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Exploring conditions for the effective implementation and use of computerised cognitive tools

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A thesis submitted in fulfilment of the requirements for the award of

DOCTOR OF PHILOSOPHY

by

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USE OF THESIS

Declaration

I certify that this thesis does not, to the best of my knowledge and belief:

(i) incorporate without acknowledgment any material previously submitted for a degree or diploma in any institution of higher education;

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Abstract

In recent times, the term *cognitive tool* has been applied to computer technology that promotes reflective thinking and student-regulated learning. The interactive qualities of cognitive tools, and their ability to visually represent students' knowledge construction processes, promotes cognitive and metacognitive thinking and fosters learning for understanding. When used appropriately, cognitive tools are purported to bring about advanced cognitive gains through the amplification and augmentation of thinking and learning.

These gains, however, have not been widespread given that information on how to use cognitive tools appropriately has largely eluded educators to date. The purpose of this study, therefore, was to identify an implementation framework that facilitated effective use of cognitive tools such that their potential could be maximised. This framework, which emerged from the literature, was based on a social constructivist perspective of learning where discourse and collaboration were highly valued, and students were encouraged to distribute their learning across social, physical, symbolic and intellectual resources. Known as a distributed learning environment (DLE) framework, it also permitted insight into the extent to which cognitive tools, when used appropriately, contributed to student learning.

Using action research methodology, this framework was implemented on two separate occasions into a fourth year tertiary unit. In keeping with the specific features of the DLE framework, modifications were made to the characteristics of the teaching contexts, which ultimately influenced the ways in which the students approached class activities and their learning in general. In both instances, data was collected from collaborative groups by recording and transcribing their discussions during class activities. Student interviews were also conducted and transcriptions were made of their self-reflective journals. The purpose of the first implementation was to determine the success of the framework in terms of the extent to which it encouraged students to distribute their learning to resources within the classroom. While there were varying degrees of distribution, the data suggests that the students relied heavily on many resources to support their understanding of the unit material.

Based on these encouraging findings, the second implementation proceeded and the DLE framework was used as a catalyst for the introduction of a cognitive tool called *Inspiration®* into the same unit the following semester. The activities within this unit

were based on collaborative group work, the understandings from which were built into a concept-map that each group created for the five modules within the unit. Discourse analysis revealed that this setting enhanced student learning in that deep-level socio-cognitive processes were frequently present within the collaborative groups' dialogue. By forming visual, metacognitive, collaborative and motivational partnerships with the cognitive tool, the groups were able to place structure and coherency in their dialogue, identify gaps in their understandings and take the appropriate steps towards integrating knowledge.

The major implication to emerge from this study is that the DLE framework successfully supported the inherent qualities associated with the cognitive tool. Although extensive, its features present educators with a practical opportunity to operationalise current learning theory in their classrooms and, at the same time, implement an environment that embraces and advances the learning benefits associated with cognitive tools.

Acknowledgments

This thesis is testimony to its central argument that learning is not a solitary pursuit but is coaxed and nurtured along by a range of invaluable supports. Thanks to the unwavering support from the following individuals, this study has run its course and many important lessons have been learned.

The supervision provided by my Principal Supervisor, Dr Jan Herrington and my Associate Supervisor, Professor Ron Oliver have guided me throughout every stage of this study. Their expertise in the area of educational technology, attention to detail and professional excellence have enriched my work substantially. Despite their own busy schedules, they cheerfully and enthusiastically embraced my ideas, questions, concerns and frustrations, providing timely advice and mentorship of the highest quality. For this, I am truly grateful. A special word of gratitude goes to Jan whose continuing achievements in her field provide inspiration to my own aspirations and, no doubt, others like me.

Thanks also to Dr Tony Fetherston and Dr Catherine McLoughlin whose advice on certain aspects of the study were very constructive and extremely useful.

Above all, I would like to thank my family whose unconditional patience and understanding have kept me going over the past four years. Thank you to my husband Jeff who tirelessly held the fort and ensured my absences were not too noticeable. His readiness to read and edit countless drafts of this thesis, and his unrelenting encouragement, have been invaluable. Thank you also to my gorgeous children Noelle, Vivienne and Ryan whose inherent acceptance of, and belief in my goals are the driving force behind everything I do. They remain my greatest achievements and it is to them that this work is dedicated.

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Introduction

Background to the study

A myriad of literature exists supporting the use of computer technology in educational contexts. Over the decades, numerous claims have been made regarding the positive impact computers have had on the process of learning. Technology has enabled students to expand their thinking capabilities; to work harder, faster and smarter (Jonassen, Peck & Wilson, 1999; Norman, 1993; Reusser, 1993), to go beyond the boundaries of human processing limitations (Bruner, 1990; Pea, 1985), and extend individuals' intellects to limits not yet fully explored nor understood (Adams, 1985). These ambitious claims are typically made in relation to the use of computers as *cognitive tools*, that is, software applications that facilitate critical thinking and higher order learning.

Cognitive tools differ from the more traditional 'instructivist' notion of computer technology in that they do not provide prescribed communications or interactions, nor do they transmit bodies of knowledge (Jonassen & Reeves, 1996). In the true sense, cognitive tools are *un*intelligent applications (Jonassen, 1995; 1996) that provide flexible, didactic supports which encourage students to make maximum use of their own intelligence and knowledge structures (Reusser, 1993). Rather than force students down pre-determined paths, cognitive tools encourage self-directed, intentional learning (Salomon, Perkins & Globerson, 1991). The interactive qualities of cognitive tools, and their ability to visually represent students' knowledge construction processes, promotes cognitive and metacognitive thinking (Lajoie, 1993) and fosters learning for understanding (Norman, 1983).

However, despite these impressive qualities, cognitive tools have largely failed to deliver the transformation in learning that so many claimed they could and would (Cuban, 1996; Hunter, 1998; Jonassen & Reeves, 1996; Rogers, 2001, Selwyn, 1999; Stoney & Oliver, 1999). Recent reports indicate that cognitive tools have not been used to facilitate student-directed learning, nor have they enhanced learning outcomes in any notable way (Evans, 1998). Despite its strong presence in schools today, computer technology is primarily being used to supplement traditional expository patterns of classroom activity, rather than as a tool to cultivate higher-order thinking and learning (Conte, 1997; Hooper & Hokanson, 2000).

What critics tend to forget, however, is that the way in which a cognitive tool is used will ultimately influence its ability to enhance learning. Crook (1994) writes, "Across different settings, there may be significant variation in how radically the same technology serves to restructure the activity of learning" (p. 9). For example, computers that are used to conduct drill and practice will be less likely to stimulate higher-order thinking compared to those that are used to represent internal knowledge structures. Similarly, those that are used to instruct and transmit information will be less successful compared to those that are used to support self-directed analysis and interpretation of information. Even the most competent cognitive tools can be rendered useless if the student is using it to carry out activities that support the absorption of meaningless pieces of information.

Consequently, in judging the impact of cognitive tools, the focus is not so much on the tool itself but on its perceived role in the classroom (Reeves, 1996) and the way in which the students interact with it. As is the case with any educational tool, interaction with it is largely dependent on the objectives of the learning activity which, in turn, are influenced by the nature of the learning environment as a whole. This view is supported by Salomon (1993c) who writes, "... no tool is *good* or *bad* in and of itself; its effectiveness results from ... the whole configuration of events, activities, contents and interpersonal processes taking place in the context of which it has been used (p. 189).

It can be inferred from this statement, that the value of cognitive tools can only be realised when they are implemented within learning environments that are conducive to their inherent qualities. And given their potential to facilitate the construction of meaningful knowledge, it comes as no surprise that many theorists propose constructivist learning environments as being the most appropriate (Cole & Engeström, 1993; Evans, 1998; Jonassen, 1996, 1998; Jonassen & Reeves, 1996; Lajoie, 1993). Constructivism, after all, promotes the sort of active mental involvement in learning – the mindful engagement that cognitive tools require from students if they are to be used effectively (Jonassen, 1996).

Although Edelson, Pea and Gomez (1996) acknowledge the value of a constructivist learning environment, they argue that (on its own) it is not the optimal environment for cognitive tools. Because learning is widely recognised as a social experience, Edelson et al. cite the individualistic focus of constructivism as being one of its main shortcomings in relation to cognitive tools. Based on the belief that learning is enhanced when students have opportunities to communicate and collaborate with each other (and with a range of learning tools), they propose that the constructivist approach be supplemented with a *socio-cultural* perspective of learning. In doing so, the learning environment becomes one where students construct knowledge in *partnership* with each other and with its culturally defining resources.

This partnership has been frequently described in the literature as an 'intellectual' one (Jonassen, 1995, 1996; Jonassen & Reeves, 1996; Reeves, 1996; Salomon et al., 1991) in that cognitive processes are shared and distributed across the student, the learning resources and the learning environment in general. Learning outcomes, therefore, are potentially enhanced by accessing the contributions of an array of resources, not just one individual thinking alone. This notion of the whole being greater and more powerful than the sum of its parts is supported by Torraco (1999) as he states, "Rather than being limited to a single agent, the *learner* is an aggregate concept representing a corps of individuals [and other resources] engaged in collaborative effort to achieve a common goal" (p. 257).

This picture provides a useful starting point for the implementation of the computer as a cognitive tool and also raises some presently unanswered questions. Introduced as a partner in cognition, one to which cognitive activity could be distributed, would the cognitive tool be able to fulfill its role as a powerful learning tool? Would it enable students to effectively represent their knowledge construction processes and encourage them to think at deeper, more sophisticated levels? What actually are the characteristics of this environment where learning is distributed across students and resources? Might a 'distributed learning environment' contribute a practical solution to the implementation of cognitive tools which has evaded educators and theorists to date?

Purpose of the study and research questions

These questions and concerns were at the heart of this study, the purpose of which was two-fold; one, to develop an implementation framework that facilitated appropriate use of computers as cognitive tools and two, to explore the extent to which computers, when used as cognitive tools, promoted student learning. These aims were carried out in three interrelated parts which are outlined below.

Part 1: Identification of a distributed learning environment framework

Fundamental to this investigation was the premise that learning is not an individual pursuit, but rather is a collaborative process distributed across a variety of resources found within the learning environment. In an effort to facilitate this process, it was first necessary to develop a framework which would be conducive to the distribution of cognition. Consequently, the related literature was extensively reviewed to identify the key characteristics associated with distributed learning environments. Books, journal articles, research projects and web sites were the primary referents for these characteristics, which were subsequently formulated into a framework which consisted of three main components (*teaching characteristics, student characteristics and process characteristics*).

Part 2: Implementation of the distributed learning environment framework

Research question 1: *To what extent do students distribute their learning within a distributed learning environment?*

During Part 2 of this study, the framework developed in the previous phase was introduced into a fourth year education unit. Data were gathered by video recording students as they completed class activities, by individually interviewing students and by collecting their journals which they maintained throughout the semester. This information was used to determine the extent to which the students distributed their cognition to individual, social, physical and symbolic resources evident within the learning environment.

The understandings formed here, as well as constant observation of the framework throughout the semester, were used to modify the distributed learning environment accordingly. Furthermore, any issues that appeared to influence the students' distribution of cognition, but were not evident in the framework, were subsequently incorporated.

Part 3: Introduction of a computerised cognitive tool into the classroom using the distributed learning environment framework

Research question 2: *How does a cognitive tool contribute to student learning when implemented in a distributed learning environment?*

Using the framework, modified in accordance with findings that emerged in Part 2, a computerised concept-mapping cognitive tool was implemented into the same education unit but in the following semester. Students were familiarised with the principles of distributed cognition at the beginning of the unit, and were also taught how to use the concept-mapping tool. Throughout the unit, students worked in collaborative groups around the computer. Four of these groups were observed to assess the effects the cognitive tool had on their learning. Data were collected by audio-taping their interactions with each other and with the cognitive tool.

Research question 3: *What reactions typify students' responses to the use of computers as cognitive tools in a distributed learning environment?*

Because many of the students had little prior experience in learning with cognitive tools, data were also gathered to determine their attitudes towards this endeavour. It was assumed that the students' perceptions of using the computer as a cognitive tool, and their commitment towards a distributed learning environment, might affect their learning outcomes. The findings to emerge from this research question, therefore, were used to supplement the findings of the previous research question. Data were collected by individually interviewing the students after each recorded class activity, and by reviewing entries in their journals.

The students' perspectives on computer technology, as part of the learning culture within education, were also examined. These issues added an affective element to the study and provided insight into the process of integrating computer technology into the culture of education courses.

Figure 1.1 provides a diagrammatic overview of the three parts of the study, and their respective investigations.

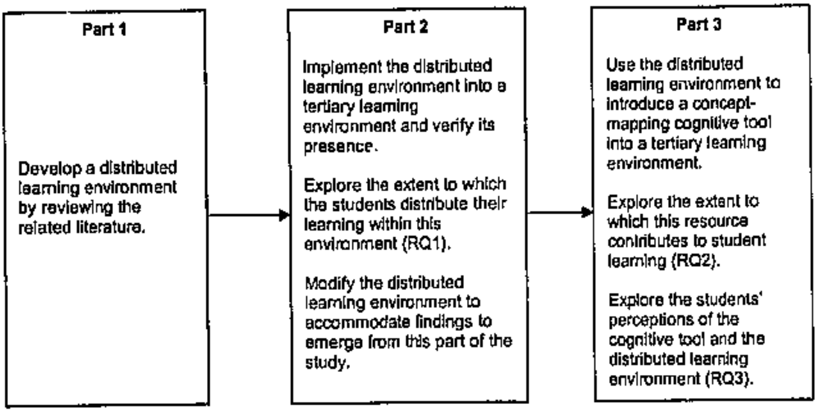

Figure 1.1 Overview of research design and its investigations

Structure of the thesis

Because cognitive tools were the focal point of this study, it was necessary to begin the thesis with a comprehensive overview of this resource. **Chapter 2**, therefore, is a review of the literature that defines cognitive tools. The attributes of effective cognitive tools are described, as are the educational benefits of using them. It is postulated that cognition can be extended, redefined and augmented when cognitive tools are used as partners in the process of learning.

Chapter 3 discusses the theoretical framework which underpins the development of this partnership. Termed *social constructivism*, this perspective describes learning as a social activity where students collaborate to construct knowledge in resource-rich learning communities. Vygotsky's socio-culturalism and Piaget's constructivism form the basis of the assumptions which constitute social constructivism.

In **Chapter 4** distributed cognition is introduced as an extension of social constructivism. A continuum of varying conceptions of distributed cognition is proposed and the one aligned most closely with this study is identified. Because resources are central in all conceptions (to a greater or lesser extent) a broad overview of their role as vehicles of distribution is given.

Chapter 5 constitutes Part 1 of the research and discusses the fundamental characteristics of a distributed learning environment. Drawing on the principles of distributed cognition presented in Chapter 4, the specific features of this framework are described in detail. Given that this framework constitutes the foundation upon which the rest of the study was built, it is constantly referred to throughout the thesis.

Chapter 6 discusses the method of research used in all three parts of the study. It begins with a literature review of the research methodology, the principles of which facilitated the study's overall design. The two research contexts and procedures of data collection and analysis are described in detail, as are ethical considerations and the methods used to ensure reliability and validity.

Chapters 7 and 8 constitute Part 2 of the research where the distributed learning environment framework was implemented into the classroom context. **Chapter 7** is a verification that all features of the distributed learning environment framework were appropriately implemented and **Chapter 8** is an analysis of the extent to which students distributed their cognition when learning under these conditions.

Chapters 9 and 10 constitute Part 3 of the research where the distributed learning environment framework was used as a catalyst for the introduction of a concept-mapping cognitive tool. **Chapter 9** presents an analysis of the data and the findings in relation to the extent to which the cognitive tool contributed to effective student learning. **Chapter 10** explores this issue further but from the perspectives of the students themselves.

As a conclusion to the study, its design, methodology and findings are summarised in **Chapter 11**. The implications associated with these findings are also discussed. These implications provide a practical perspective in terms of the key issues in setting up a distributed learning environment, as well as the impact this environment might have on teachers and students. The chapter also provides insight to the significance of this study, its limitations as well as opportunities for further related research.

-2-

Cognitive Tools

Chapter Overview

This chapter provides a detailed discussion about cognitive tools – what they are, how effective cognitive tools are defined and what benefits students can expect when they are used appropriately. The differences between learning *from* and *with* a cognitive tool are described and the information-processing model is drawn on to explain the types of cognitive functions cognitive tools can facilitate. Cognitive, social, affective and administrative affordances are described as the four primary affordances associated with 'good' cognitive tools, the educational benefits of which are subsequently discussed.

What are cognitive tools?

While the notion of intellectual tools encompasses any device that facilitates cognitive processing, cognitive tools, more specifically, refer to computer-based devices (Jonassen, 1995). For example, electronic concept maps, databases and spreadsheets, as well as programming software, the internet and word processors, have been recognised by a multitude of authors as computerised cognitive tools (Chipman, 1993; Jonassen, 1996; Jonassen, Reeves, Hong, Harvey & Peters, 1997; Reeves, 1996; Salomon, 1993c and others).

In keeping with information processing models of thinking and learning, cognitive tools can be classified according to the cognitive functions they facilitate (Iiyoshi & Hannafin, 1998). For example, Table 2.1 provides an overview of the types of cognitive tools that can support cognition throughout all phases of information processing. While it is possible for some cognitive tools to facilitate multiple phases of cognitive processing (e.g., concept-mapping software), the examples provided in Table 2.1 have been classified according to their most notable functional ability.

Table 2.1 Classification of cognitive tools according to the information-processing model of thinking and learning (adapted from Iiyoshi & Hannafin, 1998)

Cognitive processes	Functional tool classifications	Role of cognitive tools
Seeking information	Information seeking tools (e.g., the Internet)	Support students as they attempt to identify and locate relevant information, as well as retrieve new and existing knowledge.
Selecting information	Information presentation tools (e.g., word processors, spreadsheets)	Support students as they attempt to present the information they encounter. Assist them in clarifying the relationship among the information.
Organising information	Knowledge organisation tools (e.g., database software)	Support students as they attempt to establish conceptual relationships in new information. Help them interpret, connect and organise the represented information meaningfully.
Integrating information	Knowledge integration tools (e.g., concept-mapping software)	Support students in connecting new with existing knowledge. Facilitate the processing of content at deeper levels in order to construct personally meaningful knowledge.
Generating information	Knowledge generation tools (e.g., programming)	Support the manipulation and generation of knowledge. Help students to represent their newly generated knowledge flexibly and meaningfully.

Although computer technology in the classroom is not a new concept, implementing it as a cognitive tool is (Jonassen, 1996). In many classroom environments, computer applications are used as 'teaching tools' that mimic the traditional role of the expository teacher. This type of application is very different from one that is implemented as a cognitive tool with which students are encouraged to construct their own meaning of knowledge, rather than absorb ideas preconceived by others (Jonassen & Reeves, 1996). Salomon et al. (1991) make the distinction between computers used in this way as learning *with* technology as opposed to the effects *of* technology on learning. The notion of learning *with* technology implies the development of an intellectual partnership where the student and computer work together to achieve learning outcomes. In contrast, the effects *of* technology refer to the knowledge or skills acquired by the student as a result learning from the computer.

When computer technology is used as a teaching tool (which students learn *from*), rather than as a cognitive tool (which students learn *with*), a certain amount of intelligence is implied. In theory, computerised tutoring applications are intelligent enough to replace human teachers' diagnoses of the cognitive abilities and needs of their students (Reusser, 1993). Not only do these applications provide ready-made knowledge, they also decide how much of that knowledge students should learn and the pace at which they should learn it. This level of intelligence can be detrimental to learning (Derry & Lajoie, 1993) considering that all-controlling computer applications generally encourage students to abdicate their responsibility in the learning process and become passive recipients rather than active constructors of knowledge.

In contrast, cognitive tools promote reflection (Norman, 1983), critical thinking (Reeves, 1996) and student-regulated knowledge construction (Jonassen et al., 1999). Provided they are deployed within appropriate classroom environments, they facilitate cognitive and metacognitive thinking (Lajoie, 1993) and ultimately rely on students for decisions as to the pace and direction of their learning. While some refer to these types of applications as *un*intelligent (Jonassen, 1995, 1996) or *empty shells* (Hedberg, Harper & Brown, 1993) their 'deficiency' is only evident in the sense that they do not provide prescribed instruction. It does not imply any inability to aid in the learning process. Used primarily to represent student thought processes, cognitive tools can foster the development of deep understandings by enabling students to inspect, reflect on, manipulate and discuss concepts and strategies that are normally intangible and abstract (Reusser, 1993).

The visual component, therefore, is potentially a vital characteristic of any cognitive tool. Through the manipulation of graphic interfaces, cognitive tools enable students to generate conceptual networks, diagrams, hierarchical structures, graphs, tables, symbol systems and more. Not only do these visuals provide concrete representations of thought against which meaning can be indexed and explained, they also facilitate the intentional construction and externalisation of mental models. Because mental models are typically constructed incidentally, they are generally not readily available for reflection nor are they easily manipulated (Wild, 1996). However, building mental models with cognitive tools is an intentional pursuit that requires active mental participation from the students. As such, the understandings these computer-mediated mental models represent are more accessible, flexible and, above all, useful.

The effectiveness of the visual component is inherent within a range of fundamental attributes that all 'good' cognitive tools should possess. Even though the value of a cognitive tool is ultimately influenced by the purpose for which it is being used (i.e., as a tool to learn *with* or *from*), these fundamental attributes should be present nonetheless.

Attributes of a *good* cognitive tool

Reusser (1993) contends that the design of effective cognitive tools should be based on current research in cognitive psychology. More specifically, they should acknowledge that knowledge is actively constructed by students, and that this knowledge is typically produced, shared and transformed within groups of students working together to solve problems. Therefore, to be characterised as effective, cognitive tools must support the *cognitive* and *social* aspects of learning.

In addition to this Lepper, Woolverton, Mumme and Gurtner (1993) argue that the *affective* side of cognitive tools is also critical to successful learning yet this issue remains largely unaddressed in the literature. The assumption is that if the cognitive and social issues are addressed, then high levels of motivation will naturally ensue. As will be elaborated upon in Chapter 4, Perkins (1985, 1992) warns against making this assumption and argues that the cognitive tool and the learning environment must openly attend to the motivational state of the student by a) providing appropriate levels of challenge, b) enabling the student to maintain a sense of control and c) eliciting from the student a high level of curiosity. Lepper et al. (1993) concur with these goals and maintain that they are integral to the development of intrinsic motivation.

Furthermore, Jonassen (1996) contends that cognitive tools should possess certain *administrative* features, although these more practical aspects are not necessarily critical to effective learning. He states that aspects such as affordability and availability should be evident in cognitive tools as they render them accessible to a greater population of students.

Consequently, cognitive tools should possess cognitive, social, affective and administrative features if they are to contribute to quality learning outcomes. Cognitive features encompass those criteria that relate to the mental constructions of knowledge, whilst social features encompass those criteria that relate to the shared constructions of knowledge. Affective features relate to the motivational aspects of learning and administrative features refer to criteria of practicality.

The extent to which these four fundamental features characterise good cognitive tools is better understood if they are thought of as 'affordances' (refer to Figure 2.1). Pea (1993) contends that the way in which something is used is determined by the perceived and actual properties it possesses, that is, its affordances. For example, a cup can be used as a drinking utensil according to its actual property, but can also double as a pencil holder in relation to an individual's perception of it as a desk organiser. Similarly, the above mentioned features describe the actual attributes that should be characteristic in the design of cognitive tools, but may or may not be exploited depending on the students' perceptions of these affordances.

