tr>
<tr>
<td>Ning</td>
<td>Computer technology is one of the tools in my toolbox that can help the students make meaning of what they are learning.</td>
</tr>
<tr>
<td>Angela</td>
<td>Computer technology to teaching is like seasoning to cooking. Appropriate quantity added at an appropriate time makes the dish taste better.</td>
</tr>
<tr>
<td>Tan</td>
<td>Computer technology in my teaching is like a bank. A lot of wealth is stored there pupils withdraw from it.</td>
</tr>
<tr>
<td>Woo</td>
<td>The teacher gives the skeleton and the students use computer technology to build up the meat of the skeleton</td>
</tr>
</tbody>
</table>
Appendix G

Lists of common metaphoric language fragments

Participants' images of lessons integrating computer technology into teaching: “Lessons with moving objects moving towards a destination

flows quite easily; how the lesson is going; go through; don't have to cover so much; able to follow; run through it; set them on their own; (Sundari); move in this direction; go through it; all will follow; lesson should go along; go on to the hard stuff; just carry on; carry on without it; go on to write; (Anthony); carry on with the lesson; along the way, beyond them; leading to, starting it off; normally touch and go; going beyond it; (Ning); smooth running of the lesson; keep them on task; flow is there, help us along; going on of the lesson; carry on with the discussion; start off; guide them along; guiding through the lesson, proceed on; learn further; could set them thinking; keep them going on; (Angela) and can go onto; get across; on the right track or not; we have to run through; go astray; can go on exploring; go beyond it; pace of students; (Tan).

Metaphorical language fragments that indicated the destination of the moving lesson as a moving object.

targeted at the end of the lesson, what I targeted at the end of the lesson; (Sundari); at a certain point; point out like a signpost; show directions; at a certain point introduce; (Anthony); which direction I decide to go; continuous part of the lesson, (Ning); keep them going on; have a target, (Angela); and get across better; get across; finish their mission; (Tan).

Supporting

able to follow; reconnect; don't have to cover so much; reach a lot of information; played around; lesson flows smoothly, lesson flows quite easily; (Sundari); lighten
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up the lesson; brighten up the lesson; lesson should go along well avenues to make things clearer; played around; play with it; (Anthony); easily carry out the lesson; lighten up my lesson; I can reach that easily, I am reaching out; leading them to; starting it off; opens up the topic for discussion; able to carry out for themselves; play with it; (Ning); helps us along; the going on of the lesson; support what you are doing; carry on with the discussion; (Angela); and follow my lesson; can go on to; get the concept across better; get the lesson across, can get a lot of things across, get across better; (Tan).

Metaphoric language fragments which were semantic terms opposite to the metaphoric language fragments above

(when the computer technology doesn’t function) the lesson goes off track; I don’t have to talk at length; (Sundari); bog down; not easily carried out; can confine them; might go offshoot; go off tangent (Anthony); loose the students; rather than giving it to them direct (Ning); and (teacher’s monotonous voice) drives them to sleep; cannot carry out; (Tan).

Visualizing

are to focus on; visual grasp of the concept; visual impact; get their attention; processes are clearer; attracts the students attention; to focus on the concepts; capture their attention; they are to focus; (Sundari); grasp the concepts; on the spot; comes alive; (Anthony); got their attention; (Ning); and catch their attention; have a target...more focussed; show them on the spot; focussed...able to focus them onto the main things (Angela) and go to the computer and focus; (Tan).
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Developing

incorporate everything into one; put it into one; put it all into one; reconnect; (Sundari); brings in all kinds of things; bring the whole world into the classroom; fill in those areas; it is a whole; make connections; give some sparks; (Anthony); and link them from one to another; stirs up; sparks here and there; spark off some questions; line to spark off more things; like a detonator; not just sticking to the facts; (Ning).

Equipping

delivers the facts; where a lot of knowledge is stored; pick it up; get some information; able to pick it up; a place where students can draw knowledge; are taking it up; leaves a lasting impression; retain the facts better; retain in the memory ; (Sundari); more knowledge to share; picked up from the CD-ROM; to pick it up; as a tool to pick up information; go and pick up; picking it up from the computer; will pick it up; search for answers; whatever they pick up; one of the means for students to pick up, equipped at a certain level; (Ning); bring back with them; gathered all the answers; get the main concept; get the information; can get out of the computer technology; pick up; (Angela) and get some data; get the information; add it to my students; pick out; draw all the knowledge its free; get all the results from; will stay with the student; give; (Tan).

Facilitator

don’t have to talk at length; don’t have to cover so much; cuts down on the explanations; takes my place as a teacher giving facts, computer technology takes centre stage; supply the facts; (Sundari); puts it all together; overall view of the thing enhances the content; makes the lesson come alive; more dynamic, moving and less fixed; combines everything in the appropriate amounts, gives a nice
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picture; (Anthony); reach out to students; leading them to objectives; starting it off for them; not forcing it in; rather than giving it to them; provides the lesson with more linkages; carries out the lesson; puts up the lesson; (Ning); help them link; relate to them; gather feedback; makes a big picture; will set them to relate; (Angela); and link; help them make meaning; help them to go to; to dig it out with them; provides the lesson with more linkages; carries out the lesson; puts up the lesson; makes a big picture; will set them to relate; and helps et all the results; gives them the details; where they dig out information; (Tan).

Guiding

bring them back; tend to go astray; (Sundari); get down to the solid stuff; (Anthony); cannot run away; still boils down to; (Ning); focus them back on guide them back; go out of focus; (Angela) and on the right track or not; go astray; go step by step; (Tan).

Woo’s teaching and learning images

guide them to; navigate them along the correct path; make sure they are on task; and provide the navigation signs; drawing for them a skeleton for them to fill up; can gain from computer technology to build up the skeleton, framework is already there; and they will fill it up.
<table>
<thead>
<tr>
<th>Features</th>
<th>Diamond</th>
<th>Graphite</th>
<th>Silicon</th>
<th>Silicon dioxide</th>
<th>Sodium chloride</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of particles (atoms or ions) in the structure</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Type of bonding (covalent or ionic) between the particles</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Type of structure (Giant ionic or giant covalent)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arrangement of particles.</td>
<td>Each carbon atom is bonded to ...... other carbon atoms tetrahedrally.</td>
<td>Each carbon atom is bonded to ...... other carbon atoms to form hexagonal layers. The layers are held together by weak Van der Waals forces.</td>
<td>Each silicon atom is bonded to ...... other silicon tetrahedrally.</td>
<td>Each silicon atom is bonded to ...... oxygen atoms tetrahedrally.</td>
<td>Each sodium ion, Na⁺, is surrounded by ...... chloride ions, Cl⁻. Each chloride ion, Cl⁻, is surrounded by ...... sodium ions, Na⁺.</td>
</tr>
</tbody>
</table>
Worksheet on Bonding

Name: .......................................... ( )  Date: .....................
Class: Sec3/......

Objective: To compare and contrast the structure and bonding of diamond, graphite, silicon, silicon dioxide and sodium chloride.

Instructions:
1. Click on the icon 'Chemistry Set'
2. Click on the icon 'A-Z Index'.
3. Scroll down and click each of the following substances in turn:
diamond, graphite, silicon, silicon dioxide and sodium chloride.
   For each substance, click on the 'Moleculiser Icon' to see the 3-D molecular graphics.
   You can rotate the structure by clicking the respective key. Stop the rotation by clicking the same key.
   Click on the Index Icon at the bottom to return to the A-Z Index.
4. Make a comparison of the 5 substances by filling up the following table.