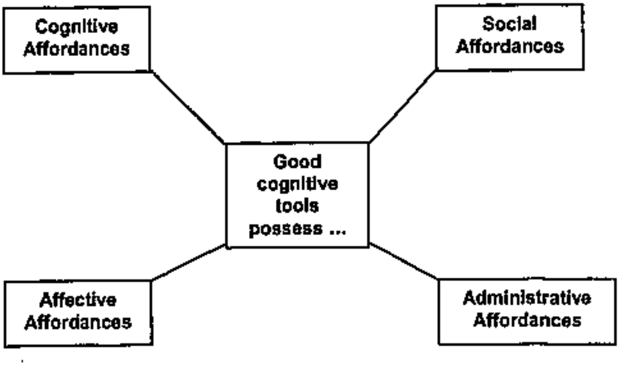

Figure 2.1 Affordances associated with *good* cognitive tools

With this framework in mind, literature describing the use of cognitive tools in classroom situations, as well as those examined in empirical studies (e.g., Anderson-Inman & Zeitz, 1993; Beyerbach & Smith, 1990; Fisher, 1990; Goldenson, 1996; Hyerle, 1996; Kellog & Mueller, 1989; McLean & Gibson, 1993; Maddux, Lamont Johnson & Willis, 1992; Jonassen, 1996; Manouchehri, 1997; Maor, 1991; Ridout, 1990; Roland, 1997; Ryba & Anderson, 1990 and Seidel, 1996), was reviewed to determine the fundamental characteristics of the four affordances and the way in which they support learning. These characteristics (which are described below) are not exhaustive, and it is acknowledged that others may emerge beyond the cited literature base. They should, however, still fall within one of the four affordances defined.

Cognitive affordances

- *The cognitive tool supports student-centeredness* (Anderson-Inman & Zeitz, 1993; Beyerbach & Smith, 1990; Fisher, 1990; Hyerle, 1996; McLean & Gibson, 1993; Maddux, et al., 1992; Jonassen, 1996; Manouchehri, 1997; Maor, 1991; Ridout, 1990; Roland, 1997 and Seidel, 1996). While the cognitive tool is perceived to be a partner in the learning process, all actions are controlled by the student. Therefore, active mental engagement on the part of the student is imperative.

- *The cognitive tool supports cognitive transfer* (Goldenson, 1996; Jonassen, 1996; Ryba & Anderson, 1990; Seidel, 1996). Knowledge and skills developed while working with the cognitive tool in a particular context can be transferred to other similar or different contexts, either with or without the cognitive tool. For example, strategies developed while working with a cognitive tool in mathematics can be used in social studies also. Salomon et al. (1991) and others (Salomon & Perkins, 1998; Underwood & Underwood, 1990) describe this transferability as the cognitive residue that partnerships with computers leave behind.

- *The cognitive tool supports reflection and critical thinking* (Anderson-Inman & Zeitz, 1993; Beyerbach & Smith, 1990; Fisher, 1990; Hyerle, 1996; Maddux, et al., 1992; Jonassen, 1996; Manouchehri, 1997; Maor, 1991; Ridout, 1990; Roland, 1997 Ryba & Anderson, 1990 and Seidel, 1996). Cognitive tools display students' thinking. Visualising their own thoughts encourages a deep level reflection about what students know and what they don't know.

- *The cognitive tool is unintelligent and hence supports the student's intellect* (Anderson-Inman & Zeitz, 1993; Beyerbach & Smith, 1990; Fisher, 1990; Goldenson, 1996; Jonassen, 1996; Manouchehri, 1997; Roland, 1997; Ryba & Anderson, 1990 and Seidel, 1996). Software doesn't contain prescribed facts. Students provide the intelligence and thus create knowledge rather than receive it. After all, knowledge does not exist as an external entity, but is actively constructed by students as they endeavour to understand its inherent meaning (Candy, 1991).

- *The cognitive tool supports metacognitive thinking* (Beyerbach & Smith, 1990; Fisher, 1990; Goldenson, 1996; Hyerle, 1996; Maddux, et al., 1992; Jonassen, 1996; Manouchehri, 1997; Ryba & Anderson, 1990; Seidel, 1996). The interactive nature of many cognitive tools stimulates self-questioning and self-instruction. Also, design is such that students can visualise their thinking processes. Graphics enable students to see the decisions they've made, evaluate them, and then proceed accordingly.

Social affordances

- *The cognitive tool supports discussion and collaboration* (Beyerbach & Smith, 1990; Hyerle, 1996; McLean & Gibson, 1993; Maddux, et al., 1992; Jonassen, 1996; Manouchehri, 1997; Maor, 1991; Ridout, 1990; Ryba & Anderson, 1990). Through discussion and collaboration with others, students are able to negotiate the meaning of a concept by questioning existing understandings as well as explaining, evaluating and clarifying new and developing understandings. These opportunities for collaboration can occur either when working in group situations around the cognitive tool, or as an individual working at a distance from others (e.g., the world wide web).

Affective Affordances

- *The cognitive tool supports intrinsic motivation* (Anderson-Inman & Zeitz, 1993; Beyerbach & Smith, 1990; Fisher, 1990; Hyerle, 1996; McLean & Gibson, 1993; Maddux, et al., 1992; Ridout, 1990; Ryba & Anderson, 1990; Seidel, 1996). Cognitive tools engender a sense of satisfaction which comes from being challenged, in control and intrigued by the activities that are supported by the application. Positive feelings towards a novel, yet sound method of learning encourage students to make sense of the material and seek further opportunities to tackle similar problems in other contexts. In relation to interactive multimedia, Chan Lin and Reeves (1994) cite a large literature base that places computer graphics at the centre of student motivation and, subsequently, enhanced learning outcomes.

Administrative Affordances

- *The cognitive tool is affordable* (Jonassen, 1996; Maddux, et al., 1992). Cognitive tools should be inexpensive and readily available.

- *The cognitive tool is easy to use - not time consuming* (Anderson-Inman & Zeitz, 1993; Fisher, 1990; Goldenson, 1996; Kellog & Mueller, 1989; Maddux, et al., 1992; Jonassen, 1996; Maor, 1991; Ryba & Anderson, 1990; Seidel, 1996). Students should be able to easily navigate their way around without expending too much cognitive effort. Software should not be so sophisticated that students spend most of their time trying to work out how to use it rather than actually learning with it.

- *The cognitive tool can be used in a variety of subject areas* (Fisher, 1990; Goldenson, 1996; Hyerle, 1996; Maddux, et al., 1992; Jonassen, 1996; Roland, 1997; Ryba & Anderson, 1990). The software is not domain-specific, but promotes the use of domain-specific language and symbols in a variety of different subjects across the curriculum.

A summary of the extent to which these characteristics appeared in the literature is provided in Table 2.2.

Table 2.2 Attributes of good cognitive tools

References	Cognitive Tool	Cognitive Affordances					Social Affordances	Affective Affordances	Administrative Affordances		
		Student-Centred	Cognitive Transfer	Supports Reflection and Critical Thinking	(Un)intelligent	Supports Metacognitive Thinking	Supports Discussion and Collaboration	Intrinsic Motivation (Enjoyable)	Affordable	Easy to use	Generalisable across contexts
Beyerbach & Smith, 1990	Concept Map	√		√	√	√	√	√			
Fisher, 1990	Concept Map	√		√	√	√		√		√	√
Anderson-Inman & Zeitz, 1993 (in relation to *Inspiration®*)	Concept Map	√		√	√	√		√		√	√
Hyerle, 1996	Concept Map	√		√		√	√	√			√
Ryba & Anderson, 1990	Database	√	√	√		√	√			√	
Maor, 1991	Database	√		√			√			√	
Jonassen, 1996	Database	√	√	√			√		√	√	√
Seidel, 1996	Database	√	√	√	√	√		√		√	
Ryba & Anderson, 1990	Programming			√		√				√	
Ridout, 1990	Programming	√		√			√	√			
Goldenson, 1996	Programming		√		√					√	√
Jonassen, 1996	Programming	√		√			√		√		√
Maddux, et al., 1992	Spreadsheet	√		√						√	√
Jonassen, 1996	Spreadsheet	√	√	√		√	√		√		
Manouchehri, 1997	Spreadsheet	√		√	√	√	√				
Roland, 1997	Spreadsheet	√		√	√						√
Kellog & Mueller, 1989	Word Processor									√	
Ryba & Anderson, 1990	Word Processor		√	√	√	√	√	√			√
Maddux, et al., 1992	Word Processor	√				√	√	√	√		√
McLean & Gibson, 1993	Word Processor	√					√	√			

Why use cognitive tools?

Knowledge construction is largely an unobservable, complex process that occurs within the minds of individuals who are either collaborating with others or working alone. To build knowledge, information is attended to, deliberated upon, related to similar existing information, and then filed away in a new, more sophisticated form. Cognitive tools can be used to mediate this (often taxing) process by visually representing thinking paths for overt analysis and organization. This exposure can also generate a level of discussion that would perhaps not be possible with covert cognition.

The outcomes of this mediation process are not altogether clear in the literature, nor are existing interpretations agreed upon. While most theorists agree that computers 'support' cognition, it is their interpretation of 'support' that varies. Some say that cognitive tools amplify learning through a division of labour process. In these instances, the cognitive tool primarily supports the lower-level cognitive processes in order to free the student to engage in higher-level activities. With drill and practice applications, for example, students can off-load tedious or repetitive tasks onto the cognitive tool, thus enabling them to complete tasks more efficiently and at a quicker pace.

While Pea (1985) acknowledges the worthy status of cognitive tools as amplifiers of human capability, he extends this profile to contend that cognitive tools can in fact change the way in which students think and learn. Confining the value of cognitive tools to an amplification perspective restricts their true powers, that is, the potential for them to extend, redefine and *augment* student cognition. Augmentation comes about when students work collaboratively - in partnership - with the cognitive tool to open up new possibilities of thought and to construct deep understandings and conceptions. Seen in this light the cognitive tool becomes "an indispensable instrument of mentality, and not merely a tool" (Pea, 1985, p. 175).

Augmentation is essentially a by-product of 'reflection', which is a process encouraged by cognitive tools through the visual representation of thinking paths (Norman, 1983; Reusser, 1993). Reusser (1993) writes:

Exploring conditions for the effective implementation and use of computerised cognitive tools

A thesis submitted in fulfilment of the requirements for the award of

DOCTOR OF PHILOSOPHY

by

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2002

Declaration

I certify that this thesis does not, to the best of my knowledge and belief:

(i) incorporate without acknowledgment any material previously submitted for a degree or diploma in any institution of higher education;

(ii) contain any material previously published or written by another person except where due reference is made in the text; or

(iii) contain any defamatory material.

Signed:

Date:

Abstract

In recent times, the term *cognitive tool* has been applied to computer technology that promotes reflective thinking and student-regulated learning. The interactive qualities of cognitive tools, and their ability to visually represent students' knowledge construction processes, promotes cognitive and metacognitive thinking and fosters learning for understanding. When used appropriately, cognitive tools are purported to bring about advanced cognitive gains through the amplification and augmentation of thinking and learning.

These gains, however, have not been widespread given that information on how to use cognitive tools appropriately has largely eluded educators to date. The purpose of this study, therefore, was to identify an implementation framework that facilitated effective use of cognitive tools such that their potential could be maximised. This framework, which emerged from the literature, was based on a social constructivist perspective of learning where discourse and collaboration were highly valued, and students were encouraged to distribute their learning across social, physical, symbolic and intellectual resources. Known as a distributed learning environment (DLE) framework, it also permitted insight into the extent to which cognitive tools, when used appropriately, contributed to student learning.

Using action research methodology, this framework was implemented on two separate occasions into a fourth year tertiary unit. In keeping with the specific features of the DLE framework, modifications were made to the characteristics of the teaching contexts, which ultimately influenced the ways in which the students approached class activities and their learning in general. In both instances, data was collected from collaborative groups by recording and transcribing their discussions during class activities. Student interviews were also conducted and transcriptions were made of their self-reflective journals. The purpose of the first implementation was to determine the success of the framework in terms of the extent to which it encouraged students to distribute their learning to resources within the classroom. While there were varying degrees of distribution, the data suggests that the students relied heavily on many resources to support their understanding of the unit material.

Based on these encouraging findings, the second implementation proceeded and the DLE framework was used as a catalyst for the introduction of a cognitive tool called *Inspiration®* into the same unit the following semester. The activities within this unit

were based on collaborative group work, the understandings from which were built into a concept-map that each group created for the five modules within the unit. Discourse analysis revealed that this setting enhanced student learning in that deep-level socio-cognitive processes were frequently present within the collaborative groups' dialogue. By forming visual, metacognitive, collaborative and motivational partnerships with the cognitive tool, the groups were able to place structure and coherency in their dialogue, identify gaps in their understandings and take the appropriate steps towards integrating knowledge.

The major implication to emerge from this study is that the DLE framework successfully supported the inherent qualities associated with the cognitive tool. Although extensive, its features present educators with a practical opportunity to operationalise current learning theory in their classrooms and, at the same time, implement an environment that embraces and advances the learning benefits associated with cognitive tools.

Acknowledgments

This thesis is testimony to its central argument that learning is not a solitary pursuit but is coaxed and nurtured along by a range of invaluable supports. Thanks to the unwavering support from the following individuals, this study has run its course and many important lessons have been learned.

The supervision provided by my Principal Supervisor, Dr Jan Herrington and my Associate Supervisor, Professor Ron Oliver have guided me throughout every stage of this study. Their expertise in the area of educational technology, attention to detail and professional excellence have enriched my work substantially. Despite their own busy schedules, they cheerfully and enthusiastically embraced my ideas, questions, concerns and frustrations, providing timely advice and mentorship of the highest quality. For this, I am truly grateful. A special word of gratitude goes to Jan whose continuing achievements in her field provide inspiration to my own aspirations and, no doubt, others like me.

Thanks also to Dr Tony Fetherston and Dr Catherine McLoughlin whose advice on certain aspects of the study were very constructive and extremely useful.

Above all, I would like to thank my family whose unconditional patience and understanding have kept me going over the past four years. Thank you to my husband Jeff who tirelessly held the fort and ensured my absences were not too noticeable. His readiness to read and edit countless drafts of this thesis, and his unrelenting encouragement, have been invaluable. Thank you also to my gorgeous children Noelle, Vivienne and Ryan whose inherent acceptance of, and belief in my goals are the driving force behind everything I do. They remain my greatest achievements and it is to them that this work is dedicated.

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Introduction

Background to the study

A myriad of literature exists supporting the use of computer technology in educational contexts. Over the decades, numerous claims have been made regarding the positive impact computers have had on the process of learning. Technology has enabled students to expand their thinking capabilities; to work harder, faster and smarter (Jonassen, Peck & Wilson, 1999; Norman, 1993; Reusser, 1993), to go beyond the boundaries of human processing limitations (Bruner, 1990; Pea, 1985), and extend individuals' intellects to limits not yet fully explored nor understood (Adams, 1985). These ambitious claims are typically made in relation to the use of computers as *cognitive tools*, that is, software applications that facilitate critical thinking and higher order learning.

Cognitive tools differ from the more traditional 'instructivist' notion of computer technology in that they do not provide prescribed communications or interactions, nor do they transmit bodies of knowledge (Jonassen & Reeves, 1996). In the true sense, cognitive tools are *un*intelligent applications (Jonassen, 1995; 1996) that provide flexible, didactic supports which encourage students to make maximum use of their own intelligence and knowledge structures (Reusser, 1993). Rather than force students down pre-determined paths, cognitive tools encourage self-directed, intentional learning (Salomon, Perkins & Globerson, 1991). The interactive qualities of cognitive tools, and their ability to visually represent students' knowledge construction processes, promotes cognitive and metacognitive thinking (Lajoie, 1993) and fosters learning for understanding (Norman, 1983).

However, despite these impressive qualities, cognitive tools have largely failed to deliver the transformation in learning that so many claimed they could and would (Cuban, 1996; Hunter, 1998; Jonassen & Reeves, 1996; Rogers, 2001, Selwyn, 1999; Stoney & Oliver, 1999). Recent reports indicate that cognitive tools have not been used to facilitate student-directed learning, nor have they enhanced learning outcomes in any notable way (Evans, 1998). Despite its strong presence in schools today, computer technology is primarily being used to supplement traditional expository patterns of classroom activity, rather than as a tool to cultivate higher-order thinking and learning (Conte, 1997; Hooper & Hokanson, 2000).

What critics tend to forget, however, is that the way in which a cognitive tool is used will ultimately influence its ability to enhance learning. Crook (1994) writes, "Across different settings, there may be significant variation in how radically the same technology serves to restructure the activity of learning" (p. 9). For example, computers that are used to conduct drill and practice will be less likely to stimulate higher-order thinking compared to those that are used to represent internal knowledge structures. Similarly, those that are used to instruct and transmit information will be less successful compared to those that are used to support self-directed analysis and interpretation of information. Even the most competent cognitive tools can be rendered useless if the student is using it to carry out activities that support the absorption of meaningless pieces of information.

Consequently, in judging the impact of cognitive tools, the focus is not so much on the tool itself but on its perceived role in the classroom (Reeves, 1996) and the way in which the students interact with it. As is the case with any educational tool, interaction with it is largely dependent on the objectives of the learning activity which, in turn, are influenced by the nature of the learning environment as a whole. This view is supported by Salomon (1993c) who writes, "... no tool is *good* or *bad* in and of itself; its effectiveness results from ... the whole configuration of events, activities, contents and interpersonal processes taking place in the context of which it has been used (p. 189).

It can be inferred from this statement, that the value of cognitive tools can only be realised when they are implemented within learning environments that are conducive to their inherent qualities. And given their potential to facilitate the construction of meaningful knowledge, it comes as no surprise that many theorists propose constructivist learning environments as being the most appropriate (Cole & Engeström, 1993; Evans, 1998; Jonassen, 1996, 1998; Jonassen & Reeves, 1996; Lajoie, 1993). Constructivism, after all, promotes the sort of active mental involvement in learning – the mindful engagement that cognitive tools require from students if they are to be used effectively (Jonassen, 1996).

Although Edelson, Pea and Gomez (1996) acknowledge the value of a constructivist learning environment, they argue that (on its own) it is not the optimal environment for cognitive tools. Because learning is widely recognised as a social experience, Edelson et al. cite the individualistic focus of constructivism as being one of its main shortcomings in relation to cognitive tools. Based on the belief that learning is enhanced when students have opportunities to communicate and collaborate with each other (and with a range of learning tools), they propose that the constructivist approach be supplemented with a *socio-cultural* perspective of learning. In doing so, the learning environment becomes one where students construct knowledge in *partnership* with each other and with its culturally defining resources.

This partnership has been frequently described in the literature as an 'intellectual' one (Jonassen, 1995, 1996; Jonassen & Reeves, 1996; Reeves, 1996; Salomon et al., 1991) in that cognitive processes are shared and distributed across the student, the learning resources and the learning environment in general. Learning outcomes, therefore, are potentially enhanced by accessing the contributions of an array of resources, not just one individual thinking alone. This notion of the whole being greater and more powerful than the sum of its parts is supported by Torraco (1999) as he states, "Rather than being limited to a single agent, the *learner* is an aggregate concept representing a corps of individuals [and other resources] engaged in collaborative effort to achieve a common goal" (p. 257).

This picture provides a useful starting point for the implementation of the computer as a cognitive tool and also raises some presently unanswered questions. Introduced as a partner in cognition, one to which cognitive activity could be distributed, would the cognitive tool be able to fulfill its role as a powerful learning tool? Would it enable students to effectively represent their knowledge construction processes and encourage them to think at deeper, more sophisticated levels? What actually are the characteristics of this environment where learning is distributed across students and resources? Might a 'distributed learning environment' contribute a practical solution to the implementation of cognitive tools which has evaded educators and theorists to date?

Purpose of the study and research questions

These questions and concerns were at the heart of this study, the purpose of which was two-fold; one, to develop an implementation framework that facilitated appropriate use of computers as cognitive tools and two, to explore the extent to which computers, when used as cognitive tools, promoted student learning. These aims were carried out in three interrelated parts which are outlined below.

Part 1: Identification of a distributed learning environment framework

Fundamental to this investigation was the premise that learning is not an individual pursuit, but rather is a collaborative process distributed across a variety of resources found within the learning environment. In an effort to facilitate this process, it was first necessary to develop a framework which would be conducive to the distribution of cognition. Consequently, the related literature was extensively reviewed to identify the key characteristics associated with distributed learning environments. Books, journal articles, research projects and web sites were the primary referents for these characteristics, which were subsequently formulated into a framework which consisted of three main components (*teaching characteristics, student characteristics and process characteristics*).

Part 2: Implementation of the distributed learning environment framework

Research question 1: *To what extent do students distribute their learning within a distributed learning environment?*

During Part 2 of this study, the framework developed in the previous phase was introduced into a fourth year education unit. Data were gathered by video recording students as they completed class activities, by individually interviewing students and by collecting their journals which they maintained throughout the semester. This information was used to determine the extent to which the students distributed their cognition to individual, social, physical and symbolic resources evident within the learning environment.

The understandings formed here, as well as constant observation of the framework throughout the semester, were used to modify the distributed learning environment accordingly. Furthermore, any issues that appeared to influence the students' distribution of cognition, but were not evident in the framework, were subsequently incorporated.

Part 3: Introduction of a computerised cognitive tool into the classroom using the distributed learning environment framework

Research question 2: *How does a cognitive tool contribute to student learning when implemented in a distributed learning environment?*

Using the framework, modified in accordance with findings that emerged in Part 2, a computerised concept-mapping cognitive tool was implemented into the same education unit but in the following semester. Students were familiarised with the principles of distributed cognition at the beginning of the unit, and were also taught how to use the concept-mapping tool. Throughout the unit, students worked in collaborative groups around the computer. Four of these groups were observed to assess the effects the cognitive tool had on their learning. Data were collected by audio-taping their interactions with each other and with the cognitive tool.

Research question 3: *What reactions typify students' responses to the use of computers as cognitive tools in a distributed learning environment?*

Because many of the students had little prior experience in learning with cognitive tools, data were also gathered to determine their attitudes towards this endeavour. It was assumed that the students' perceptions of using the computer as a cognitive tool, and their commitment towards a distributed learning environment, might affect their learning outcomes. The findings to emerge from this research question, therefore, were used to supplement the findings of the previous research question. Data were collected by individually interviewing the students after each recorded class activity, and by reviewing entries in their journals.

The students' perspectives on computer technology, as part of the learning culture within education, were also examined. These issues added an affective element to the study and provided insight into the process of integrating computer technology into the culture of education courses.

Figure 1.1 provides a diagrammatic overview of the three parts of the study, and their respective investigations.

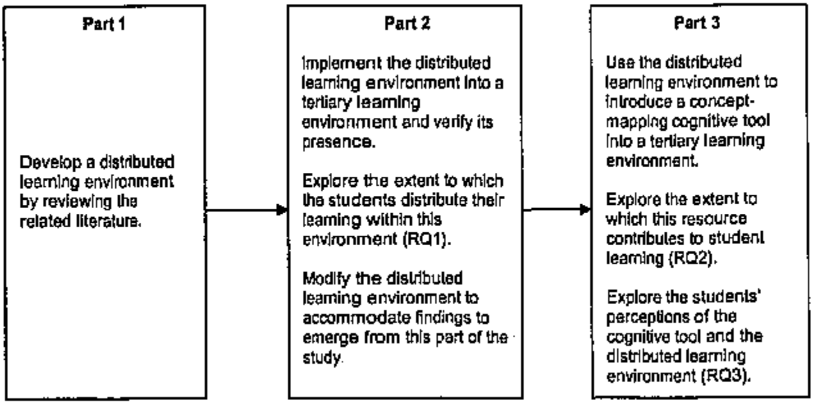

Figure 1.1 Overview of research design and its investigations

Structure of the thesis

Because cognitive tools were the focal point of this study, it was necessary to begin the thesis with a comprehensive overview of this resource. **Chapter 2**, therefore, is a review of the literature that defines cognitive tools. The attributes of effective cognitive tools are described, as are the educational benefits of using them. It is postulated that cognition can be extended, redefined and augmented when cognitive tools are used as partners in the process of learning.

Chapter 3 discusses the theoretical framework which underpins the development of this partnership. Termed *social constructivism*, this perspective describes learning as a social activity where students collaborate to construct knowledge in resource-rich learning communities. Vygotsky's socio-culturalism and Piaget's constructivism form the basis of the assumptions which constitute social constructivism.

In **Chapter 4** distributed cognition is introduced as an extension of social constructivism. A continuum of varying conceptions of distributed cognition is proposed and the one aligned most closely with this study is identified. Because resources are central in all conceptions (to a greater or lesser extent) a broad overview of their role as vehicles of distribution is given.

Chapter 5 constitutes Part 1 of the research and discusses the fundamental characteristics of a distributed learning environment. Drawing on the principles of distributed cognition presented in Chapter 4, the specific features of this framework are described in detail. Given that this framework constitutes the foundation upon which the rest of the study was built, it is constantly referred to throughout the thesis.

Chapter 6 discusses the method of research used in all three parts of the study. It begins with a literature review of the research methodology, the principles of which facilitated the study's overall design. The two research contexts and procedures of data collection and analysis are described in detail, as are ethical considerations and the methods used to ensure reliability and validity.

Chapters 7 and 8 constitute Part 2 of the research where the distributed learning environment framework was implemented into the classroom context. **Chapter 7** is a verification that all features of the distributed learning environment framework were appropriately implemented and Chapter 8 is an analysis of the extent to which students distributed their cognition when learning under these conditions.

Chapters 9 and 10 constitute Part 3 of the research where the distributed learning environment framework was used as a catalyst for the introduction of a concept-mapping cognitive tool. **Chapter 9** presents an analysis of the data and the findings in relation to the extent to which the cognitive tool contributed to effective student learning. **Chapter 10** explores this issue further but from the perspectives of the students themselves.

As a conclusion to the study, its design, methodology and findings are summarised in **Chapter 11**. The implications associated with these findings are also discussed. These implications provide a practical perspective in terms of the key issues in setting up a distributed learning environment, as well as the impact this environment might have on teachers and students. The chapter also provides insight to the significance of this study, its limitations as well as opportunities for further related research.

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Cognitive Tools

Chapter Overview

This chapter provides a detailed discussion about cognitive tools – what they are, how effective cognitive tools are defined and what benefits students can expect when they are used appropriately. The differences between learning *from* and *with* a cognitive tool are described and the information-processing model is drawn on to explain the types of cognitive functions cognitive tools can facilitate. Cognitive, social, affective and administrative affordances are described as the four primary affordances associated with 'good' cognitive tools, the educational benefits of which are subsequently discussed.

What are cognitive tools?

While the notion of intellectual tools encompasses any device that facilitates cognitive processing, cognitive tools, more specifically, refer to computer-based devices (Jonassen, 1995). For example, electronic concept maps, databases and spreadsheets, as well as programming software, the internet and word processors, have been recognised by a multitude of authors as computerised cognitive tools (Chipman, 1993; Jonassen, 1996; Jonassen, Reeves, Hong, Harvey & Peters, 1997; Reeves, 1996; Salomon, 1993c and others).

In keeping with information processing models of thinking and learning, cognitive tools can be classified according to the cognitive functions they facilitate (Iiyoshi & Hannafin, 1998). For example, Table 2.1 provides an overview of the types of cognitive tools that can support cognition throughout all phases of information processing. While it is possible for some cognitive tools to facilitate multiple phases of cognitive processing (e.g., concept-mapping software), the examples provided in Table 2.1 have been classified according to their most notable functional ability.

Table 2.1 Classification of cognitive tools according to the information-processing model of thinking and learning (adapted from Iiyoshi & Hannafin, 1998)

Cognitive processes	Functional tool classifications	Role of cognitive tools
Seeking information	Information seeking tools (e.g., the internet)	Support students as they attempt to identify and locate relevant information, as well as retrieve new and existing knowledge.
Selecting information	Information presentation tools (e.g., word processors, spreadsheets)	Support students as they attempt to present the information they encounter. Assist them in clarifying the relationship among the information.
Organising information	Knowledge organisation tools (e.g., database software)	Support students as they attempt to establish conceptual relationships in new information. Help them interpret, connect and organise the represented information meaningfully.
Integrating information	Knowledge integration tools (e.g., concept-mapping software)	Support students in connecting new with existing knowledge. Facilitate the processing of content at deeper levels in order to construct personally meaningful knowledge.
Generating information	Knowledge generation tools (e.g., programming)	Support the manipulation and generation of knowledge. Help students to represent their newly generated knowledge flexibly and meaningfully.

Although computer technology in the classroom is not a new concept, implementing it as a cognitive tool is (Jonassen, 1996). In many classroom environments, computer applications are used as 'teaching tools' that mimic the traditional role of the expository teacher. This type of application is very different from one that is implemented as a cognitive tool with which students are encouraged to construct their own meaning of knowledge, rather than absorb ideas preconceived by others (Jonassen & Reeves, 1996). Salomon et al. (1991) make the distinction between computers used in this way as learning *with* technology as opposed to the effects *of* technology on learning. The notion of learning *with* technology implies the development of an intellectual partnership where the student and computer work together to achieve learning outcomes. In contrast, the effects *of* technology refer to the knowledge or skills acquired by the student as a result learning from the computer.

When computer technology is used as a teaching tool (which students learn *from*), rather than as a cognitive tool (which students learn *with*), a certain amount of intelligence is implied. In theory, computerised tutoring applications are intelligent enough to replace human teachers' diagnoses of the cognitive abilities and needs of their students (Reusser, 1993). Not only do these applications provide ready-made knowledge, they also decide how much of that knowledge students should learn and the pace at which they should learn it. This level of intelligence can be detrimental to learning (Derry & Lajoie, 1993) considering that all-controlling computer applications generally encourage students to abdicate their responsibility in the learning process and become passive recipients rather than active constructors of knowledge.

In contrast, cognitive tools promote reflection (Norman, 1983), critical thinking (Reeves, 1996) and student-regulated knowledge construction (Jonassen et al., 1999). Provided they are deployed within appropriate classroom environments, they facilitate cognitive and metacognitive thinking (Lajoie, 1993) and ultimately rely on students for decisions as to the pace and direction of their learning. While some refer to these types of applications as *un*intelligent (Jonassen, 1995, 1996) or *empty shells* (Hedberg, Harper & Brown, 1993) their 'deficiency' is only evident in the sense that they do not provide prescribed instruction. It does not imply any inability to aid in the learning process. Used primarily to represent student thought processes, cognitive tools can foster the development of deep understandings by enabling students to inspect, reflect on, manipulate and discuss concepts and strategies that are normally intangible and abstract (Reusser, 1993).

The visual component, therefore, is potentially a vital characteristic of any cognitive tool. Through the manipulation of graphic interfaces, cognitive tools enable students to generate conceptual networks, diagrams, hierarchical structures, graphs, tables, symbol systems and more. Not only do these visuals provide concrete representations of thought against which meaning can be indexed and explained, they also facilitate the intentional construction and externalisation of mental models. Because mental models are typically constructed incidentally, they are generally not readily available for reflection nor are they easily manipulated (Wild, 1996). However, building mental models with cognitive tools is an intentional pursuit that requires active mental participation from the students. As such, the understandings these computer-mediated mental models represent are more accessible, flexible and, above all, useful.

The effectiveness of the visual component is inherent within a range of fundamental attributes that all 'good' cognitive tools should possess. Even though the value of a cognitive tool is ultimately influenced by the purpose for which it is being used (i.e., as a tool to learn *with* or *from*), these fundamental attributes should be present nonetheless.

Attributes of a *good* cognitive tool

Reusser (1993) contends that the design of effective cognitive tools should be based on current research in cognitive psychology. More specifically, they should acknowledge that knowledge is actively constructed by students, and that this knowledge is typically produced, shared and transformed within groups of students working together to solve problems. Therefore, to be characterised as effective, cognitive tools must support the *cognitive* and *social* aspects of learning.

In addition to this Lepper, Woolverton, Mumme and Gurtner (1993) argue that the *affective* side of cognitive tools is also critical to successful learning yet this issue remains largely unaddressed in the literature. The assumption is that if the cognitive and social issues are addressed, then high levels of motivation will naturally ensue. As will be elaborated upon in Chapter 4, Perkins (1985, 1992) warns against making this assumption and argues that the cognitive tool and the learning environment must openly attend to the motivational state of the student by a) providing appropriate levels of challenge, b) enabling the student to maintain a sense of control and c) eliciting from the student a high level of curiosity. Lepper et al. (1993) concur with these goals and maintain that they are integral to the development of intrinsic motivation.

Furthermore, Jonassen (1996) contends that cognitive tools should possess certain *administrative* features, although these more practical aspects are not necessarily critical to effective learning. He states that aspects such as affordability and availability should be evident in cognitive tools as they render them accessible to a greater population of students.

Consequently, cognitive tools should possess cognitive, social, affective and administrative features if they are to contribute to quality learning outcomes. Cognitive features encompass those criteria that relate to the mental constructions of knowledge, whilst social features encompass those criteria that relate to the shared constructions of knowledge. Affective features relate to the motivational aspects of learning and administrative features refer to criteria of practicality.

The extent to which these four fundamental features characterise good cognitive tools is better understood if they are thought of as 'affordances' (refer to Figure 2.1). Pea (1993) contends that the way in which something is used is determined by the perceived and actual properties it possesses, that is, its affordances. For example, a cup can be used as a drinking utensil according to its actual property, but can also double as a pencil holder in relation to an individual's perception of it as a desk organiser. Similarly, the above mentioned features describe the actual attributes that should be characteristic in the design of cognitive tools, but may or may not be exploited depending on the students' perceptions of these affordances.

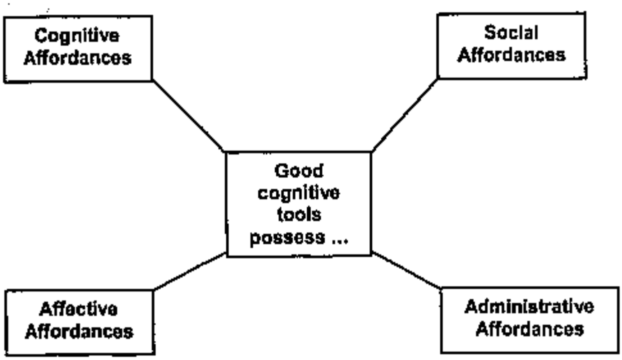


Figure 2.1 Affordances associated with *good* cognitive tools

With this framework in mind, literature describing the use of cognitive tools in classroom situations, as well as those examined in empirical studies (e.g., Anderson-Inman & Zeitz, 1993; Beyerbach & Smith, 1990; Fisher, 1990; Goldenson, 1996; Hyerle, 1996; Kellog & Mueller, 1989; McLean & Gibson, 1993; Maddux, Lamont Johnson & Willis, 1992; Jonassen, 1996; Manouchehri, 1997; Maor, 1991; Ridout, 1990; Roland, 1997; Ryba & Anderson, 1990 and Seidel, 1996), was reviewed to determine the fundamental characteristics of the four affordances and the way in which they support learning. These characteristics (which are described below) are not exhaustive, and it is acknowledged that others may emerge beyond the cited literature base. They should, however, still fall within one of the four affordances defined.

Cognitive affordances

- *The cognitive tool supports student-centeredness* (Anderson-Inman & Zeitz, 1993; Beyerbach & Smith, 1990; Fisher, 1990; Hyerle, 1996; McLean & Gibson, 1993; Maddux, et al., 1992; Jonassen, 1996; Manouchehri, 1997; Maor, 1991; Ridout, 1990; Roland, 1997 and Seidel, 1996). While the cognitive tool is perceived to be a partner in the learning process, all actions are controlled by the student. Therefore, active mental engagement on the part of the student is imperative.

- *The cognitive tool supports cognitive transfer* (Goldenson, 1996; Jonassen, 1996; Ryba & Anderson, 1990; Seidel, 1996). Knowledge and skills developed while working with the cognitive tool in a particular context can be transferred to other similar or different contexts, either with or without the cognitive tool. For example, strategies developed while working with a cognitive tool in mathematics can be used in social studies also. Salomon et al. (1991) and others (Salomon & Perkins, 1998; Underwood & Underwood, 1990) describe this transferability as the cognitive residue that partnerships with computers leave behind.

- *The cognitive tool supports reflection and critical thinking* (Anderson-Inman & Zeitz, 1993; Beyerbach & Smith, 1990; Fisher, 1990; Hyerle, 1996; Maddux, et al., 1992; Jonassen, 1996; Manouchehri, 1997; Maor, 1991; Ridout, 1990; Roland, 1997 Ryba & Anderson, 1990 and Seidel, 1996). Cognitive tools display students' thinking. Visualising their own thoughts encourages a deep level reflection about what students know and what they don't know.

- *The cognitive tool is unintelligent and hence supports the student's intellect* (Anderson-Inman & Zeitz, 1993; Beyerbach & Smith, 1990; Fisher, 1990; Goldenson, 1996; Jonassen, 1996; Manouchehri, 1997; Roland, 1997; Ryba & Anderson, 1990 and Seidel, 1996). Software doesn't contain prescribed facts. Students provide the intelligence and thus create knowledge rather than receive it. After all, knowledge does not exist as an external entity, but is actively constructed by students as they endeavour to understand its inherent meaning (Candy, 1991).

- *The cognitive tool supports metacognitive thinking* (Beyerbach & Smith, 1990; Fisher, 1990; Goldenson, 1996; Hyerle, 1996; Maddux, et al., 1992; Jonassen, 1996; Manouchehri, 1997; Ryba & Anderson, 1990; Seidel, 1996). The interactive nature of many cognitive tools stimulates self-questioning and self-instruction. Also, design is such that students can visualise their thinking processes. Graphics enable students to see the decisions they've made, evaluate them, and then proceed accordingly.

Social affordances

- *The cognitive tool supports discussion and collaboration* (Beyerbach & Smith, 1990; Hyerle, 1996; McLean & Gibson, 1993; Maddux, et al., 1992; Jonassen, 1996; Manouchehri, 1997; Maor, 1991; Ridout, 1990; Ryba & Anderson, 1990). Through discussion and collaboration with others, students are able to negotiate the meaning of a concept by questioning existing understandings as well as explaining, evaluating and clarifying new and developing understandings. These opportunities for collaboration can occur either when working in group situations around the cognitive tool, or as an individual working at a distance from others (e.g., the world wide web).

Affective Affordances

- *The cognitive tool supports intrinsic motivation* (Anderson-Inman & Zeitz, 1993; Beyerbach & Smith, 1990; Fisher, 1990; Hyerle, 1996; McLean & Gibson, 1993; Maddux, et al., 1992; Ridout, 1990; Ryba & Anderson, 1990; Seidel, 1996). Cognitive tools engender a sense of satisfaction which comes from being challenged, in control and intrigued by the activities that are supported by the application. Positive feelings towards a novel, yet sound method of learning encourage students to make sense of the material and seek further opportunities to tackle similar problems in other contexts. In relation to interactive multimedia, Chan Lin and Reeves (1994) cite a large literature base that places computer graphics at the centre of student motivation and, subsequently, enhanced learning outcomes.

Administrative Affordances

- *The cognitive tool is affordable* (Jonassen, 1996; Maddux, et al., 1992). Cognitive tools should be inexpensive and readily available.

- *The cognitive tool is easy to use - not time consuming* (Anderson-Inman & Zeitz, 1993; Fisher, 1990; Goldenson, 1996; Kellog & Mueller, 1989; Maddux, et al., 1992; Jonassen, 1996; Maor, 1991; Ryba & Anderson, 1990; Seidel, 1996). Students should be able to easily navigate their way around without expending too much cognitive effort. Software should not be so sophisticated that students spend most of their time trying to work out how to use it rather than actually learning with it.

- *The cognitive tool can be used in a variety of subject areas* (Fisher, 1990; Goldenson, 1996; Hyerle, 1996; Maddux, et al., 1992; Jonassen, 1996; Roland, 1997; Ryba & Anderson, 1990). The software is not domain-specific, but promotes the use of domain-specific language and symbols in a variety of different subjects across the curriculum.

A summary of the extent to which these characteristics appeared in the literature is provided in Table 2.2.

Table 2.2 Attributes of good cognitive tools

References	Cognitive Tool	Cognitive Affordances					Social Affordances	Affective Affordances	Administrative Affordances		
		Student-Centred	Cognitive Transfer	Supports Reflection and Critical Thinking	(Un)intelligent	Supports Metacognitive Thinking	Supports Discussion and Collaboration	Intrinsic Motivation (Enjoyable)	Affordable	Easy to use	Generalisable across contexts
Beyerbach & Smith, 1990	Concept Map	√		√	√	√	√	√			
Fisher, 1990	Concept Map	√		√	√	√		√		√	√
Anderson-Inman & Zeitz, 1993 (in relation to *Inspiration®*)	Concept Map	√		√	√	√		√		√	√
Hyerle, 1996	Concept Map	√		√		√	√	√			√
Ryba & Anderson, 1990	Database	√	√	√		√	√			√	
Maor, 1991	Database	√		√			√			√	
Jonassen, 1996	Database	√	√	√			√		√	√	√
Seidel, 1996	Database	√	√	√	√	√		√		√	
Ryba & Anderson, 1990	Programming			√		√				√	
Ridout, 1990	Programming	√		√			√	√			
Goldenson, 1996	Programming		√		√					√	√
Jonassen, 1996	Programming	√		√			√		√		√
Maddux, et al., 1992	Spreadsheet	√		√						√	√
Jonassen, 1996	Spreadsheet	√	√	√		√	√		√		
Manouchehri, 1997	Spreadsheet	√		√	√	√	√				
Roland, 1997	Spreadsheet	√		√	√						√
Kellog & Mueller, 1989	Word Processor									√	
Ryba & Anderson, 1990	Word Processor		√	√	√	√	√	√			√
Maddux, et al., 1992	Word Processor	√				√	√	√	√		√
McLean & Gibson, 1993	Word Processor	√					√	√			

Why use cognitive tools?

Knowledge construction is largely an unobservable, complex process that occurs within the minds of individuals who are either collaborating with others or working alone. To build knowledge, information is attended to, deliberated upon, related to similar existing information, and then filed away in a new, more sophisticated form. Cognitive tools can be used to mediate this (often taxing) process by visually representing thinking paths for overt analysis and organization. This exposure can also generate a level of discussion that would perhaps not be possible with covert cognition.

The outcomes of this mediation process are not altogether clear in the literature, nor are existing interpretations agreed upon. While most theorists agree that computers 'support' cognition, it is their interpretation of 'support' that varies. Some say that cognitive tools amplify learning through a division of labour process. In these instances, the cognitive tool primarily supports the lower-level cognitive processes in order to free the student to engage in higher-level activities. With drill and practice applications, for example, students can off-load tedious or repetitive tasks onto the cognitive tool, thus enabling them to complete tasks more efficiently and at a quicker pace.

While Pea (1985) acknowledges the worthy status of cognitive tools as amplifiers of human capability, he extends this profile to contend that cognitive tools can in fact change the way in which students think and learn. Confining the value of cognitive tools to an amplification perspective restricts their true powers, that is, the potential for them to extend, redefine and *augment* student cognition. Augmentation comes about when students work collaboratively - in partnership - with the cognitive tool to open up new possibilities of thought and to construct deep understandings and conceptions. Seen in this light the cognitive tool becomes "an indispensable instrument of mentality, and not merely a tool" (Pea, 1985, p. 175).

Augmentation is essentially a by-product of 'reflection', which is a process encouraged by cognitive tools through the visual representation of thinking paths (Norman, 1983; Reusser, 1993). Reusser (1993) writes:

> Giving students [repeated] opportunities to monitor ... the visually displayed traces of their planning and thought processes, including alternative routes taken through problem spaces, and to retrospectively analyse those traces and products by reconsidering what has been done, may eventually lead ... to an overall *reflectivity*. (p. 155, 156)

Reflectivity is necessary for deep-level processing as it is through the contemplation of concepts, in relation to other similar concepts, that meaning is found and developed. In this way, new information is integrated into a network of related themes and images, which in themselves are connected to other related themes and images. Subsequently, these newly formed and enhanced networks are used to infer, explain and interpret new knowledge, the consequences of which are deeper, *augmented* understandings.

As previously argued, some theorists also contend that cognitive tools have a residual effect in the sense that they equip students with new tools of thought which can be accessed even when working autonomously (Salomon et al., 1991; Salomon & Perkins, 1998; Underwood & Underwood, 1990). As a result of engaging in a partnership with the cognitive tool, the student develops improved knowledge and skills, which can be applied to a range of alternative contexts. Given the inevitability of students being faced with numerous situations where the cognitive tool is not present, the value of this 'cognitive residue' increases substantially.

Conclusion

Clearly, the reasons why students should be exposed to cognitive tools can be argued from an amplification, augmentation or residual perspective. However, given that either one of these outcomes is possible depending on the functional capabilities of the application being accessed (see Table 2.1), or the way in which it is being used (Knuth & Cunningham, 1993; Salomon, 1993c), this 'either/or' argument becomes a superfluous one. In light of the fact that cognitive tools *can* transform activity upon the world, perhaps a more pertinent concern is how to *cultivate* mediations such that effective learning ensues.

This concern was central to this study and, as such, a framework was developed in an attempt to enable the mediational powers of the cognitive tool to be realised. In light of the assertions that cognitive tools can *augment* learning, this framework endeavoured to support the use of an *un*intelligent application that could facilitate (multiple but in particular) the latter phases of information processing (see Table 2.1), and one that could be defined as a 'good cognitive tool' (see Table 2.2). Fundamental to this framework, therefore, was learning theory that recognised the cognitive, social and affective affordances of the cognitive tool. This theory is discussed in detail in the following chapter.

-3-

Theoretical Framework – Social Constructivism

Chapter Overview

Reviews of the literature have revealed several common themes about cognitive tools. One theme in particular relates to the theoretical perspective that appears to most effectively support this resource in the classroom. Constructivist learning environments have been espoused by many as being the most suitable for cognitive tools given that the active construction of knowledge is an objective of both (Cole & Engeström, 1993; Evans, 1998; Jonassen, 1996, 1998; Jonassen & Reeves, 1996; Lajoie, 1993). While firmly based on the principle of knowledge construction, a more contemporary view of constructivism establishes learning as a social experience and posits that mediational tools (such as the cognitive tool) transform ways in which students interact with one another and their learning environment in general (Crook, 1994; Edelson et al., 1996).

This perspective is the cornerstone of this study and is addressed in this chapter under the heading of *social constructivism*. In essence, social constructivism is a derivative of Vygotsky's socio-culturalism and Piaget's constructivism. Both these theorists, (and their advocates), have been drawn on in an attempt to describe the key principles of social constructivism, the outcome of which is a set of defining assumptions. These assumptions stem from the belief that knowledge is not an entity unto itself, but is actively constructed by students in socio-cultural learning communities. Given that these assumptions form the basis for the use of cognitive tools in the classroom, the relationships between the two are briefly explored. This exploration is not to be misconstrued as an assertion that cognitive tools are fundamental to social constructivism.

In the final assumption, the notion of distributed cognition is introduced and described as an extension of social constructivism. The general principles of this construct are drawn on to explain how cognition is distributed to resources across the learning environment and how the potential afforded by resources is maximised when they are viewed as partners in the process of learning. Within this discussion, certain discrepancies that exist between constructivism and socio-culturalism are briefly addressed and subsequently resolved.

Social constructivism - the individual and social nature of learning

Social constructivism has many pseudonyms in the literature. Otherwise known as co-constructivism (Crook, 1994), cultural constructivism (Scott, Cole, & Engel, 1992), socio-cultural constructivism (Duffy & Cunningham, 1996), situated rationalism (Resnick, 1996) and socio-cognitivism (McLoughlin & Oliver, 1998), this theory recognises both the social and personal aspects of learning (McRobbie & Tobin, 1997). Drawing upon theorists such as Vygotsky (1978), Wertsch (1985) and Piaget (1963), social constructivism establishes learning as a social experience but also acknowledges the private mental world of the individual. This belief stems from several primary assumptions about learning which are outlined as follows:

- All knowledge is constructed.

People do not simply absorb information from the environment but rather they construct personally meaningful understandings by relating new information to what they already know. Existing knowledge then, becomes an important factor in the process of learning, as it determines to a large extent what will be learned in the future (Shuell, 1986).

This view stems from Piaget's (1963) theory that understanding something occurs through interaction with, and active manipulation of, the physical world. These interactions provide opportunities for students to make interpretations of experiences based on their existing knowledge structures. In an effort to understand an event or a problem, a student will attempt to link incoming information to understandings already held in his or her mind. If this new information somehow challenges the existing knowledge structures, then the student must reconstruct and reorganise his or her schemata to accommodate this disparity accordingly (Hodson & Hodson, 1998). This process is facilitated by the student's genuine need to understand and willingness to take ownership of the learning situation at hand (Jonassen, Peck & Wilson, 1999).

However, this process is not straightforward and, without appropriate support, interpretations may have little depth or meaning attached to them. For example, cognitive tools are catalysts that can guide students in the organisation and representation of what they know (Jonassen, 1995) thus supporting what might be described as a 'cognitively demanding experience'. Pea (1985, 1993) even contends that cognitive tools can enable students to construct powerful understandings of phenomena that would not be possible without their support.

Therefore, opportunities to ascribe meaning to experiences, and to construct rich understandings, can be augmented by cognitive tools (Pea, 1985, 1993). A fundamental addendum to this belief, however, is developed in the following assumption where it is argued that knowledge construction cannot be separated from the environment within which it occurs.

- Knowledge construction is context dependent.

Any account of learning cannot be separated from the environment within which it occurs (Vygotsky, 1978; Wertsch, 1985). The environment provides the catalyst, that is, the experiences from which knowledge is constructed. In relation to this, Savery and Duffy (1996) write, "...what we understand is a function of the content, the context [and] the activity of the learner..." (p. 136). Knowledge, then, is not located within the student alone, but is in fact a property of the entire learning context. This view is the core concept behind the notion of distributed cognition, which is elaborated upon in Chapter 4.

In essence, context is made up of people, language, objects, symbols and situations that are steeped in knowledge and which together constitute a type of 'collective memory' (Hodson & Hodson, 1998). This collective memory provides students (and groups of students) with the appropriate tools and background knowledge they need to construct new and more advanced understandings. The history embedded in the context is rich with meaning that has been defined and re-defined over time and is accessed by students as a springboard for new and subsequent learnings.

Various researchers have examined the interconnected nature of cognition and context. Bronfenbrenner (cited in Ceci & Ruiz, 1993) contends that any investigation of human intelligence needs to take into consideration the interrelationships between *person*, *process* and *context*. Lave and Wenger (1991) believe learning is influenced by the interaction between *agent*, *activity* and *world*, and Herrington (1997) argues that the overlap and influence of *the learner*, *the implementation* and *the interactive multimedia program* is integral to the design of interactive multimedia environments.

Similar interdependent influences could be seen in this study, where the aim was to determine the extent to which cognitive tools promoted effective learning when used within a distributed learning environment. In essence, the activity that emerged from interactions between the *students*, the *cognitive tool* (as well as other resources) and the *learning environment* provided the context for investigation (see Figure 3.1). Consequently, the findings from this study are representative of the activity within the entire context, not simply certain elements of it.

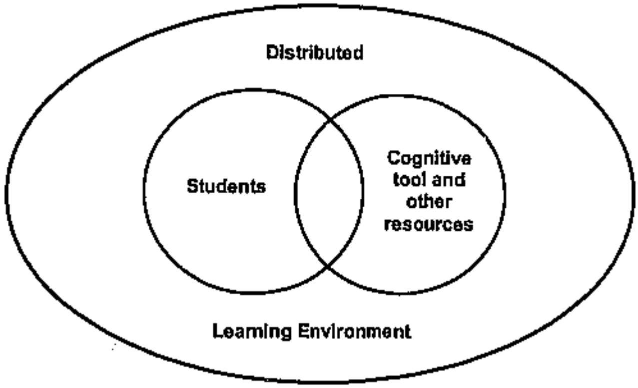


Figure 3.1 Interdependent elements of a computer-based distributed learning environment

This model differs slightly to those developed by Bronfenbrenner (cited in Ceci & Ruiz, 1993), Lave and Wenger (1991) and Herrington (1997) in that it emphasises the relationship between the students and the computer *as they occur within* the learning environment. Rather than treat context as a mutually constitutive influence (as the earlier models have), the design proposed in Figure 3.1 reinforces the view that learning cannot occur in a vacuum, but instead it is indivisible from, and in fact a part of, the entire context. This is in keeping with Vygotsky's (1978) theory that individuals' cognitions are situated *within* social and cultural contexts of activity, rather than just outcomes of interactions with the environment.

Furthermore, it is believed that this model more closely reflects Rogoff's (1990) and Wilson's (1996) portrayal of the classroom as a 'learning community', that is, a place where students construct knowledge with the assistance of others and the various learning tools found within the learning environment. Learning, in this light, is a shared process – a procedure that occurs in a team-like fashion where the student collaborates with the teacher, peers and other intellectual and physical resources as partners in cognition (Salomon, 1993a). This scenario significantly impacts the way in which we think about technology in education. The focus is not so much on what the student in isolation can do with the cognitive tool, but the activity of the community as it interacts with the cognitive tool as a powerful mediational resource. This notion is at the core of the next assumption.

- Learning is mediated by tools and symbols.

According to Vygotsky (1978) and Wertsch (1985), the cognitive attributes of individuals are largely the outcomes of their interactions with culture. These interactions are mediated by tools, otherwise referred to as artefacts, tangible and intangible resources, objects, signs or symbols. From a social constructivist perspective, these tools are central to cognition as they determine the ways in which concepts, objects, events and phenomena are interpreted. In other words, in an attempt to better understand and control the activity of a learning environment, students will employ an array of resources that will facilitate this process, such as measuring devices, textbooks, dialogue, computers, diagrams and many more.

Most references to tools in the literature are in relation to those that are *external* to students (e.g., language, symbols, and physical resources). A handful of authors, however, also acknowledge tools that are *internal* to students, such as cognitive and metacognitive learning strategies (Hedberg et al., 1993; Jonassen, 1992). Learning strategies are embodied within a student's existing knowledge structures and can be described as a collection of mental techniques which are used to facilitate the effective processing of information (McKeachie, Pintrich, Lin & Smith, 1986). Learning, then, is mediated both by the knowledge internal to a student, and the knowledge within the external learning environment, as it is manifested in its resources, people and rituals. Both are as important as each other, although Resnick (1996) states:

> ... what one carries with one to a new situation ... is determinative only as one enters the new situation. Thereafter, all of the people, tools and material resources of the new situation shape a new situated practice. Cognition is emergent in the situation and specific to it (p. 51).

It is important to note, however, that tools do not directly mediate learning (Jonassen, 1992; Jonassen et al., 1999; Knuth & Cunningham, 1993). Common classroom resources such as books, videos and even teachers cannot transmit knowledge to students. Rather, knowledge is constructed by students and this process is mediated by thinking. Effective tools, therefore, are those that activate cognitive and metacognitive learning strategies and engage students in the process of thought. In relation to this, cognitive tools have been widely recognised as a technology that supports access to new, powerful mediational means (Crook, 1994; Duffy & Cunningham, 1996; Pea, 1985; 1993; Perkins, 1993 and more). Some even suggest that the interactive qualities of the cognitive tool are effective for resourcing the social construction of shared knowledge (Crook, 1994). Given that learning is fundamentally a social experience, and that people (along with other resources) mediate cognition, this is an invaluable attribute of the cognitive tool. This is the essence of the next assumption.

- Knowledge is socially constructed

As a result of his work into the social context of cognitive development, Vygotsky (1978) argued that all cognitive functions originate in social activity and are inextricably linked to language, which in itself is a social construction. It is through social interactions (whether they are in a classroom, office or a café) that the cognitive and communicative skills of a particular culture are learned. Therefore, in order to explain the phenomenon of learning, we must consider not only the student's mental constructions (as Piaget did) but also the immediate social world in which the student is located and the nature of the interactions that take place within it. In other words, all mental functions have social origins and occur, initially, between students before they become internalised within the student (Vygotsky, 1978).

Language plays a key role in this process of internalisation (Vygotsky, 1978). Various concepts, skills and understandings are first revealed to students in social situations where they are disseminated through language – written or spoken. As the student becomes comfortable with these new understandings, they are transformed into an inner speech, otherwise known as 'thought', for the subsequent construction and reconstruction of related understandings. So, "What has started out as an external socially-constructed artefact is transformed by the [student], first into an external aid to help organise problem-solving, and later into the very constructive core of thought itself" (Hodson & Hodson, 1998, p. 36). Consequently, cognitive achievements are essentially the outcomes of participation in particular 'communities of practice' (Crook, 1994, p. 38).

Other people within these communities of practice (teachers, parents, peers etc) play an essential role in a student's ability to participate effectively and grow intellectually. They offer a type of mediating support that will guide the student through the appropriate learning steps before he or she can appreciate the significance of these steps independently. This support is typically appropriate to the student's zone of proximal development (ZPD), that is, the level between what the student can achieve alone and what he or she can achieve with the assistance of others (Vygostky, 1978). In this way, "... knowledge is not merely handed on, nor is it discovered solely by the individual learner. Rather it is co-constructed through social interaction" (Hodson & Hodson, 1998, p. 37).

This feature of social constructivism cannot be supported by computer-based learning where students work *at* computers and learning is essentially dissociated from the core of classroom life (Crook, 1994). Teachers will have little chance of engaging students in their ZPDs when the objective is to complete computer activities that offer individualised instruction (e.g., drill and practice software etc). Social and dialogic exchanges have been observed, however, when students collaborate *around* computers (McLoughlin & Oliver, 1998). In these situations "... technology does not 'simply' serve human interests in some benign fashion: it actively transforms human relations" (Crook, 1994, p. 24). For this to occur, however, the computer must be integrated into the very fabric of classroom life where communication between peers and the teacher is mediated by computer activity. Research shows that collaborative exchanges in these instances lead to higher order learning behaviours (Herrington, 1997; Stoney & Oliver, 1999).

The final assumption is both an amalgamation and an extension of the first four. It is firmly grounded in the belief that cognition is distributed among people and resources as they interact together in activity. Although some people may argue that distributed cognition is a theory separate (albeit related) to social constructivism, others are finding is difficult to discuss one without the other. For example, Cole and Engeström (1993) write, "In essence, when one takes mediation through artefacts as the central distinctive characteristic of human beings [as social constructivists do], one is declaring one's adoption of the view that human cognition is distributed" (p. 42).

- Cognition as a distributed phenomenon

As has been argued above, learning is the active construction of knowledge that has emerged from interactions with people and resources in a culturally defined context. In this way, learning is distributed across minds that are connected by way of the activity within which they are collectively participating. No one particular entity embodies knowledge, rather it is a property of the student's engagement with the specific situation at hand; it is spread over the entire context which includes people, resources, rituals and culture. Duffy & Cunningham (1996) write, "Thinking ... is always dialogic, connected to another, either directly as in some communicative action or indirectly via some form of semiotic mediation: signs and/or tools appropriated from the sociocultural context" (p. 177).

According to Cole and Engeström (1993), the precise way in which cognition is distributed depends on the tools (resources) available within the environment. These tools, which have ultimately been shaped by the culture of the environment, are the means through which students gain access to, and interpret their world. In this way, learning can be described as "a process of tuning into the affordances of the environment" (Resnick, 1996, p. 43) and working with them in an effort to develop new understandings. These new understandings will ultimately effect subsequent learning situations, and so it can be said that "Cultural mediation has a recursive, bidirectional effect; mediated activity simultaneously modifies both the environment and the subject" (Cole & Engeström, 1993, p. 9). Salmon (1993b) and Salomon and Perkins (1998) refer to this bi-directional effect as a spiral of reciprocal relations between socially distributed understandings, mediating resources and individual cognition.

The mediating resources typically present within learning environments can be described as either the student's intellectual resources (e.g., prior knowledge, metacognitive knowledge), social resources (e.g., the teacher, peers), symbolic resources (e.g., language and symbols representative of the subject being studied), and physical resources (e.g., textbooks, computers). For example, when a student is presented with a learning task, he or she usually considers it in light of existing knowledge on the subject. This existing knowledge is then cultivated in conjunction with other students and classroom resources. For instance, given the chance the student will collaborate with the teacher and peers, as well as available physical resources such as textbooks and/or notebooks. He or she will employ language and symbols representative of the subject at hand, while simultaneously using his or her metacognitive knowledge to monitor progress and call upon learning strategies as required. These resources mediate the student's thinking and learning on the subject and contribute to his or her developing understanding. This revised understanding in turn influences execution of future learning tasks, and the cycle begins again. Figure 3.2 represents this process diagrammatically.

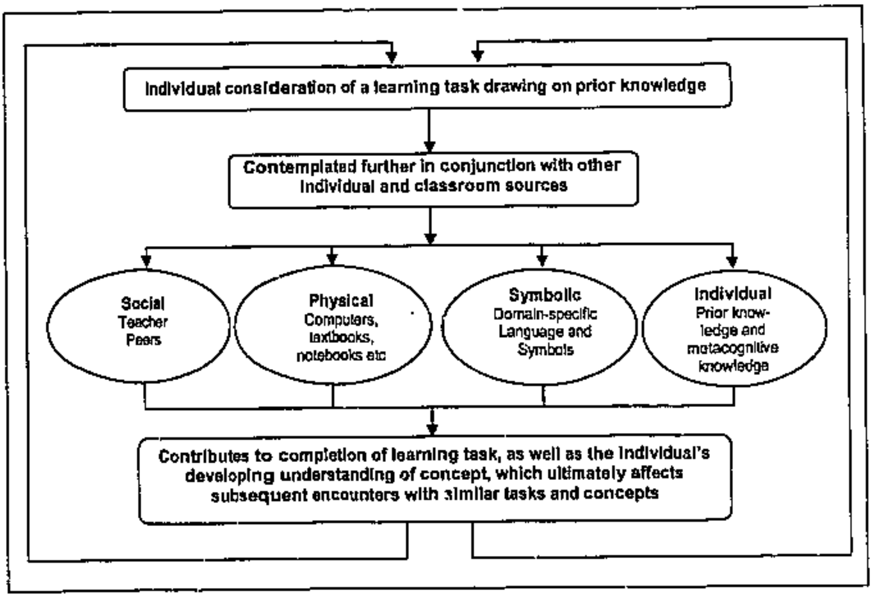


Figure 3.2 The distribution of cognition across a variety of resources found within classroom learning environments

While it is possible for students to pursue learning tasks drawing on perhaps only one resource (e.g., their prior knowledge), this study accedes with others (e.g., Derry, DuRussel & O'Donnell, 1998; Hewitt & Scardamalia, 1998; Lebeau, 1998) and argues that cognition is most powerful when it is distributed across a variety of resources. In fact, while these resources can operate on their own, their full potential is most likely to be achieved when used in conjunction with other resources. More specifically, it is the premise of this study that the full potential of the computer as a cognitive tool is achieved when used in conjunction with the student's intellectual resources, social resources, symbolic resources and other physical resources as they function together within a social constructivist oriented learning environment.

Social constructivism as a derivative of constructivism and socio-culturalism

Interestingly, there are few references in the literature (on distributed cognition) that explicitly recognise 'individual intellect' (prior knowledge, metacognitive knowledge) as a resource which supports cognitive activity. While many debate the locus of cognition, that is, whether it resides within the student or is a joint product of the person plus the surround (Pea, 1993; Perkins, 1993; Salomon, 1993b), the idea that it constitutes a potentially powerful resource tends to be overlooked. Hedberg et al. (1993) contend however, that the metacognitive knowledge a student holds is a cognitive tool in itself to be utilised wisely in the pursuit of effective learning. Metacognition involves two separate but interrelated phenomena, a) awareness about cognition, and b) regulation of cognitive behaviour (Brown, Bransford, Ferrara & Campione, 1983). Given that metacognition is mandatory for students to be aware of the skills, strategies and resources they need to learn something effectively, it is therefore an essential tool in the learning context and one that should not be neglected.

This issue of individual intellect being a resource is perhaps related to a growing debate between constructivism and socio-culturalism. The common contention is that constructivism focuses too heavily on the 'in-the-head' processes of cognition without giving due recognition to the social and cultural factors that contribute to these processes. Socio-culturalists argue that it is impossible for knowledge to be contained in the mind of any one student given the important role context plays in the construction of this knowledge. While it is not the purpose of this thesis to extend this debate, nor to form any unnecessary polarisations, Table 3.1 provides an overview of the fundamental tensions between the two theories.

Table 3.1 Fundamental differences between constructivism and socio-culturalism

	Constructivism	Socio-culturalism
Knowledge	...is actively constructed in the minds of students by linking what is already known to new information (Piaget, 1963).	...is socially constructed as students interact with one another in activity (Vygotsky, 1978).
Prior knowledge	...constrains or enables learning (Shuell, 1986)..	...is a derivative of social cognition (Vygotsky, 1978)
Context	...is the venue within which interactions with the world are experienced (Piaget, 1963).	...constrains or enables learning. The context provides the activity as well as the culturally defined tools which will mediate the experience (Wertsch, 1985).
Language	...is a consequence of learning (Piaget, 1963).	...is the primary mediating means through which learning occurs (Vygotsky, 1978).
Learning therefore is	...defined by a student's independent discovery of knowledge and skills. The discoveries emerge from opportunities to a) interact with the material world and, b) to reflect on and interpret the consequences and outcomes of these interactions (Piaget, 1963).	...a shared process that occurs in a team-like fashion where the student collaborates with the teacher, peers and other intellectual and physical tools as partners in cognition (Pea, 1985).

Social constructivism appears to have overcome these tensions by blending aspects of both constructivism and socio-culturalism together. In this way, it affords a richer account of learning by acknowledging both the personal and social/cultural features of the mind. Drawing on Resnick's (1996) account of social constructivism (referred to by her as situated rationalism), it acknowledges the internalised knowledge structures possessed by students, but contends that these frames are expanded through engagement with a specific context.

The social, physical and cultural attributes of a particular setting will afford possibilities for learning only if the student's existing knowledge structures enable him or her to tune into the attributes and activity of the context. If there is a complete mismatch between the student's exisdng knowledge and the affordances of the context, then the student will more than likely tune out of the situation and no learning will occur. If there is a harmony between the two, then the student will probably complete the activity accordingly but no new learning will take place. If however, there is a partial match, that is, the affordances of the environment sparks an interest and challenges the student's existing knowledge structures, then learning is likely to occur.

Conclusion

This chapter provided an in-depth look at the theoretical framework underpinning this study. Referred to as 'social constructivism', this perspective draws on both constructivism, in that learning experiences should be student-centred and evolve from students' prior knowledge, as well as socio-culturalism in that consideration must also be given to the social, historical and cultural design of the context as a whole. The notion of distributed cognition has been drawn on to speculate how the principles of social constructivism are put into practice in the classroom. From a distributed point of view, cognition does not occur within the mind of an individual alone but is spread over resources found within the learning environment. This idea is developed further in the following chapter along with a more comprehensive discussion of learning resources as vehicles of distribution.

-4-

Distributed Cognition

Chapter Overview

In the previous chapter, the notion of distributed cognition was introduced as an extension of social constructivism. In essence, the principles of distributed cognition were drawn upon to 'operationalise' social constructivism in the classroom. It was postulated that learning occurs when cognition is distributed across a range of resources found within the learning environment, thus supporting the view that cognition is socially and contextually constructed.

In this chapter, distributed cognition is developed further. A continuum of varying conceptions of distributed cognition is proposed and the one aligned most closely with the theoretical framework underpinning this study is identified. Examples of this conception-in-practice are then drawn from the literature and there is some discussion on how distributed, shared cognitions are transformed into private knowledge. Finally, because resources are central to all conceptions of distributed cognition (to a greater or lesser extent) a broad overview of their role as vehicles of distribution is given.

Distributed Cognition

"The mind rarely works alone" (Pea, 1993, p. 47). This is the premise upon which the phenomenon of distributed cognition is based. In most learning situations, students will call upon any number of resources for support. Take, for example, a student studying a chapter in a textbook. It is quite likely that this student will use a textliner to highlight important points and key ideas, make notes in the margin, and perhaps summarise the overall meaning in a separate notebook. Even though these notes may not be internalised within the student's head at the time of reading the chapter, they represent his or her thinking and reasoning nonetheless. They are the observable characteristics of the student's cognition being distributed to resources in the instructional environment. And although the student may not remember these notes in detail once the textbook is closed, they will become a significant point of reference for subsequent related study or in preparation for examinations (Perkins, 1992; 1993).

While this example encompasses the essence of distributed cognition, its defining principles are open to interpretation and, as such, a variety of conceptions about this construct exist. Moore and Rocklin (1998) have explored these conceptions and have arranged them on a continuum in accordance with their interpretations of cognition. These views range from the belief that students construct knowledge for themselves but are supported by resources found within the environment, to the belief that knowledge does not reside within any one student's head but is in fact a property of the entire socio-cultural context within which it was constructed. Somewhere in between these views is the conception that both the individual (supported by the environment), together with socio-cultural constructs, facilitate distribution. The extreme opposite of the socio-cultural view, is the cognitivist belief that cognition is a mental construct onıy, defined in terms of private, computational processes (Craik & Lockhart, 1972; Newell & Simon, 1972). Although this view was not explored by Moore and Rocklin, it has been added to the continuum (refer to Figure 4.1) to further illustrate the nature of the differences between the conceptions of distributed cognition.

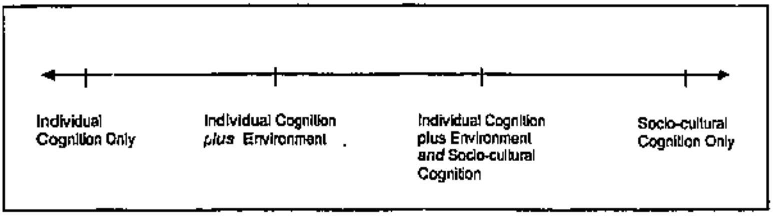


Figure 4.1 Continuum of varying conceptions of distributed cognition (adapted from Moore & Rocklin, 1998)

A brief description of each conception follows. However, because these categories are largely distinguished by the focus placed on the notion of learning, cognition and intelligence, it is necessary to operationally define these terms in advance.

Learning is the acquisition of knowledge and understandings through interaction with the environment (Biggs & Moore, 1993). Students typically pass through a series of phases when learning (e.g., Shuell, 1990) ranging from: a) the accrual of knowledge, to

b) the shaping of this knowledge into meaningful structures, to c) the reshaping of these structures into sophisticated expert-like understandings. Transition to the second and third phase is not mandatory and it is possible to remain at the first phase when learning something new.

Cognition is the vehicle driving learning through these phases. It is the process of thinking; of performing a mental operation with some specific content to achieve a particular outcome (Woolfolk, 1990). Each of these phases demands different levels of cognition ranging from basic thought processes for the accrual of knowledge, to the use of more complex ones that facilitate understanding. Norman states that cognition is multidimensional "involving all of the senses, internal activities and external structures" (1994, p. 16) but again, the degree to which the senses, internal activities and external structures are called upon depends on the phase of learning the student is actually working within.

Underlying the student's competence in performing cognitive tasks is his or her intelligence (Biggs & Moore, 1993), that is, acquiring, remembering, retrieving and using knowledge depends on a student's intellectual ability (Woolfolk, 1990). Traditional models of intelligence claim this ability is an inherited characteristic that remains static across contexts and time (Spearman, 1927; Wechsler, 1958 both cited in Woolfolk, 1990). In contrast, contemporary theories focus on intelligence as a combination of higher-order thinking skills, and even those that are inherited can be influenced by the environment, experience and education (Sternberg, 1995).

The conceptions of distributed cognition are described as follows:

Conceptions of distributed cognition

- Individual cognition only

This conception is drawn from the theory of cognitivism which describes any act of cognition, including thinking, reasoning and reflection, as a property of the mind alone. The brain is likened to a computer and learning is a process of inputting, storing, processing and retrieving data (Craik & Lockhart, 1972; Newell & Simon, 1972). This metaphor captures the private, individual nature of cognition and while context is acknowledged, it is typically seen as a group of variables that can be controlled and manipulated to enhance mental processes (Crook, 1994). Resources such as computers, texts, pens and paper may display a student's thoughts, but they do not form part of his or her intelligence (Perkins, 1992).

- Individual cognition plus environment

Proponents of this conception of distributed cognition acknowledge that intelligence primarily resides within the minds of individuals, but is amplified significantly as a result of effective use of resources found within the learning environment (Brown, Ash, Rutherford, Nakagawa, Gordon & Campione, 1993; Derry et al., 1998; King, 1998; Perkins, 1993; Salomon, 1993b). In this sense, individual cognitions are distinguishable from distributed cognitions but the two are viewed as an "interdependent dynamic interaction" (Salomon, 1993a, p. xvi). People (teachers, peers), physical resources (computers, printed material, calculators, whiteboards) as well as symbolic systems (mathematical formulae, language) are powerful vehicles for supporting thinking and learning. These resources are 'partners in cognition' (Perkins, 1993; Salomon, 1993b), but ultimately exist as separate entities to a student's intelligence. Apart from other people, these resources are largely *un*intelligent constructs that mediate learning and cognition.

- Individual cognition plus environment *and* Socio-cultural cognition

This conception of distributed cognition draws aspects from both the previous and subsequent categories. It is similar to the previous conception in that intelligence is believed to be an individual construct, however, more credence is given to the role of resources. Cognition is the generation of knowledge representations across media within a given environment. This media may be internal (e.g., a student's memories) or external (e.g., other people, physical and symbolic resources). In this way, the traditional divisions between the inside/outside boundary of the student is dissolved as the interactions between the distributed structures – the functioning system – is what's important (Rogers, 1997).

Proponents of this conception believe that embedded in the design of a resource is an intelligence that has been shaped by the resource's originator (Lebeau, 1998; Rogers & Ellis, 1994). This embodied intelligence is subsequently distributed to those who use it as a tool in learning, but remains separate and distinct, from a student's intelligence. It is important to note however, that proponents of tools as intelligent resources, do not say that these resources 'do' cognition. Rather, they mediate it (Pea, 1993).

- Socio-cultural cognition only

Perhaps the most extreme perspective of distributed cognition is that of the socio-cultural perspective. At the heart of this conception is the notion that intelligence cannot be decontextualised from activity, nor from the resources used during this activity (Cole & Engeström, 1993; Hatch & Gardner, 1993; Hewitt & Scardamalia, 1998; Norman, 1993; Pea, 1993; Reusser, 1993). While intelligence enables this activity, it is not purely the intelligence of a student alone. Rather, intelligence is distributed across and between resources within an environment, such as other students, physical resources and symbols. These resources not only influence internal cognitions, but the activities that emerge from interactions with them can be construed as cognitions in themselves. Resources are believed to possess an intelligence of their own, and students exploit this intelligence when using them for particular purposes in learning activities. Therefore, it is impossible to separate individual cognition from the cognition embodied in the learning environment. Intelligence is accomplished through interaction with the environment. It is not possessed by any one individual (Pea, 1993).

A balanced view of distributed cognition

Fundamental to the differences that exist between these conceptions of distributed cognition is the nature of cognition, that is, how knowledge is constructed and where it ultimately resides. For example, the 'individual plus environment' conception depicts cognition as being shared between the student and resources, but is essentially a property of the student represented by internal knowledge structures. The socio-cultural conception however, depicts cognition as being spread over students, resources and the activity of the context and, as such, is a property of the entire context (Hewitt & Scardamalia, 1998). Cognition is so context-bound and varied from one setting to the other, that a distinction between a student's cognition, context and the activity is indiscernible (Pea, 1993).

Similarities can be drawn between the disparity between these two conceptions of distributed cognition and the disparity between constructivism and socio-culturalism. As described in Chapter 3, cognition is also central to the debate between these two theories. Constructivists claim that cognition is a student's internal representation of an external event, whereas socio-culturalists assert that cognition is situated *within* social and cultural contexts of activity, rather than just an outcome of a student's interaction with the environment. Social constructivism draws on both perspectives to give a more balanced view of cognition as it acknowledges both the student's internal mental actions as well as the undeniably influential role of activity, context and culture.

In searching for a more balanced conception of distributed cognition, the continuum in Figure 4.1 is useful as it offers a visual representation of this middle ground. The conception labeled 'individual cognition plus environment *and* socio-cultural cognition' blends together its flanking conceptions that distributed cognition is an individual plus environment construct, and a socio-cultural construct. This view postulates that cognition is situated in a culturally defined context where resources (social, physical, symbolic, and intellectual) embody affordances which can support thinking at both the communal level and the individual level. While the activity of the environment sustains the construction of shared knowledge, students also 'appropriate' this knowledge which in itself becomes a resource for subsequent cognitions (both at the communal and individual level).

This conception has been characterised in Lebeau's (1998) study where he analysed the distributed functioning between physicians, their patients and medical resources, in an attempt to diagnose medical problems. Drawing on the belief that knowledge and reasoning is shared amongst individuals and the resources available within a context, Lebeau argues that doctors come to 'appropriate' the intellect embodied in a distributed activity, thereby constructing new understandings that contribute to his or her overall expertise as a physician. When investigating patient complaints, doctors typically discuss the problems with their patients, consult medical histories, conduct physical examinations and initiate laboratory tests. These routine activities are referred to by Lebeau as resources that embody a knowledge that facilitates the doctor's thinking in not only diagnosing the patient's problem, but also in recognising and treating future instances that are similar in nature.

One can infer from this conception that cognition is something which is shared, or jointly pursued by students interacting with each other and with surrounding physical, social, symbolic and intellectual resources. These resources, according to Lebeau (1998) "distribute cognition by bringing current users into conversation with those who have designed and used the tool in the past" (p. 6). Manifested in a medical history, for example, is the doctor's (or other doctors') thinking about a patient's problem. It usually contains past medical history, family history, medicines previously prescribed and/or physical examinations carried out. Thinking with this resource, and in conjunction with the actual patient, distributes cognition, thus supporting the doctor's diagnosis of the patient's illness and the identification of a suitable therapy. The outcome of this context-driven experience is the doctor's development of a deeper understanding of the symptoms related to this particular illness – the appropriation of a greater medical awareness and intuitive feel for similar cases in the future.

Both Brown et al. (1993) and Lebeau (1998) use the term 'appropriation' to explain how distributed, contextually constructed knowledge inevitably becomes individual knowledge. Through activity and interaction with the context, understandings are developed. While the entire context has contributed to the development of these understandings, students appropriate them, that is, they interpret them thereby fusing them onto their own existing knowledge structures. It is through appropriation, that students gain greater control over their environment, becoming more competent in their fields of study or professional practice. In this way, appropriation can be related to Salomon et al's. (1991) notion of cognitive residue where students walk away from distributed learning encounters with personally improved competencies, greater awareness, and deeper understandings of concepts.

Consequently, the conception that distributed cognition is an individual (plus the environment) and a socio-cultural construct is in keeping with the principles of social constructivism. Central to both of these concepts is the assumption that cognition is initially driven through discourse and interaction with resources, but through the process of appropriation, these contextually constructed understandings are ultimately transformed into personal interpretations. These personal interpretations, otherwise known as existing knowledge structures, then constitute both individual and social learning resources for future distributed learning encounters. This process was described earlier as a spiral-like, or bi-directional, effect (Cole & Engeström, 1993; Salomon, 1993b; Salomon & Perkins, 1998).

This type of distributed cognition is prevalent in everyday activities. Whether it is at home, at work, in the supermarket or during leisurely pursuits, people interact on various levels with their physical, social and symbolic surrounds. In fact, the degree to which students function successfully, depends largely on their effective use of available resources. An example of this is provided by Hutchins (cited in Resnick, 1987) in his analysis of navigational practices of US navy ships. While the responsibilities of individual sailors are described, Hutchins' analysis contends that it is the distributed nature of these responsibilities between sailors, symbols and artefacts, which determines the ship's position around the world at any one time. The individual sailor's knowledge alone amounts to little until it is combined and coordinated with the knowledge of others and the necessary tools.

More often than not, classroom practices do not reflect the distributed practices within navy ships. In fact, to a casual observer, learning activities within classrooms probably are more in line with the 'individual cognition only' conception from which it can be inferred cognition cannot be distributed at all. This is evident in the emphasis schools place on the success achieved by students without the assistance of resources. For example, consider a typical examination situation where students are expected to perform in isolation from their notes, textbooks and peers. While many justifications for this situation exist, Pea's (1993) assertion that resources have been taken for granted is also pertinent. He writes, "[resources] have become so deeply a part of our consciousness that we do not notice them. Turned from history into nature, they are invisible, un-'remarkable' aspects of our experiential world" (p. 53). This assumption is explored later, but first a broad overview of the role of resources as vehicles of distribution is given.

Resources as vehicles of distribution

Resources are instrumental in a distributed learning environment. In the literature, they are typically referred to as being of the social, physical or symbolic kind. Intellectual resources are less frequently examined and when they are, it is usually in an ill-defined way. Given that the conception of distributed cognition drawn upon in this study acknowledges individual cognition, intellectual resources are seen as paramount and therefore have not only been included in this literature review, but also developed further.

The role of resources in distributed cognition has been defined in many ways, often in alliance with the author's conception of this construct. Socio-culturalists, for example, contend that people think and learn socially and by interacting with other more physical and symbolic resources. Social, physical and symbolic resources, therefore, provide opportunities to learn and are inseparable from the experience and activity of learning. Other less extreme socio-culturalists concur that resources are significant aspects of learning environments but explore them from an individualistic perspective, that is, what the individual can achieve with resources as opposed to what the individual can do alone. While resources are never ranked as such, it can be inferred that both camps perceive social resources to be the primary catalysts for opening up opportunities for cognition to be distributed from one source to another. Perhaps this is a consequence of the social constructivist contention that the maintenance of meaningful social exchanges between students is the primary source of cognitive growth (Stage, Muller, Kinzie, Simmons, 1998).

Rogers and Ellis (1994) and Rogers (1997) describe social resources as communicative pathways that distribute individuals' representational states across the environment. Although they do discuss other types of resources as communicative pathways (e.g., computer terminals), dialogue between and across individuals is possibly the most powerful and certainly the most common. The 'dialectical interplay of minds' (Goodman, cited in Stage et al., 1998) provides the opportunity for a common language to be established and for knowledge to be intersubjectively constructed. Intersubjectivity refers to the mutual understandings that are achieved between individuals as they negotiate and renegotiate meanings of phenomena (Rogoff, 1990; Vygotsky, 1978).

Any dialogue between two people, or between groups of people can be perceived as an opportunity to distribute cognition. Collaborative groupings, however appear to be the most common as they are widely recognised as frameworks that complement the distribution of cognition (Brown et al., 1993; Crook, 1994; Derry et al., 1998; Hatch & Gardner, 1993; Hewitt & Scardamalia, 1998; King, 1998; Pea, 1993; Perkins, 1992, 1993; Torraco, 1999). In these instances, distribution is bi-directional in that all students have opportunities to guide their peer's participation in the activity as well as appropriate knowledge and skills for themselves. King (1998) terms this mutual appropriation as a 'transactive cognitive partnership', where each student reciprocates in scaffolding each other's thinking and learning to progressively higher levels.

Although Vygotsky never wrote of distributed cognition specifically, many of his theories have been extrapolated to explain its defining principles. The zone of proximal development (ZPD), for example, has been drawn upon to rationalise the nature of distribution in social settings. Brown et al., (1993) perceive social (and other) resources as 'seeds' within the learning environment that provide a range of ideas and concepts for those working within appropriate ZPDs. King (1998) and Brown, Collins and Duguid, (1989) apply ZPD theory to reciprocal teaching and cognitive apprenticeships, claiming that these sorts of social arrangements provide opportunities for less knowledgeable students to carry out tasks with the help of more capable others. Pea (1993) writes, "Such 'guided participation'... distributes the intelligence required to carry off the activity across [participants]" (p. 61).

The Vygotskian perspective that tools mediate learning has also been widely drawn upon by those who advocate distributed cognition. In fact, the whole idea that cognition is distributed across contexts by resources is firmly entrenched in Vygotsky's (1978) theory that people act through both psychological and technical tools in their attempt to gain greater control of their world. For example, Vygotsky's belief that "the sign acts as an instrument of psychological activity in a manner analogous to the role of tool in labour" (p. 52) is central to subsequent assertions that symbolic resources (such as language systems) support and distribute cognitive activity (Cole & Engeström, 1993; Pea, 1985; Perkins, 1992, Salomon, 1993c). As a rule, people sustain thinking through socially shared symbol systems such as writing, diagrams, scientific formula, mathematical algorithms and even medical records as was illustrated in Lebeau's (1998) research. These sorts of symbols participate in cognition, not just as a vehicle of transmission, or as source of record, but as a vehicle of thought (Perkins, 1992).

The portrayal of resources as 'tools' is prevalent throughout the literature. Physical resources in particular are frequently likened to tools which humans have developed throughout history to provide them with physical and intellectual advantages (Crook, 1994; Jonassen, 1996; Pea, 1985, 1993). In fact, Pea (1985) believes that the way in which we have come to interact with physical tools has significantly changed the way in which we interact with the environment. Drawing on the plough as an example, Pea argues that tools have not only served to increase productivity, but they have essentially caused the nature of tasks to change as well as the ways in which these tasks are accomplished. Looking at this from a learning perspective, physical tools (such as the calculator, have the potential to not only amplify our thinking, but also restructure our thoughts, the way we think, and ultimately the way we behave as individuals.

The outcome of using a tool is often dependent on the relationship between the tool and the user. For example, in her discussion of the computer as a cognitive tool, Gilbert (1999) proposes three main roles which the cognitive tool often plays – the servant, the partner or the expert. As a servant, the computer supports lower level cognitive processes in order to enable the student to engage in higher level activities. As an expert, the computer makes decisions and directs interaction between it and the student. As a partner, the student and the computer work in an interactive partnership, directed by the student's intent.

In developing this type of intellectual partnership, it is easy to see why students would develop a dependency on tools. It is the student in partnership with the computer (or any other resource found within the learning environment) that facilitates the successful completion of a task. This dependency has encouraged Perkins (1992) to question traditional models of information processing. Rather than assume that knowledge only resides within a student's long-term memory, Perkins argues that the physical surround is also an invaluable source of knowledge. Termed the 'access framework' he maintains that *access* to knowledge is more important than where it is located. The knowledge in a journal, for example, is as valid as the knowledge in one's head, but neither is of much use if they cannot be accessed swiftly and easily.

Hewitt and Scardamalia (1998) support this view and contend that work produced by students (e.g., essays, assignments and journals), are rich cognitive resources for all students, not just those who originally composed them. In storing these documents in a publicly accessible database, theories, perspectives, questions and ideas become a collection of cognitions. These cognitions not only constitute the thinking of a community of learners, but also become the collective knowledge base upon which new constructions are developed. Known as a 'computer supported intentional learning environment' (CSILE), this computer application advances the spiral-like nature of distributed cognition where one student's cognition feeds into the understandings shared by the classroom community.

While Hewitt and Scardamalia (1998) and others acknowledge the importance of individual intellect, they stop short of characterising it as a resource to which students can distribute their cognitions. Lebeau (1998), on the other hand, identifies intellect as a resource with which individuals interact in the joint construction of knowledge, however there is no attempt to elaborate upon the attributes of this resource and how one's mind contributes to distribution. Similar observations can be made with Rogers and Ellis (1994) who acknowledge individuals' memories as important to distributed cognition, but fail to actually define this resource. These references clearly highlight the need for an individual's intellect as a resource to be examined more closely.

Based on the findings from related literature, it is assumed that intellect serves as a resource in two main ways. The first is in relation to the mental knowledge constructs which individuals retain in their minds as memories, otherwise known as prior knowledge. As mentioned earlier, an individual's experiences, thoughts, ideas, beliefs and understandings are rich resources that not only permit access into the distribution of cognition, but also feed the process (Salomon, 1993b). The second aspect pertains to the metacognitive knowledge one has about the processes of learning. Very little has been documented about metacognition as a resource in the distribution of cognition which is surprising considering its widely encouraged presence in other learning situations. Hedberg et al's. (1993) contention that metacognitive knowledge is a cognitive tool to be used wisely in the pursuit of effective learning, is particularly important in a distributed learning environment as this resource essentially oversees the entire process through the deployment of learning strategies.

Many authors propose categorisations of different types of learning strategies, however, those by McKeachie, et al. (1987) are perhaps the most concise. They classify learning strategies as being either cognitive, metacognitive or resource management related. Cognitive learning strategies are those that facilitate the processing of information with the goal of achieving meaning and/or remembering (e.g., note-taking, paraphrasing, concept-mapping, rote rehearsal). Metacognitive learning strategies are those that relate to the control and regulation aspect of learning (e.g., self-questioning, setting goals, re-reading, reviewing). Resource management strategies are those that assist students in managing the environment and resources available to them (e.g., scheduling, organising quiet areas, managing effort, seeking help from peers and others).

From a social constructivist point of view, a student's internal knowledge structures (of which knowledge about the three types of learning strategies is an interrelated component) are an integral part of the learning context. From a distributed learning point of view, these knowledge structures are the non-observable mental resources to which cognition is distributed internally, as well as externally to the more tangible resources. A student's prior knowledge not only provides him or her with the requisite knowledge upon which to develop subsequent understandings, but also with the know-how of how to read the environment; how to organise it and available resources such that intellectual partnerships can be established and cognition distributed across the mind, as well as the external surround. But how are these partnerships actually formed? The next section attempts to answer this question.

The fingertip effect

In the preceding section, it was argued that the partnerships between individuals (and groups of individuals) and social, physical, symbolic and intellectual resources are central to distributed cognition. In light of this, resources of all shapes, sizes and affordances should be made available to students. Can we assume, though, that by simply making resources available to students, the opportunities the resources afford will be automatically exploited? This is unlikely according to Perkins (1985, 1992, 1993) and others (Pea, 1985, 1993; Nickerson, 1993). A mistake made by many teachers is the assumption that because resources are available - at students' fingertips so to speak - their potential will be maximised. While the immediate conveniences of resources are often taken advantage of (e.g., using the word processor to write a story) their full potential is rarely exploited (e.g., using the word processor to provoke intelligent revision) (Perkins, 1985).

One has only to reflect on the classroom context to see that this concern is real. Television, computer applications, collaborative and cooperative group work, calculators and other innovative resources have largely failed due to the assumption that their mere presence will yield immediate and profound transformations in education (Perkins, 1992). The consensus was (and arguably still is), that the rich opportunities afforded by most of these resources would do the teaching itself – that intervention by the teacher would not be necessary as students would naturally gravitate towards the educational opportunities on offer. As a result of this misconception, initiatives have failed with the blame falling squarely on the resources as being of little use after all. According to proponents of distributed cognition, however, the problem is not with the resources but with lack of teacher intervention guiding students to discover these opportunities. Perkins (1992) writes:

> The image of simply putting something into place – say, a word processor – and seeing wonderful learning experiences unfold organically is seductive. But innumerable lost hopes argue for a more hardheaded posture toward the fingertip effect. We must not expect new technologies, the grouping of students, and like innovations to do the job by themselves. We must accept the responsibility of mediating students' good use of these person-plus resources. (p. 147-148)

In essence, what this means is that the opportunities inherent within resources cannot be taken for granted. In the first place, it cannot be assumed that all resources afford educational opportunities. Secondly, even if resources do afford opportunities, this does not mean students are aware of them and, thirdly, even if students are aware of these opportunities, it cannot be assumed that they will be sufficiently motivated to take them (Perkins, 1985). Teachers, therefore, must be aware of these issues and engineer the conditions necessary for allowing sound intellectual partnerships to form. One of the first steps to take in this process is for teachers to become aware of the nature of resources available to students and to question how they can potentially enhance learning. Satisfied that they afford sound educational benefits, teachers must arrange opportunities for students to interact with the resources, all the while mediating this process to ensure potential is known and exploited.

This mediation process was central to the implementation of a distributed learning environment, which in turn was paramount to the development of an effective partnership between the students and the computer as a cognitive tool. The characteristics of this environment are explored in the following chapter, the specific features of which are defined and presented as the means by which the distribution of cognition is operationalised in the classroom environment.

-5-

Characteristics of a Distributed Learning Environment

Chapter overview

Chapter 5 discusses the fundamental characteristics of a distributed learning environment (DLE). It begins with a description of the process through which these characteristics were defined and built into a comprehensive DLE framework. The specific features of each characteristic are then examined in more detail before being summaried in tabular form. Finally, the implications associated with the interrelated nature of these characteristics are briefly discussed before the chapter is concluded.

Building a distributed learning environment: The process

In an effort to uncover the fundamental characteristics associated with a DLE, relevant literature was extensively reviewed. Books discussing and developing the subject were examined, as were journal articles, research projects and web sites. These sources provided accounts of distributed cognition that swept a broad range of contexts, both educational and other. The temporal span of the literature covered ranged from 1985 to the present.

Although these sources discussed many facets of distributed cognition, very few explicitly discussed ways of operationalising it in the classroom. For example, Brown et al's. (1993) article (and others like it) was useful in identifying the practicalities of a DLE, but stopped short of actually defining implementation strategies. Initially, therefore, there were no specific criteria for formulating a framework and any aspect that appeared relevant to the distribution of cognition was noted. Table 5.1 is a list of potential elements of a DLE as they emerged from early reviews of the literature.

Table 5.1 Preliminary characteristics of a DLE

Elements of a distributed learning environment	Source
Active and explicit encouragement by teacher to use the full potential afforded by resources.	Pea, 1993
Availability of, and easy access to, a variety of resources within and beyond the classroom.	Hatch & Gardner, 1993; Pea, 1992, 1993; Pea & Gomez, 1992; Perkins, 1992, 1993; Rogers & Ellis, 1994
Collaboration between peers, teachers and others in the negotiation and development of understandings.	Hatch & Gardner, 1993; Pea, 1993; Pea & Gomez, 1992; Perkins, 1992, 1993; Rogers & Ellis, 1994
Use of language, symbols, diagrams and pictures as catalysts to clarify and explain the meaning of concepts.	Pea, 1993; Pea & Gomez, 1992; Perkins, 1992, 1993
Authentic activities that have purpose and validity.	Pea, 1993; Pea & Gomez, 1992
The teacher models shared negotiation of meaning and learning as a communal endeavour.	Pea & Gomez, 1992
Goal-oriented learning from both an individual and social perspective.	Pea, 1993
Deliberate engineering of learning experiences that enable students to operate within their ZPD.	Brown et al., 1993
Students are aware of ritualistic participation frameworks and routines.	Brown et al., 1993

With further analysis of the literature, however, these initially disparate aspects began to form patterns that could be distinguished as being related to certain characteristics common to most teaching contexts. It was apparent that the ideas present in the list could be attributed to characteristics relating to either the teacher, the students or the processes of learning. Consequently, each of these ideas was 'binned' (Miles & Huberman, 1994) into one of three categories labeled *teacher characteristics, student characteristics* or *process characteristics* (see Table 5.2). Each feature to emerge from the literature thereafter was immediately assigned to one of these categories.

Table 5.2 The classification of preliminary characteristics of a DLE

Elements of a distributed learning environment	Source
Active and explicit encouragement by teacher to use the full potential afforded by resources.	Pea, 1993
Availability of, and easy access to, a variety of resources within and beyond the classroom.	Hatch & Gardner, 1993; Pea, 1992, 1993; Pea & Gomez, 1992; Perkins, 1992, 1993; Rogers & Ellis, 1994
Collaboration between peers, teachers and others in the negotiation and development of understandings.	Hatch & Gardner, 1993; Pea, 1993; Pea & Gomez, 1992; Perkins, 1992, 1993; Rogers & Ellis, 1994
Use of language, symbols, diagrams and pictures as catalysts to clarify and explain the meaning of concepts.	Pea, 1993; Pea & Gomez, 1992; Perkins, 1992, 1993
Authentic activities that have purpose and validity.	Pea, 1993; Pea & Gomez, 1992
The teacher models shared negotiation of meaning and learning as a communal endeavour	Pea & Gomez, 1992
Goal-oriented learning from both and individual and social perspective.	Pea, 1993
Deliberate engineering of learning experiences that enable students to operate within their ZPD.	Brown et al., 1993
Students are aware of ritualistic participation frameworks and routines.	Brown et al., 1993

Based on Biggs and Moore's (1993) assertion that the key components of any learning context, namely the teacher, the students and the learning processes, interact and influence one another, it was inferred that these emergent categories were interrelated. For example, it was postulated that within a DLE the *teaching context characteristics* would influence the *student characteristics* which together would affect the *process characteristics* and (ultimately) the learning outcomes. This 'systems theory' approach effectively captured the intricate nature of a DLE in that implementation of change in one component would potentially induce change in others. Figure 5.1 provides a diagrammatic representation of this interrelationship.

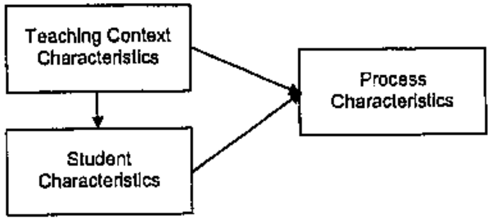


Figure 5.1 The interrelated nature of the characteristics within a DLE

What does a distributed learning environment look like?

Having identified the key components of the DLE, it was then necessary to explicitly describe their defining features as they pertained to the classroom context. This process was paramount in bridging the gap between theory and practice as it effectively 'operationalised' the key principles of distributed cognition that were gleaned from the literature. The following section, therefore, provides a comprehensive examination of the specific features that comprise the three components of the DLE framework, that is, the *teaching context characteristics*, the *student characteristics* and the *process characteristics*.

Teaching Context Characteristics

The *teaching context characteristics* comprise a wide range of complex phenomena which constitute the foundations upon which the entire DLE framework is built. That is, the subsistence of the *student characteristics* and the *process characteristics* is derived from the fundamental make-up of the *teaching context characteristics*. These characteristics relate to the primary features within any teaching context such as the teacher, the curriculum, the learning tasks and assessment procedures. Each of these features will be discussed independently.

Teacher features

In keeping with Hativa's (1986) contention that the teacher is the most crucial factor in implementing and maintaining any innovation in the classroom, effective distribution of cognition is contingent on the teacher's ability to carefully assemble an infrastructure that embeds distribution into the fabric of everyday classroom life. This infrastructure enables students to participate in procedures and rituals that, in effect, propagate cognition across a variety of resources within the learning environment. As Brown et al. (1993) note, if students are to participate effectively, they need to become adept in recognising these rituals, understand their structure and move fluidly between them.

These rituals are firmly grounded in the resources which define the learning environment. In other words, participating in the distribution of cognition is synonymous with collaborating with others (social resources), accessing a range of tangible and intangible resources (physical and symbolic resources) and tapping into existing knowledge structures and learning strategies (intellectual resources). Consequently, collaboration, resource-based learning and thinking strategically are the fundamental features of the participation framework that enable students to navigate effectively within a DLE (see Figure 5.2). And although the learning activities vary from week to week, the rituals of participation remain constant and characteristic of the culture of a DLE.

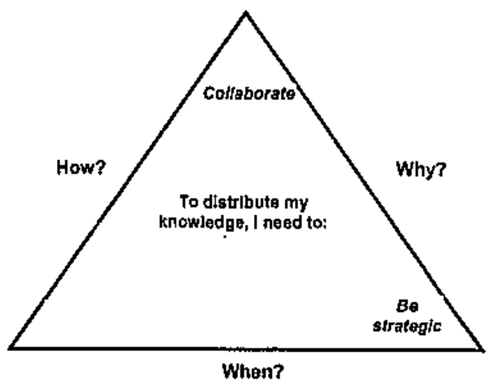


Figure 5.2 Infrastructure supporting the primary participation framework within a DLE

While this participation framework would appear to be a straightforward endeavour, the extent to which students maximise the potential offered by these resources is a *learned* construct and one which requires active input from the teacher. Through constant guidance, modelling and encouragement, he or she effectively shows the students *how* to collaborate, use a broad range of resources and think strategically. The teacher's role in each component of the participation framework is discussed as follows.

- Collaboration

Collaboration is not a natural by-product of grouping students together. Perkins (1992) writes, "While the opportunities to collaborate are created by ... grouping students, *follow-through* depends on much more than the existence of opportunity" (p. 145). This *follow-through* is a highly orchestrated endeavour through which collaboration eventually evolves. Hewitt and Scardamalia (1998) support this in their observation that effective peer relations largely hinges on teacher intervention. In their attempts to construct 'knowledge building communities', they found it necessary for teachers to explicitly discuss collaboration strategies (e.g., strategies for reading and commenting on other student's work, effective & ineffective strategies for disagreeing and criticising) with their students. King (1998) also recognised the need for teachers to scaffold peer groupings if the students were to engage in 'transactive cognitive partnerships'.

Because dialogue and discussion is the principal communicative link for the actual process of distributing knowledge from one source to another (Brown et al., 1993; Rogers & Ellis, 1994), it is crucial that students know *how* to collaborate effectively. Before they can successfully set group goals and develop a sense of autonomy in group collaborations, they need to know what they stand to gain from doing so. They need to know how to manage the inevitability of intellectual conflict (and perhaps even social conflict), how to question, provide feedback and how to support each other's learning. In short, students need prearranged opportunities to collaborate with one another – opportunities where they, through constant encouragement, guidance and support from the teacher, can learn to distribute their cognition to one another and across other small group arrangements.

- Using resources

As illustrated in Figure 5.2, the participation framework is also resource-based. That is, for students to effectively distribute their cognition, they must come to recognise social, physical, symbolic and intellectual resources as learning supports and communicative pathways. These resources are the tools which Vygotsky (1978) referred to as support mechanisms that enable students to extend their zones of proximal development (ZPD). This support may come in the form of questions posed by the teacher or another peer, or it might be ideas and prompts found in texts, cognitive tools, journals, tables and diagrams. Mastery of concepts with the support of resources pushes back the boundaries of the individual's ZPD (Brown et al., 1993) so while supports are no longer required for learned concepts, new supports are needed for subsequent, more complex ones.

Distributed cognition, therefore, is about accessing resources that contain appropriate supports for a range of ZPDs (Brown et al., 1993; Pea & Gomez, 1992; Pea; 1993; Perkins, 1992). However, accessing resources is only half the battle and as Nickerson (1993) points out, students should also learn how to use these resources effectively. There is little point in having a range of resources available if students do not know how to use them, why they should use them, when to use them and when not to use them. Perkins (1985, 1992) claims that the responsibility for helping students take these opportunities clearly falls onto the teacher who must mediate the students' interactions with resources and guide them towards effective use. This process is cumulative and develops gradually as the teacher models, coaches and encourages resource awareness such that their use eventually becomes part of the classroom culture.

This last point poses implications for the timeframe over which the framework should be implemented. Given that the DLE *gradually* encourages students to distribute their learning to social, physical, symbolic and intellectual resources, implementation must occur over an extended period of time. Expecting immediate results from a DLE, or implementing it into a short-term unit, is unrealistic. Similarly, expecting cognitive tools to restructure cognitive functioning immediately will result in disappointment and perhaps add (unfairly) to the argument that cognitive tools cannot enhance learning.

- Being strategic

Although resources exist in most classrooms, they are often not perceived to be integral to effective cognitive functioning and the potential power they yield regularly goes unnoticed (Perkins, 1992). This is evident in activities that encourage students to work without supports, and assessment methods that reward solo performances (Perkins, 1992; Resnick, 1987). Even when physical, social or symbolic supports are used the more obscure and less observable intellectual resources are frequently undervalued. These resources are fundamental to the participation framework described previously, as they are the catalysts for strategic learning.

As discussed in the previous chapter, when students use their intellectual resources, they tap into existing knowledge structures onto which new information can be linked. They also access learning strategies that help them cope with a range of task demands. The larger the students' repertoires of different types of learning strategies, the more effective they are as learners (Chalmers & Fuller, 1996). Although it is possible to acquire some learning strategies incidentally, these are usually basic ones that enable students to acquire information only (e.g., rote learning and note taking). Complex learning strategies (e.g., those that facilitate understanding and/or enable students to regulate their learning) are rarely acquired by chance and, more often than not, need to be learned.

In a social constructivist learning environment, the best way to acquire learning strategies is through teacher modelling, coaching and constant encouragement. And as Chalmers and Fuller (1996) suggest:

> When this is followed by opportunities to practice the use and implementation of the strategies in a number of different contexts, to receive feedback on the appropriateness and effectiveness of their implementation, and to compare their effectiveness against alternative strategies, then it is likely that students will use a wide range of learning strategies appropriately and effectively (p. 36).

Finally, distribution of cognition in the classroom requires students to participate in procedures and routines that are collaborative, resource-based and strategic in nature. Given that implementation of these procedures and routines is controlled by the teacher, the extent to which they encourage the distribution of cognition is a reflection of his or her commitment to this construct (Brown et al., 1993; Pea & Gomez, 1992). Based on a firm understanding of the principles that underpin distributed cognition, this commitment is the driving force behind every feature of the teaching context characteristics. Unless this commitment is evident, then any distribution that occurs may be superficial in nature.

Teacher features are summarised as follows. The teacher is:

- responsible for the development and implementation of a framework that will enable students to participate in the distribution of their cognition through collaboration, using resources and thinking strategically (Brown et al., 1993; Hewitt & Scardamalia, 1998; Pea, 1985, 1993; Pea & Gomez, 1992; Perkins, 1992).
- committed to a DLE and constantly models distribution (Brown et al., 1993; Pea & Gomez, 1992).

Curriculum and task features

In simple terms, curriculum refers to the selection and arrangement of content to be taught in a particular subject to a particular year level (Biggs & Moore, 1993). While teachers are restricted to the actual 'what' of the curriculum, the 'how' and 'when' are very much a reflection of their own personal conceptions of teaching. Conceptions of teaching are subjective statements that represent the fundamental beliefs teachers have about how students learn and how they should be taught (Chalmers & Fuller, 1996).

Comparison of the findings from research into teachers' conceptions of teaching shows that curriculum dissemination can be viewed in qualitatively different ways (Gow & Kember, 1993; Larsson, 1986; Samuelowicz & Bain, 1992). For example, Larson (1986) found that teachers perceived their skills to increase as they shifted their focus from communicating large quantities of facts to students, to helping them develop as critical thinkers. The findings from the other cited studies were similar and could be summarised in terms of two main orientations, a) teaching as the transmission of knowledge, and b) teaching as the facilitation of student understanding. Teachers who perceive teaching to be the transmission of knowledge see themselves as experts in their area and aim to present subject matter to students in an accurate and efficient manner. In contrast, teachers who perceive teaching to be the facilitation of understanding believe the responsibility of learning lies ultimately with students and, as such, aim to develop independent learners through the promotion of critical thinking and metacognitive skills.

Because conceptions of curriculum are implicit within conceptions of teaching, it is possible to infer from these orientations that teachers who perceive teaching to be the transmission of knowledge see curriculum as a collection of essential facts and skills to be taught, assimilated and tested on cue. In contrast, teachers who perceive teaching to be the facilitation of understanding see curriculum as a series of meaningful themes that promote discussion, problem solving and critical thinking, not just memorisation and recall. This latter orientation is in keeping with a DLE where teachers discriminately present themes that are thoroughly explored by the students, revisited often and used as the basis for further learning opportunities. Depth of understanding is fostered in preference to breadth of coverage, even though practical constraints require teachers to at least balance the two (Brown et al., 1993).

Given that learning tasks are the catalysts through which the students come to learn curricula themes, teachers must design class activities that complement curricula objectives. In . DLE, therefore, tasks should be structured such that they encourage students to search for the meaning inherent in the subject matter and facilitate conceptual growth within and between themes. Rather than focus on the surface features of concepts, tasks in a DLE must encourage students to tap into their existing networks of knowledge and use them as the basis upon which new, more extensive understandings can be built (Brown et al., 1993). Through discussion and collaboration, this prior knowledge becomes an intellectual resource for the learning community with which it is shared.

Furthermore, tasks within a DLE should possess authenticity in that they are representative of real world problems and situations (Pea, 1993; Pea & Gomez, 1992). When this occurs, learning is situated in a context that is meaningful and relevant to the students and clearly "reflects the multiple uses to which their knowledge will be put in the future" (Collins, Brown & Newman, 1989, p. 487). In this way, knowledge becomes a tool which can be used to interpret or inform subsequent learning situations, as opposed to remaining inert and usable in limited situations only (Brown, 1997).

As an example of an authentic learning task, primary mathematics students might be asked to develop specifications for a new play area intended for their school. Multiple mathematics concepts would be encountered as students endeavour to achieve an objective that is not only real, but purposeful and valuable to them personally. The open nature of this task is also conducive to group collaboration, using a variety of resources and employing strategic thought – the fundamental elements of participating in a DLE. Tasks that require students to complete worksheets or note-take in lectures, not only lack authenticity but are at odds with the very forces that drive the distribution of cognition.

Finally, the relationship between the learning tasks and the participation framework is a mutually dependent one. While tasks need to complement the participation framework, in that they should open up communicative pathways and encourage the use of resources and strategic thinking, it is through execution of the task that these very skills are developed. That is, the task is the catalyst that enables the skills of distribution to be learned in context. By participating in authentic tasks, students are learning how to collaborate, how to use resources and how to think strategically in a context that is both meaningful and relevant. Consequently, these skills make sense to the students because they are using them to achieve valued goals and aims. In this way "students acquire acts, principles [and] theories as conceptual tools for reasoning and problem solving that make sense because they have consequences in meaningful contexts" (Pea & Gomez, 1992).

Curriculum and task features are summarised as follows:

- Curricula emphasises depth of coverage over breadth; understanding over memorisation and recall (Brown et al., 1993).
- Tasks complement curricula objectives which are based on objectives that emphasise understanding (Brown et al., 1993).
- Tasks are situated and authentic (Pea, 1993; Pea & Gomez, 1992).
- Tasks are conducive to collaboration, using resources and learning strategies (Pea & Gomez, 1992).

Assessment Features

The third feature of the *teaching context characteristics* relates to assessment procedures, the main purpose of which is "to determine whether learners have achieved the goals and objectives of ... instruction" (Reeves & Okey, 1996, p. 196). Assessment in any learning environment should be clearly aligned with the learning objectives, content, learning tasks, pedagogy and resources. In this way, students will be encouraged to maximise all the affordances of the learning environment, rather than simply weed out those which are perceived to carry the necessary grades (Reeves, 2000a). As such, the traditional divisions between learning and assessment are blurred, thus enhancing the authenticity of the learning environment as a whole.

In a DLE, therefore, this alignment should not only exist (Brown et al., 1993) but be clearly articulated to students. If students are aware that the assessment procedures will be consistent with the methods used to learn the material, then they will be more likely to make use of available resources within the classroom. Also, those students who are unsettled by the notion of constructing knowledge socially will potentially feel less threatened knowing that these pr cesses are also integral to the assessment procedures. However, ensuring this consistency is not always straightforward, as Sumara and Davis (1997) point out in the following quote:

> It is not unusual for teachers in schools to direct a group of students to 'work together' (e.g., to come up with ideas for a project, an essay, a presentation) and then to prepare 'individual' products for assessment. Not only do we find this a rather strange cultural practice – as it separates the actions and understandings of the individual from those of the collective – it is a contradictory practice that subordinates 'group work' to the work of the individual. (p. 405)

Polarising learning and assessment into a social, tool based experience *versus* an individual, non-mediated experience is detrimental to the success of a DLE as it undermines the principles upon which it is built. Moreover, because students are encouraged to think with and through multiple resources when learning in a DLE, it is quite feasible for some or all of these resources to retain part of that learning (Brown et al., 1993) and, as such, should be available during assessment. This is particularly important in light of Perkins (1992) contention that the long-term memory is not (nor should it be), the sole retainer of knowledge.

> What really counts is not where knowledge is – inside or outside the skull, but what might be called the 'access characteristics' of relevant knowledge – what kind of knowledge is represented, how it is represented [and] how readily it is retrieve. (Perkins, 1992, p. 135)

Furthermore, in keeping with curricula and task objectives, depth of understanding should be the focus of assessment in a DLE, not fact retention (Brown et al., 1993). However, because conceptual growth is a gradual process of extending and developing knowledge structures, teachers should avoid assessment methods that look for an 'all-or-none' result (Gelman & Greeno, 1989). In an environment that acknowledges and encourages students to work within their own ZPD, it is to be expected that a range of understandings will exist. Assessment, therefore, should reflect the temporal nature of a DLE and aim to capture students' understandings in their early conceptual form and as they progress towards deeper levels. This will enable the teacher to monitor the development of misconceptions, determine the appropriate time to extend students' ZPDs and generally evaluate achievement and performance (Brown et al., 1993).

Portfolio assessment, where collections of students' work are assembled over time is one such method as it allows teachers to trace conceptual growth as individual ZPDs shift and change. Because portfolio assessment is focussed on process as well as product (Reeves, 2000a; Reeves & Okey, 1996), students come to value the skills of learning as well as the final outcome. This is important in a DLE where the tools of learning are the keys that provide access into an arena of shared knowledge constructions and maturing understandings. Collaborative assignments, peer assessment, student/teacher interviews and informal discussions are other examples of assessment methods that, due to their on-going social and goal-oriented nature, would be conducive to a DLE (Brown et al., 1993).

Assessment features are summarised as follows. Assessment tasks should:

- be consistent with the process of learning (Brown et al., 1993).
- evaluate student understanding not recall (Brown et al., 1993).
- acknowledge other *containers* of knowledge not just *'in-the-head'* knowledge (Brown et al., 1993; Perkins, 1992).

- look for partial understanding as well as complete understanding (Brown et al., 1993).
- use methods (e.g., portfolios) that emphasise the process of learning as well as the product (Brown et al., 1993).

Teaching context characteristics concluded

As a concluding statement to the *teaching context characteristics,* the teacher, the curriculum, the learning tasks and assessment procedures are all features of the teaching context which, in a DLE, must be considered in light of the principles of distributed cognition and those that define social constructivism. Given that the teacher is primarily responsible for these features, they could have been included as subsets of the features that define the teacher. They have been treated separately here, however, to give impact to the specific details which teachers must attend to in their endeavours to develop a DLE. Moreover, these details convey messages to students about the type of learning that is desired and rewarded in the classroom which, in turn, impacts upon the second component of the DLE known as the *student characteristics.* These characteristics are discussed as follows.

Student characteristics

Student characteristics relate to students' perceptions of the learning environment and their roles within it. Although not stated as such in the literature on distributed cognition, these perceptions are very much based on the students' conceptions of learning, that is, their beliefs about what learning means and how it occurs. Marton, Dall'Alba and Beaty (1993), have identified six different levels of conceptions of learning which can be classified as being either quantitative or qualitative in nature. Quantitative conceptions of learning are associated with students' perceptions that learning is the accumulation of isolated pieces of knowledge whereas qualitative conceptions of learning are associated with students' perceptions that learning is the construction of personally meaningful understandings. These perceptions influence the students' commitments to pedagogical approaches, as well as their acceptance of the responsibility they have for their own learning and the learning of others.

In a DLE, it is important that students align themselves with qualitative conceptions of learning. If they perceive learning to be the accumulation of facts, then attempts at distribution will be superficial, if not a little confusing. Because rote learning is largely an individual pursuit, students who endeavour to complete tasks in this fashion, but within an environment of group collaboration and communal effort, will inevitably experience some sense of mismatch and disorder. Conversely, when students perceive learning to be the construction of deep understandings, they will be more willing to access people, tools and strategies that will facilitate their endeavour.

This latter scenario is preferred because in a DLE, students must see themselves as co-learners, co-teachers and co-researchers (Brown et al., 1993) who not only access resources, but are prepared to invest themselves as social resources in a collective effort to construct knowledge (Hatch & Gardner, 1993; Nickerson, 1993; Salomon, 1993b). In doing so, a type of 'collective consciousness' transpires which, according to Torraco (1999), is fundamental to the effective distribution of cognition. He writes:

> A defining characteristic of group situations in which distributed cognition is possible is the opportunity for developing collective consciousness [which] is a state of mind achieved by group members reflecting a high level of interaction and awareness relative to a common experience ... This allows members to develop their own unique conceptions of the task within a broader systems context. Being exposed to representations of the task not only satisfies the need to see how the task is oriented within the broader system but also allows members to conceptualise how their efforts contribute to the overall experience. (p. 265)

This state of mind is not incidental to the implementation of a DLE but rather comes about when the students are fully committed to the principles of distributed cognition (Hewitt & Scardamalia, 1998). Unless this commitment is evident, any attempts at distribution will be in vain, even if all the necessary *teaching context characteristics* are in place. As Brown et al. (1993) notes, commitment breeds respect - a respect which is necessary for all comments, questions, concerns or silent contemplations to be acknowledged as worthwhile contributions to the learning endeavour. Students who are ridiculed or criticised for their contributions will be inclined to withdraw from communal learning, thus restricting attempts at distribution within the environment as a whole.

Student characteristics concluded

In summary, *student characteristics* refer to the perceptions students have of the DLE and their roles and responsibilities within it. These perceptions are largely a reflection of the students' conceptions of learning, that is, what they understand learning to mean. Qualitative conceptions of learning are more conducive to a DLE as the pursuit of understanding is more likely to be achieved through collaboration, using resources and strategic learning. Beyond the conceptions, students must consciously commit to and respect the joint construction of knowledge because, as Brown et al. (1993) state, "[an] atmosphere of joint responsibility is critical for this enterprise" (p. 199).

The features of the *student characteristics* are summarised as follows. Students must:

- see themselves as co-learners, co-teachers and co-researchers in the pursuit of understanding and making sense of material (Brown et al., 1993).
- develop a 'collective mindset' based on a strong commitment to the pedagogical approaches to learning within this environment (Hatch & Gardner, 1993; Hewitt & Scardamalia, 1998; Nickerson, 1993; Salomon, 1993b; Torraco, 1999).
- respect each other and the learning community as a whole (Brown et al., 1993).

These perceptions affect the way students approach their learning, that is, the processes they adopt in order to complete learning tasks and participate in the learning community generally. The *process characteristics* will be discussed next.

Process characteristics

The process of learning within a DLE refers to the things that students do when they distribute their knowledge – the cognitive processes they engage in when they interact with the contextual resources. As discussed in Chapter 3, resources typically available and accessed within a DLE can be categorised as physical, social, symbolic and the student's own intellect (Brown et al., 1993; Cole & Engeström, 1993; Hatch & Gardner, 1993; Pea, 1993; Pea & Gomez, 1992; Perkins, 1992, 1993; Rogers & Ellis, 1994; Salomon, 1993b). While these resources are the vehicles of knowledge distribution, they can also stimulate the thought processes and knowledge that are actually distributed. The sorts of processes that emerge from the interaction between students and these resources are outlined below, beginning with physical resources.

Physical Resources

Physical resources are tangible artefacts such as books, student journals, computers, calculators, pens, paper and whiteboards. On their own, these resources are little more than three-dimensional objects that fill space. While their affordances may be rich and plentiful, they can only be realised in concert with an active mind. For example, Brown et al., (1993) describe physical resources as seeds within ZPDs that have the potential to support intentional learning. The key word here is 'intentional' in that students must *deliberately* draw on these seeds (e.g., ideas, methods, questions, responses and perspectives) if the resources are to support their learning.

What students actually do, however, when they draw on these seeds remains largely unanswered although the concept of 'mutual appropriation' provides some degree of clarity (Brown et al., 1993). 'Appropriation' is the term used to describe the process by which students transform information provided by the learning environment into their own interpretations (Brown et al., 1993; Lebeau, 1998). 'Mutual appropriation', therefore, refers to the bi-directional nature of appropriation, that is, the support given to all students within the learning environment by others irrespective of whether they are novices or experts. Brown et al., write:

> Learners of all ages and levels of expertise and interests seed the environment with ideas and knowledge that are appropriated by different learners at different rates according to their needs and to the current state of the zones of proximal development in which they are engaged. (p. 193)

While Brown et al., (1993) use 'mutual appropriation' to describe the social process of scaffolded learning, Rogers and Ellis (1994) discuss a similar bi-directional relationship between individuals and the physical environment. They contend that a student's own cognition (known as internal representations) and physical resources (known as external representations) feed off one another to facilitate knowledge construction. For example, the information displayed on a computer terminal can change in response to an individual's input which, once publicly transmitted, will affect the representational state of those who access this information at a later date. In a way, the computer possesses a type of intellect that is derived from the combined knowledge of past users. This 'intellect' constantly changes form in response to each new input and serves to change and modify the knowledge structures of subsequent users.

Pea (1993) and Perkins (1993) support the idea that inherent within physical resources is a type of 'intelligence' that exists by way of the designer's initial input. Perkins refers to this inherent knowledge as 'cognitive investment', that is, the thinking behind the potential afforded by any one resource. For example, calculators can perform simple to complicated computations only because they have been designed to do so. This cognitive investment prevents students from having to reinvent the wheel, thus enabling them to focus on more abstract and sophisticated levels of thought (Perkins, 1993). So, while the calculator can amplify learning by allowing students to complete a large amount of basic mathematical functions quickly, it can also augment cognition by acting as a springboard for the construction of more complex concepts and understandings.

As discussed in Chapter 2, Pea (1993) argues that this latter, more sophisticated use of a physical resource results in more powerful learning outcomes. This was evident in a study conducted by Sumara and Davis (1997) where students were engaged in a literary fiction containing controversial issues ranging from euthanasia to adolescent sexuality. In an effort to examine the relationship between reading and conceptions of personal and community identity, students were asked to record their reactions to the text directly onto the pages of the novel. "This we believed, would provide material evidence ... of the way in which readings, the conditions of reading, and a sense of identity are always in flux – always becoming transformed through processes of interpretation" (Sumara & Davis, 1997, p. 419). In completing two readings of the book, the students were able to see from their own recordings that not only had their interpretations changed but also how they had changed as individuals.

Although not explicitly stated, this type of interaction with the novel unveiled a typically invisible example of distributed cognition. Because the book explored real issues, albeit through a fictional plot, it inspired reactions from the readers which were grounded in their own belief systems and experiential knowledge. The concepts within the book, and the way in which they were crafted, enabled students to formulate ideas and interpretations that evolved over a period of time. By recording these interpretations onto the pages of the book, the students could use them as reference points for their ongoing experience with the issues, using them to formulate increasingly complex interpretations. In short, the book's potential had been realised and as such, sophisticated learning outcomes were reached.

Social Resources

Social resources relate to peers, teachers or any other person either within or beyond the learning environment that can facilitate the negotiation of meaning. In a way, social resources facilitate knowledge distribution in the same way that physical resources do. In fact, the notion of mutual appropriation is perhaps more comprehendible between individuals and groups of individuals than it is between individuals and physical resources. As Vygotsky (1978) contends, language is the primary means through which individuals become aware of their own thought and, used either socially or privately, it will facilitate their construction of knowledge. Used socially, however, it also becomes a tool for others where, during the exchange of discourse, existing understandings are challenged, negotiated and renegotiated.

Hatch and Gardner (1993) liken social (and physical) resources to local 'forces' within the learning environment. These forces are a property of the interactions that occur between students and between students and physical resources that serve to embellish and enrich thinking. Using the example of two kindergarten students drawing a cartoon character, they demonstrate how collaboration, assistance seeking and support enable both students to successfully complete the activity, even though one of them is less knowledgeable about the character than the other. Each student is a force that has helped to shape the activity and the skills that they have displayed. Had these students been instructed to work individually, the outcome would be quite different in that one student would not have been able to illustrate the character and the other would perhaps have developed a less comprehensive depiction.

Symbolic Resources

Symbolic resources are diagrams, tables, algorithms, and language systems – any structure that provides indexical support for the negotiation of meaning (Pea &

Gomez, 1992). For example, to clarify a particular concept, the teacher may draw a diagram on the whiteboard that emphasises the main points in a condensed format. Or, in an effort to establish common ground, students in a group may draw on the domain-specific language of a particular subject to explain their thoughts and ideas. Pea and Gomez (1992) write:

> With indexical support, speakers opportunistically use the resources of the physical world to clarify what they mean, given the ephemeral nature of spoken language. Their words are "indexed" to referents in a situation, such as words or symbols on a ... computer screen. Such indexing is critical for establishing a shared semantics of representations, referential mappings between situations and formal symbols depicting world entities. (p. 80)

Although diagrams, tables, algorithms and language systems are the more common uses of symbolic resources in the classroom, their inherent potential frequently goes unnoticed. Often, the power of visual representations to provide alternative modes of explanation is lost within school systems that favour the more didactic modes of representation (Pea & Gomez, 1992). This is evident in situations where teachers rely mostly on chalk and talk type lectures to transmit information and incorporate few visual, audio-visual or other types of resources to facilitate the learning process. Emphasising the potential afforded by pictures, charts, maps, graphs and other symbolic resources, would inevitably cater for those students who favour more visual learning styles and would perhaps see greater rewards gained from their use.

A powerful yet possibly less common use of symbolic resources, is their employment to re-shape and deepen existing knowledge structures within and between students. The co-construction of a concept-map, for example, will not only help to establish a common ground of meaning, but can help students identify the interrelationships between concepts. Concept-maps are most effective when they are constructed between two or more students (van Boxtel, van der Linden & Kanselaar, 2000) who, through collaboration and discussion, develop a hard copy that is representative of the way in which concepts are structured in their minds. The spatial arrangement of the interrelated concepts grows and changes alongside the students' maturing understandings, which reinforces the ever-evolving nature of knowledge.

Symbolic resources are also representative of the cultural properties of a learning environment. For example, domain specific language is a set of words that symbolise a certain subject. Also, recording words, diagrams and other symbols on a whiteboard is customary of teachers' actions. These customs, and others like them, are part of the institutional practice of the classroom and, as such, can be likened to the cultural forces which Hatch and Gardner (1993) argue can shape the way students interact with their learning environment. Tapping into the richness of symbolic resources then, as one aspect of cultural forces in the classroom, can have a powerful impact on learning. Used effectively, they become catalysts of distribution, which not only establish common grounds of meaning but also serve to reshape and strengthen understandings.

Intellectual Resources

Intellectual resources refer to the wealth of knowledge students bring to the learning environment. Past experiences, memories, beliefs, values and previous learnings constitute part of a student's intellect that can facilitate the learning process. Constructivists contend that prior knowledge, also known as experiential knowledge (Pea & Gomez, 1992), is the starting point for new learning experiences. The fundamental principle underlying this perspective is the social constructivist view that people do not simply absorb information from the environment but rather they construct personally meaningful understandings by relating new information to what they already know. Existing knowledge then, becomes an important factor in the process of learning as it determines to a large extent what will be learned (Shuell, 1986). In light of this, prior knowledge is a resource pool to be accessed, not only for the student to whom it belongs, but also others who can use it to push beyond their current ZPD (Brown et al., 1993).

Intellectual resources also refer to students' know-how about how to 'work the context' and gain maximum learning benefits. This know-how is also defined as metacognitive knowledge, that is, knowledge about *how* to learn as well as *what* to learn. As previously discussed, students learn about metacognitive knowledge in the context of meaningful learning situations. This knowledge relates to the students' awareness and deployment of cognitive, metacognitive and resource management strategies

(McKeachie et al., 1986) to facilitate the development of social and individual understandings.

Hatch and Gardner (1993) refer to experiential knowledge as personal forces students bring with them to the classroom. Because learning strategies constitute part of this experiential knowledge, they too can be classified as personal forces. As with local and cultural forces, personal forces influence the students' approaches to tasks and the way they distribute their cognition. A student who is aware of the potential embedded in his or her past experiences, as well as the power of learning strategies, will be more inclined to access these resources for personal knowledge construction and in the construction of shared understandings.

Process characteristics concluded

In summary, *process characteristics* refer to the way in which distribution occurs in the classroom. It is the 'how' of distribution. Because distributed cognition is firmly grounded in the social constructivist principle that learning cannot be separated from the context within which it occurs, the 'how' of distribution is very much dependent on the contextual resources that define the learning environment. These resources are in fact the tools of distribution, and can be classified as social, physical, symbolic and intellectual.

While these resources are integral to the learning process, they alone do not ensure the distribution of cognition. Students must interact with them with the intent of using them as support mechanisms and as communicative pathways for the social construction of knowledge. Effective interaction then, is dependent upon students knowing the potential these resources afford and how to maximise this potential. Mutual appropriation can be used to describe the mental processes that occur when students endeavour to maximise the potential afforded by physical and social resources, also known as 'local forces' (Hatch & Gardner, 1993). Symbolic resources are the cultural forces evident in language systems, diagrams and illustrations that define aspects of practice within the classroom. Effective distribution also depends on the deployment of students' intellectual resources, for example, their past experiences and their knowledge of learning strategies (i.e., their 'personal forces').

The features of the *process characteristics* are summarised as follows:

- In a DLE, distribution occurs when students interact with physical, social, symbolic and intellectual resources (Brown et al., 1993; Cole & Engeström, 1993; Hatch & Gardner, 1993; Pea, 1993; Pea & Gomez, 1992; Perkins, 1992, 1993; Rogers & Ellis, 1994; Salomon, 1993b).

- Mutual appropriation explains the processes that occur when students learn from each other and from physical resources (Brown et al., 1993; Rogers & Ellis, 1994).

- Symbolic resources help to establish a common ground that encourages similar meanings and understandings between students (Pea & Gomez, 1992).

- Intellectual resources are the past experiences and learning strategies which students draw on to make sense of a situation or provide supports for others' learning needs (Salomon, 1993b).

Described above are the specific features of the *teaching context characteristics, student characteristics* and *process characteristics* as they have emerged from the literature related to distributed cognition. These features, and their corresponding referents, are summarised in Table 5.3. It is important to note however, that in explaining these features and how they relate to one another, a broader range of literature has been consulted. For example, Vygotsky (1978) has been referred to in explaining the importance of mediational tools in the learning environment. However, because he has not discussed this issue specifically in relation to the notion of distributed cognition, he has not been included as a referent in Table 5.3. Only those authors who have discussed the features *directly in relation to distributed cognition* have been cited.

Furthermore, the characteristics and features in this table have been abbreviated (e.g., TCC/TF - Teaching context characteristics: Teacher features) for cross-referencing purposes later in this thesis.

Table 5.3 Characteristics of a DLE framework

Characteristics	Features	Supporting Authors & Theorists
Teaching Context Characteristics (TCC)	*Teacher Features* (TCC/TF)	
	The teacher is committed to a distributed learning environment and models distributed learning in his or her own actions.	Pea & Gomez, 1992 Brown et al., 1993
	The teacher designs and implements appropriate frameworks that invite students to distribute their learning. This involves providing students with encouragement and opportunities to practice: ▪ group collaboration ▪ use of resources ▪ strategic learning	Brown et al., 1993; Hewitt & Scardamalia, 1998, Pea & Gomez, 1992; Pea, 1985; Pea; 1993; Perkins, 1992;
	These frameworks contain resources and experiences that challenge students to work within, and push beyond their ZPDs.	Brown et al., 1993; Pea & Gomez, 1992; Pea, 1985; Pea; 1993; Perkins, 1992
	Curriculum and Task Features (TCC/CTF)	
	Through input from the teacher, the curriculum emphasises understanding, depth of coverage and the gradual development of complex knowledge structures.	Brown et al., 1993
	The learning tasks encourage students to search for understanding, are authentic and situated and are conducive to DLE participation frameworks	Brown et al., 1993; Pea & Gomez, 1992; Pea, 1993
	Assessment Features (TCC/AF)	
	The teacher designs activities and experiences that: ▪ assess depth of understanding ▪ acknowledge the various 'locations' of knowledge ▪ are incremental and look for levels of understanding (e.g., portfolios)	Bro wn et al., 1993; Perkins, 1993
Student Characteristics (SC)	*Students:*	
	▪ see themselves and others as co-learners, co-teachers and co-researchers who are committed to communal learning. They understand the importance of a 'collective consciousness'.	Brown et al., 1993; Salomon, 1993b; Hatch & Gardner, 1993; Hewitt & Scardamalia,1998; Nickerson, 1993; Torraco, 1999
	▪ possess a sense of individual, as well as joint, responsibility for the achievement of learning goals and have a high regard and respect for other members of the learning community and its resources.	

Characteristics	Features	Supporting Authors & Theorists
Process Characteristics (PCC)	*Students communicate, collaborate and think through:* ▪ a variety of physical resources found within and beyond the classroom environment. ▪ peers, teachers and others beyond the classroom environment. ▪ language systems, diagrams, pictures and other symbols that are representative of the subject matter being studied. ▪ their prior knowledge and range of cognitive, metacognitive and resource management learning strategies.	Brown et al., 1993; Cole & Engeström, 1993; Hatch & Gardner, 1993; Pea, 1993; Pea & Gomez, 1992; Perkins, 1992, 1993; Rogers & Ellis, 1994; Salomon, 1993b

Conclusion

In conclusion, by virtue of its principal position within the framework (see Figure 5.1), *teaching context characteristics* are identified as having paramount importance within a DLE. The fundamental nature of the variables which prevail within this component will directly and indirectly impact upon the course of events within the other components. While some *teaching context characteristics* are fixed institutional features (e.g., curriculum content), most are teacher-controllable and a direct reflection of his or her commitment towards distributed learning.

That is not to say that students do not contribute to the success of a DLE. On the contrary, while an appropriate teaching context is paramount, it must be coupled with appropriate *student characteristics*. Learning within a DLE, while rewarding, is not easy and demands mental effort and involvement on the part of the students. They must be committed to the development of a learning environment that thrives on discourse, collaboration and consultation with a variety of resources. Students are responsible for their own learning and, to a great extent, the learning of others too. This commitment will impact upon the *process characteristics*, that is, the way in which they approach their learning. In a DLE, their approach is oriented towards the social construction of knowledge using physical, social, symbolic and intellectual resources to maximise distributed learning outcomes.

This DLE framework was subsequently used in Parts 2 and 3 of this study as a basis for the exploration of all three research questions. The way in which it was implemented, its relationship to each research question and its fundamental importance to the overall success of the research project, is outlined in the following chapter on methodology.

-6-

Method of Investigation

Chapter overview

The purpose of this chapter is to outline the method of research used in all three parts of this study and to describe the research contexts and procedures of data collection and analysis.

Methodology

As discussed in Chapter 3, the theoretical framework underpinning this study is based on social constructivism. Social constructivists contend that learning is the process of becoming socialised into a particular way of thinking. This occurs through participation within 'communities of practice' (Crook, 1994, p. 38), where cognition is supported by discourse, resources and the cultural rituals associated with the learning environment at hand. Viewed in this way, the classroom is a complex 'cognitive system' (Moore & Rocklin, 1998) where individuals interact with one another and a variety of resources in the pursuit of cognitive activity.

This conception of the classroom as a 'cognitive system' has direct implications for the type of research methodology chosen to explore it. Certainly, the study of isolated elements of cognitive phenomena within a classroom will be quite different to the study of the classroom as a cognitive whole. In support of this contention Salomon (1991) writes, "classrooms ... are complex, often nested conglomerates of interdependent variables, events, perceptions, attitudes, expectations and behaviours, and thus their study cannot be approached in the same way that the study of single events and single variables can" (p. 11).

These assumptions have influenced the methodological direction of this study where the objective was to determine the effectiveness of cognitive tools when implemented within a DLE. Given that the environment was based on the belief that classrooms are 'knowledge building communities' (Hewitt & Scardamalia, 1998), where resources collectively contribute to cognitive activity, the methodology was required to acknowledge the indivisible nature of the classroom in this instance. While the cognitive tool was a focal point of this study, it was acknowledged that its success depended on many other interdependent variables within the learning environment. In relation to this, Salomon et al. (1991) write, "No computer technology in and of itself can be made to affect thinking. One needs to consider both theoretically and practically, the whole social & cultural milieu in which instruction takes place" (p. 3).

Consequently, qualitative methodology was used given that its principles are in tune with a DLE, and capable of capturing and expressing the cognitive activity that emerges. It was also thought that qualitative approaches would be more sensitive to the nuances characteristic of social situations and more likely to provide results that were rich, descriptive and a genuine reflection of the participants' perspectives.

More specifically, the procedures associated with action research were followed given that the problem being investigated was within the social setting of the researcher's own class. As such, the researcher for this study was also the teacher, as well as a mediating resource who facilitated the shared construction of knowledge.

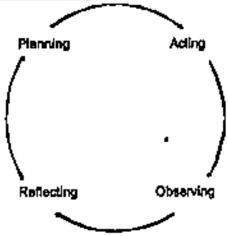
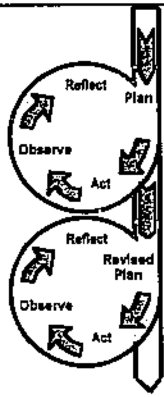
Action research

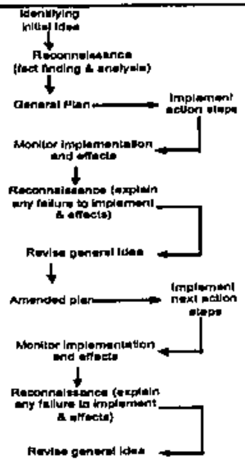
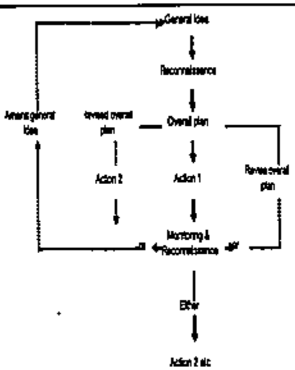
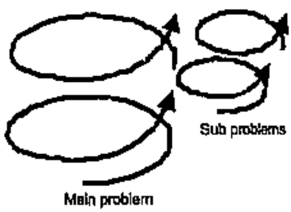
Action research is the study of a social situation with a view to changing or improving the quality of action within it (Elliot, 1982 cited in Winter, 1989). This process can be likened to a type of professional development where the practitioner attempts to learn about aspects of his or her practice. However, according to McTaggart (1994), the findings to emerge from this professional development are not only of value to the practitioner, but may be deemed valuable by other audiences with similar needs and concerns. He writes, "...action research is not merely about learning, [but] ... is about knowledge production and about the improvement of practice [amongst similarly] committed groups" (p. 317).

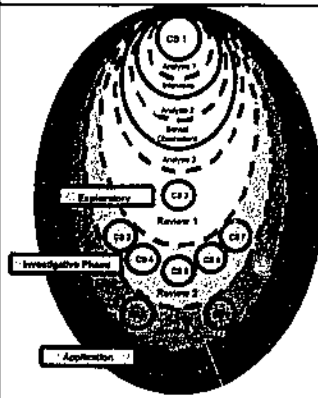
Numerous action research models have been developed during the last 50 years, all of which describe this methodology as a series of repetitive steps involving the implementation of a plan which seeks to improve a particular situation. While some of these models are more elaborate than others, each one describes the research process as a systematic, self-reflective spiral of planning, acting, observing and reflecting. These four stages constitute one step in a study's cycle and are repeated until the situation being monitored has improved, or the desired goals have been achieved. In this way, "'theories' are not validated independently and then applied to practice. They are validated through practice" (Elliott, 1982 cited in Winter, 1989, p. 13).

Due to the development and implementation of these models, much has been learned about the action research process. In particular, the literature describing and supporting their specific features has contributed to the acceptance of this inquiry as a valuable approach to educational research. And while some of these education-specific models have been criticised in the literature, these criticisms have been typically used as the basis for refining and improving action research methodology as a whole. For example, in response to claims that early action research models were generally too prescriptive and controlling (Hopkins, 1985), subsequent models have attempted to embrace the complex, non-linear 'messiness' of most classroom environments (Atkinson, 1994; McNiff, 1994). Table 6.1 provides a visual and descriptive overview of the main action research models that have been proposed to-date, and briefly addresses criticisms that are evident in the literature as well as those that have been noted by the researcher.

Table 6.1 Visual and descriptive overview of action research models, and their criticisms

Author	Model description	Visual overview	Criticisms
Lewin, 1946	A repeating cycle of four main steps - planning, action, observation and reflection.	 (diagram conceputalised by McNiff, 1994)	Not educationally oriented; too prescriptive (Hopkins, 1985).
Kemmis (in Kemmis & McTaggart, 1982)	A self-reflective spiral of planning, acting, observing and reflecting focusing on educational issues and problems.	 (diagram conceputalised by McNiff, 1994)	One-dimensional and rigid. Confusing. Does not acknowledge the multi-faceted and interrelated nature of classroom problems. Does not encourage the need to explain either the educational issue being investigated or the action plan itself (Ebbutt, 1983; McNiff, 1994).

Author	Model description	Visual overview	Criticisms
Elliott (in McNiff, 1994)	A repetitive cycle involving the main steps of: identifying initial idea, reconnaissance (fact finding), implementation of general plan, monitoring effects, reconnaissance (or review).	 (diagram conceptualised by McNiff, 1994)	One-dimensional and rigid. Confusing. Does not acknowledge the multi-faceted and interrelated nature of classroom problems. Does not encourage the need to explain either the educational issue being investigated or the action plan itself (McNiff, 1994).
Ebbutt, 1983	A series of logical steps that loops back to the start. These steps include: general idea, reconnaissance, action plan, monitoring and reconnaissance and either amend general idea or revise overall plan.	 (diagram conceptualised by McNiff, 1994)	One-dimensional and rigid. Confusing. Does not acknowledge the multi-faceted and interrelated nature of classroom problems. Does not encourage the need to explain either the educational issue being investigated or the action plan itself (McNiff, 1994).
McNiff, 1994	A spiral of plan, act, observe and reflect that generates other related spirals and issues. Each stage follows Chomsky's (1965 cited in McNiff, 1994) three levels of observation, description and explanation.	 (McNiff, 1994)	Spiral spin-offs can cause researcher to lose sight of main issue; investigation of multiple spin-off issues could result in loss of rigour and discipline in the research process (Atkinson, 1994).

Author	Model description	Visual overview	Criticisms
Ritchie, 1995	A multi-layered approach to analysis involving a series of reviews in which each past review forms the basis for subsequent ones.	 (Ritchie, 1995)	Acknowledges the fact that the deeper into the investigation the more complex the issue becomes, but does not recognise possible inexplicable occurrences that may not be able to be subsumed into the initial inquiry.

In designing this study, therefore, the strengths and shortcomings of each these action research models were considererl. In doing this, it became evident that a tentative plan was required, rather than a rigid model. The establishment of a tentative plan - one that was strong enough to guide the research process yet flexible enough to adapt to the situation as the researcher learned more about it – was more conducive to the investigation into a complex classroom system. Consequently, the concept map presented in Figure 6.1 was devised.

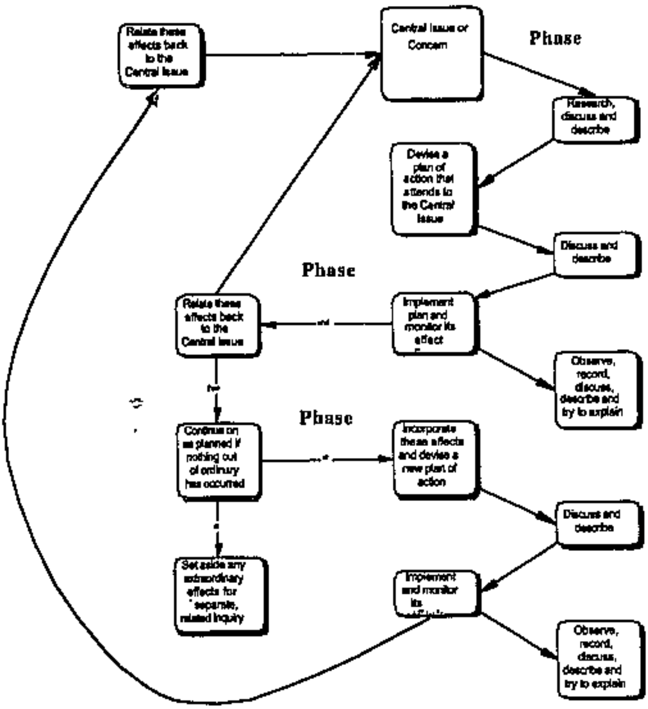


Figure 6.1 Tentative plan of action for this study

This map reflects the integrated relationship between the planning, acting, observing and reflecting phases of the inquiry, as proposed by Lewin (1946), Kemmis (Kemmis & Taggart, 1982), and Elliott (McNiff, 1994). It reflects the need for logic and order, as proposed by Ebbutt (1983) as well as the need to continuously revisit the central issue. It reflects the 'multi-layered' approach proposed by Ritchie (1995) in the sense that with every new cycle, the outcomes of previous ones are used to inform new insights, claims and plans. And above all, it reflects Chomsky's three levels of adequacy (observation, description and explanation) which, according to McNiff (1994), moves the inquiry towards an authentic resolution of the problem.

This map was integral to the entire research design in that its three primary phases and cycles formed the foundation upon which the three parts of the study emerged. Figure 6.2 provides an overview of this design and acts as an advanced organiser to the methodological discussion on each part that follows.

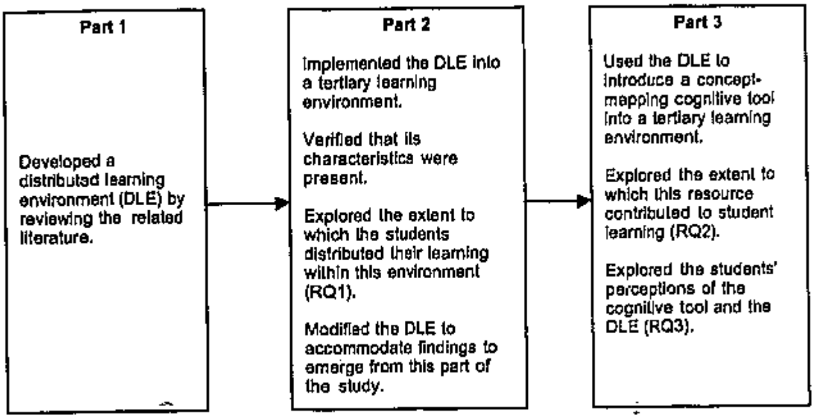


Figure 6.2 Overview of research design

Part 1: The identification of a DLE framework

As was discussed in detail in Chapter 5, the literature was extensively reviewed in an effort to develop a DLE framework. Initially, this framework was comprised of a list of features associated with the practicalities of distributing cognition in the classroom. However, upon closer examination it was possible to separate this list into categories common to most teaching contexts (*teaching context characteristics, student characteristics* and *process characteristics*).

Miles and Hubefman (1994) liken this process of identifying key categories to the development of a conceptual framework, which ultimately serves to 'focus and bound' the study. As the conceptual framework unfolds, so too does the researcher's grasp of the investigation's defining characteristics and the relationships between them. While these categories can emerge from the literature, often they are predetermined and/or based on the researcher's own experiences or commonsense knowledge.

Part 2: Implementation of the DLE framework

The DLE framework was subsequently introduced into a fourth year tertiary education unit in an attempt to determine the extent to which the students distributed their cognition when learning within this type of setting. Before this could be satisfactorily established however, it was necessary to ensure that the framework had actually been implemented and that all its characteristics and features had been attended to. A verification process was subsequently embarked upon to ensure that all features evident in the *teaching context characteristics*, were also evident in the classroom.

This verification process was essentially a 'quality control' measure to ensure that reasonable care had been taken when conducting the research and that the conclusions drawn would be dependable and trustworthy. Given that conscientious implementation of plans and procedures does not in itself lead to sound conclusions, this care must also be accompanied by methods of quality control whereby the credibility of these plans and procedures are scrutinised, judged and amended if necessary (Marshall & Rossman, 1989; Merriam, 1998; Miles & Huberman, 1994). The details of this verification/quality control process are specified in Chapter 7.

Satisfied that the framework was running effectively, eight students were closely observed to determine the extent to which they distributed their cognition within this environment. Because the introduction of the DLE framework required re-modification of the entire teaching context, all students enrolled in the unit were implicated in its implementation, yet only eight students provided supporting data. During the first week of the semester, the class was given a brief description of the background and aims of the study as well as a consent form calling for volunteers to contribute data by way of interviews, journals and videotaped class activities. From the ten students who volunteered, eight were randomly selected from the class list forming two groups of four students who provided supporting data as the framework was implemented over the course of the semester.

The following account provides an overview of the context within which this part of the study took place along with a description of the design of the study, and the way in which it was conducted.

The Research Context

- The teacher

The study was conducted in a fourth year tertiary education class. In keeping with the principles of action-research, the researcher, who was also the teacher, participated in the development of the study's findings. According to Patton's (1990) continua for thinking about one's role during the conduct of research, the researcher in this study was a 'full participant observer' (see Figure 6.3).

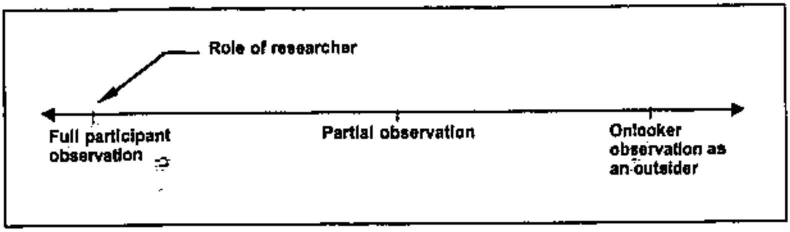


Figure 6.3 Role of the evaluator-observer (Patton, 1990)

Patton (1990) also uses a continuum to describe the role of the researcher as perceived by the participants (see Figure 6.4). In this instance, the participants were fully aware that observations were being made, why they were being made and who was making them.

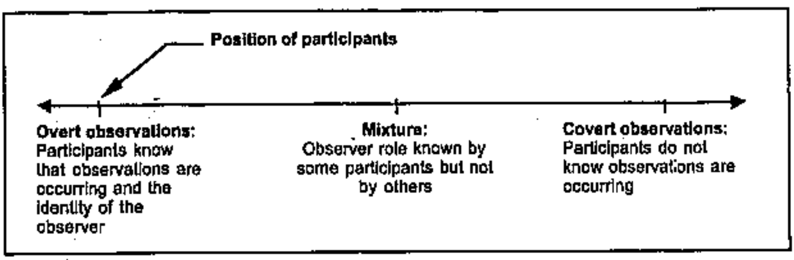


Figure 6.4 Portrayal of the observer's role, and the purpose of the study, to others (Patton, 1990)

- The students and participating students

There were a mixture of part-time and full-time students enrolled in the unit. Most had either an early childhood, primary or secondary teaching background although one student was from another discipline. Out of the 25 enrolled students, 13 of them were teaching full-time, with a large percentage of the remaining 12 performing relief-teaching duties. The participating students' reasons for enrolling in this unit, and their expectations of it, varied. Some simply wanted to pass as a requisite for gaining their degree. Most wanted to gain useful, practical knowledge that could be applied in their own classrooms, whereas others wanted to gain a better understanding of the learning process itself. The demographic make-up of the eight participating students is presented in Table 6.2.

Table 6.2 Demographic make-up of participants in Part 2 of the study

Participant	Gender	Approx Age	Teaching Status	Discipline and teaching level	Study Status
Andy	Male	25-30	Not teaching	Multimedia Interdiscipline	Full-time
Dick	Male	40-45	Not teaching	Science High school	Full-time
Fran	Female	40-45	Full-time	Music Primary	Part-time
Gill	Male	40-45	Relief duties	Business High school	Full-time
Kay	Female	25-30	Full-time	Physical Ed High school	Part-time
Linda	Female	30-35	Full-time	History High school	Part-time
Rea	Female	25-30	Relief duties	Music Primary	Full-time
Viv	Female	25-30	Full-time	ESL Primary	Part-time

- The unit

This fourth year unit was offered as part of the Teaching and Learning program within the Bachelor of Education course. It ran once a week for a three-hour period and during an evening time-slot. The unit itself was designed to introduce students to current theory and research about cognitive learning. Concepts such as *conceptions of learning, learning strategies, approaches to learning* and *information processing* were developed to promote the notion that learning for understanding is more effective than learning for the acquisition of knowledge. Students were encouraged to apply these concepts to their own learning in the belief that this more meaningful application would provide better insight into how others, namely their prospective students, learn.

The objectives, as they were defined in the unit outline, are as follows:

On the completion of this unit, you should be able to demonstrate a sound understanding of:

- the constructivist perspective on learning and teaching, and the information processing model of learning.
- the nature of learning strategies and their place in the learning process.
- the various approaches to learning typically adopted by students, and the reasons why they adopt particular approaches.
- issues and processes involved in teaching learning strategies to students.

For management purposes, content within this unit was divided into five modules. Concepts within these modules however, are inextricably linked, and a deep understanding of these concepts required these links to be identified. For example, approaches to learning are defined by the motivation students have to learn and the subsequent strategies they adopt to do so. Examination of students' motivations to learn reveals clues as to their conceptions of learning as well as the types of learning strategies they do and do not use. In an effort to modify a student's approach to learning therefore, it would also be necessary to modify his or her conception of learning and encourage the development of a large repertoire of learning strategies. These sorts of relationships needed to be recognised if students were to fully appreciate the complexity of the concepts and achieve unit objectives.

In keeping with the principles of the DLE framework, collaborative group work and whole class discussions constituted the primary pedagogical approach to learning, with the teacher assuming the role of facilitator rather than transmitter of knowledge. The students were encouraged to vary their seating throughout the semester in an attempt to listen and learn from a range of different perspectives. During data collection weeks however, the eight participating students were clustered together in two groups of four, although the make-up of these groups changed across these three weeks.

Assessment for the unit consisted of one assignment and one (open-book) end-of-semester examination. Because the assignment was heavily weighted (60% of final mark), students were encouraged to submit a partial draft for preliminary feedback prior to final submission.

Procedure

The DLE framework was implemented at the beginning of the semester but data collection did not begin until Week 6. This delay gave students time to become familiarised with the nature of a DLE and the routines it promoted. There were three data collection sessions in total, the first during Week 6, the second in Week 8 and the third in Week 10. Topic-modules were typically covered over a two-week period where students would carry out basic knowledge building activities in the first week and then more complex concept linking activities in the second week. Weeks 6, 8 and 10 fell on the second week of the topic-module being covered at the time and it was expected that students would be more comfortable with the subject matter and the language used to describe it.

As illustrated in the data collection matrix (Table 6.3), there were three data collection sessions within which three data collection methods were used. The first method was video and audio-recording students as they worked on activities within the classroom. While the whole lesson was recorded, only the collaborations that occurred during the three concept-development activities were transcribed and used as data. In the week that followed each of the recorded class activities, each student in the two groups was individually interviewed by the researcher. These interviews lasted for approximately 45 minutes. Furthermore, the entries that had been made in the student journals up to the point of each data collection session were collected, photocopied and transcribed.

Table 6.3 Data collection matrix for Part 2 of the study

	Group A	Group B
Data collection session 1	3 Class Activities	3 Class Activities
	4 Interviews	4 Interviews
	4 Journals	4 Journals
Data collection session 2	3 Class Activities	3 Class Activities
	4 Interviews	4 Interviews
	4 Journals	4 Journals
Data collection session 3	3 Class Activities	3 Class Activities
	4 Interviews	4 Interviews
	4 Journals	4 Journals

These three sources of data were initially pursued for triangulation purposes, in the event that findings emerging from one data source could be corroborated and perhaps illuminated by another data source (Rossman & Wilson, 1985). Patton (1990) concurs with this view and writes, "By using a variety of sources ... the evaluator-observer can build on the strengths of each type of data collection while minimizing the weaknesses of any single approach" (p. 245).

While this was undoubtedly a necessary facet of this (and indeed any) research, the real benefit of collecting data from multiple sources grew apparent as each of the three were accessed. In keeping with Mathison's (1988, cited in Merriam, 1998) assertion that triangulation allows for deeper, more 'holistic understandings' of the research, the video recordings, interviews and student journals provided the researcher with a greater insight into the nature of distributed learning across a *spectrum* of perspectives. The video recordings, for example, provided a group perspective of the distribution of cognition. The interviews provided an individual perspective that was (arguably) adjusted for the researcher's benefit, whereas the student journals provided the students' undiluted, private perspectives.

- Class Activities

Given that the researcher was also the lecturer for this unit, she could not part-take in the collection of data during the class activities. Therefore, in an attempt to preserve the familiar teaching and learning routines which had been established in the preceding weeks, it was necessary to hire a research assistant to work the equipment during the data collection sessions. Prior to the first recording session, this person was shown how to arrange the desks, video cameras and audio recording equipment. The video cameras were placed close enough to the desk clusters for conversations to be audible, but at a distance that would reduce possible anxiety in the students. For back-up purposes, one audio recorder was placed in the middle of each desk cluster. Figure 6.5 illustrates the physical arrangement of the classroom and the positioning of the recording equipment. The two groups of participating students are shaded in grey.

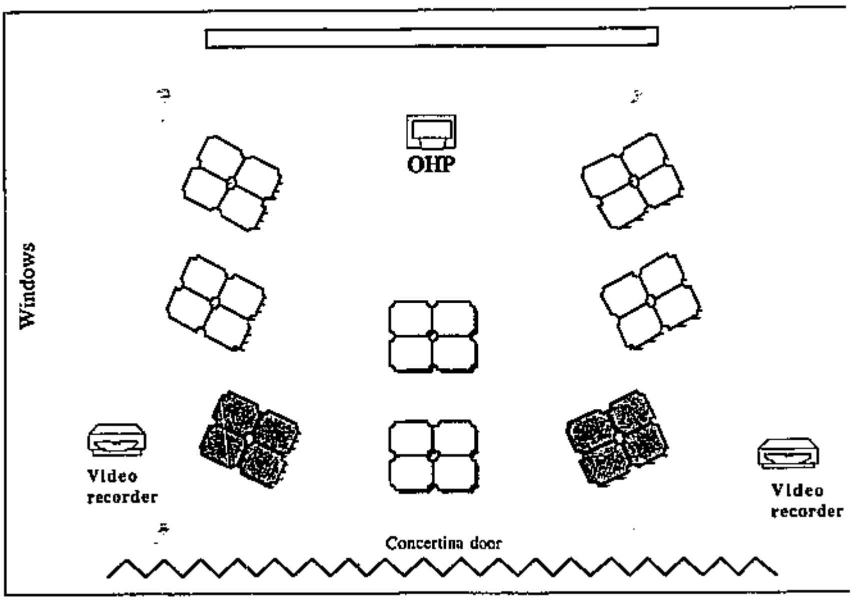


Figure 6.5 Physical arrangement of classroom and location of recording equipment to participating students for Part 2 of the study

The research assistant was also advised about the discrete role he should play in the classroom, which was reinforced by the set of guidelines (refer to Appendix A) given to him at the beginning of each session. This person's presence was explained to the students and they were advised to ignore him and the recording equipment as much as possible. While all students were encouraged to work as they normally would, the participants also received a set of guidelines (refer to Appendix B) reminding them to speak clearly and freely within their groups.

The entire three-hour lesson (minus break) was recorded during each of the three data collection sessions, even though only three concept-development activities (which ran for approximately 40 minutes each) were transcribed. The design of these concept-development activities, along with other facets of the learning environment, were influenced by the characteristics of the DLE framework in that the students were encouraged to construct joint understandings through collaboration, the employment of learning strategies and use of resources.

- Interviews

Interviews were conducted during the week following the class activity recordings. The interview schedule was semi-structured in that it was designed to obtain specific information but in a flexible and adaptable way. While the focus questions were drawn from the DLE framework, their wording was often changed to accommodate the module being studied at the time, as well as the participating students' personal experiences in the classroom. Therefore, apart from a few general (GEN) questions (which were necessary for orienting the students' thoughts), the principal interview schedule for Part 2 aimed to determine:

- the implementation of the teaching context characteristics (TCC)
- the nature of the student characteristics (SC)
- the extent to which students accessed resources when completing activities (PROC)

The codes GEN, TCC, SC and PROC are evident in the interview schedule (presented in Appendix C) to indicate the nature of each question. Assuming that the students' use of social, physical, symbolic and intellectual resources would provide the most valuable insight into the extent to which learning was distributed in the classroom environment, there were a greater percentage of process focus questions (PROC) in comparison to the others. Table 6.4 provides examples of process questions, and their rationale, which have been taken from the interview schedule:

Table 6.4 Examples of process (PROC) questions for Part 2 of the study

Question (PROC)	Rationale
What sort of things did you do in class to learn these things? What resources did you use within the classroom to help you learn these concepts? Why did you use these resources in particular? Were there resources that you would like to have used, but for some reason didn't? Explain.	Get students to focus on process of learning and types of resources accessed.

Furthermore, the interview schedule was devised in consultation with Patton's (1990) classification of question types (see Table 6.5) in an effort to elicit a range of different sorts of responses from the students. Quite often, the same question was asked in a variety of ways (in accordance with Patton's classification scheme), in the hope that the students' responses would be elaborated upon, clarified and consequently strengthened. As can be seen in Appendix C, the focus questions in the principal interview schedule have been classified according to these question types.

All 24 interviews were audio tape-recorded and fully transcribed.

Table 6.5 Question types (Patton, 1990)

	Question Type	Description
1	Experience/Behaviour	Questions aimed at eliciting descriptions of experiences, behaviours, actions and activities in relation to what the person does, or has done.
2	Opinion/Value	Questions aimed at understanding what the person thinks about a particular issue.
3	Feeling	Questions aimed at understanding the emotional responses of a person to his/her experiences and thoughts.
4	Knowledge	Questions aimed at finding out factual information regarding an issue, as opposed to feelings or opinions about this issue.
5	Sensory	Questions aimed at finding out what the person saw, heard, touched, tasted and smelled.
6	Background/Demographic	Questions aimed at finding out the identifying characteristics of the person being interviewed.

- Journals

Throughout the semester, students also kept journals in which they were encouraged to reflect on their learning experiences in the unit. The purpose of the journal, and the way in which it should be used, was outlined in the first class and then reinforced in each class thereafter. For example, students were encouraged to use their journals as opportunities to reflect upon and develop their understandings about concepts and various issues relating to the coursework, rather than using it as a personal diary. While students were given opportunities to write in their journals during class time, it was expected that reflections would also be made during private study time as a means of working through cognitive conflicts, or simply to articulate emerging understandings. The students' journals were collected during each data collection session, copied and fully transcribed.

Shortcomings of data collection methods during Part 2

- Class activities

Even though steps were taken to minimise the obtrusive nature of the video recording equipment, the researcher sensed that its presence made both the participants and the other students in the class uncomfortable. While this sense of discomfort seemed to ease with each passing recording session, the researcher felt that for future recording sessions, the video recorders should not be present. In any case, due to the ease with which the audio-recordings could be manipulated, most of the transcriptions were made from the audio-cassette tapes. The video recordings were only accessed during the first set of transcriptions when some words on the audio-cassettes were inaudible.

- Interviews

Transcriptions for the first data recording session were difficult due to the fact that the researcher relied on the microphone built into the recording equipment. Because there were no back-up recorders at the time, some transcriptions were incomplete due to inaudible words and phrases. As such, more sensitive desk microphones were used in subsequent recording sessions which alleviated this problem.

To ensure that the students answered the questions in relation to their classroom experiences, the researcher would have liked to interview them directly following each lesson. This was impractical, however, due to the late finishing time of the class. Also, due to their teaching commitments, it was not possible to interview some students up to five days after the class. Although the researcher revised the concepts at the beginning of the interview, it is believed that the students' recollections of their learning experiences would have been sharper closer to the lesson. This situation was unavoidable however.

- Journals

Most students used their journals effectively and made regular reflections about their experiences with the coursework. Despite the teacher's guidance, however, some journals were still accessed as 'dumping grounds' for personal feelings about various issues. While some of these recordings were in relation to the unit, they were more personally oriented and often focussed on students' grievances about having to do too much work in too little time. Other inadequate journals consisted of those that had too few recordings. To ensure that this would not happen in Part 3 of the study, photocopies of 'good' and 'not so good' journals were taken (with permission) and circulated as anonymous examples of effective and ineffective self-reflections.

These data collection shortcomings were not serious enough to impede the study's progress during Part 2 and, where possible, were resolved prior to the investigations carried out during Part 3. On the whole, the class activity transcripts, interview transcripts and student journal transcripts provided sufficient information upon which modifications to the DLE framework could be made as well as inform the first research question.

Part 3: Introduction of a computerised cognitive tool into the classroom using the DLE framework

The DLE framework, which was modified in accordance with Part 2 of the study, was subsequently used as a catalyst to introduce a computerised concept-mapping cognitive tool known as *Inspiration®* into the subsequent semester of the same education unit. Students were familiarised with the principles of distributed cognition at the beginning of the unit, and were also taught how to develop concept-maps using the cognitive tool. Initial instruction was deemed important in light of the 'fingertip effect' (presented in Chapter 4), and Ferry, Hedberg and Harper's (1998) observations that concept-mapping skills do not automatically develop as a consequence of simply using the tool.

Throughout the unit, students worked in collaborative groups of three (and one group of four) around the computer. Four of these groups were observed to assess the effects the cognitive tool had on their learning. The investigative procedure constitutes the remainder of the chapter.

The Research Context

- The teacher and the students

Apart from the demographic make-up of a different group of students and the introduction of the computer as a cognitive tool into the learning environment, the research context for Part 3 of this study was largely the same as it was for Part 2. For example, the teacher continued her dual role of being both researcher and teacher.

Once again, there was a mixture of part-time and full-time students with either early childhood, primary or secondary teaching backgrounds. Out of the 28 enrolled students, 12 of them were teaching full-time with a large percentage of the remaining 16 performing relief-teaching duties. Ten of the students were enrolled in the Bachelor of Music Education course and the rest were general Bachelor of Education students with varying majors. The significant number of music education students is believed to be due to timetabling constraints. It appears the unit was one of two compulsory Education units that fitted in with other course commitments.

- The participating students

Because the students were going to be working in groups for the duration of the entire unit, they were given the option of being assigned groups by the teacher, or forming groups themselves. The majority of students chose to sort themselves into groups, the remainder of which were happy to be grouped by the teacher. Consequently, there were a total of nine groups of three students, and one group of four. After being briefed about the study, its aims and objectives, these groups were asked to participate by being observed and interviewed throughout the semester. Three groups volunteered, one of which was the grouping of four. In keeping with Hurwitz and Abegg's (1999) observations that three students to one computer is the most effective arrangement, another grouping of three was approached and again asked to volunteer. This group agreed, making the sample a total of 13 students, or three groups of three students and one group of four. The specific demographic make-up of these participating students is presented in Table 6.6.

Table 6.6 Demographic make-up of participants in Part 3 of the study

Participant	Gender	Approx Age	Teaching Status	Discipline and teaching level	Study Status
Bree	Female	20-25	Not teaching	Music Primary	Full-time
Bronte	Female	35-40	Relief duties	ESL Primary	Full-time
Deb	Female	25-30	Full-time	Economics High school	Part-time
Jess	Female	20-25	Not teaching	Music Primary	Full-time
Mary	Female	20-25	Not teaching	Music Primary	Full-time
Nat	Female	25-30	Relief duties	General Primary	Full-time
Pablo	Male	25-30	Relief duties	Language Arts High school	Part-time
Sally	Female	35-40	Full-time	Art Primary	Part-time
Sean	Male	20-25	Not teaching	Music Primary	Full-time
Susie	Female	20-25	Not teaching	Music High school	Full-time
Tom	Male	25-30	Relief duties	Drama Primary	Full-time
Una	Female	20-25	Not teaching	Music Primary	Full-time
Wanda	Female	45-50	Full-time	General Primary	Part-time

- The unit

The unit objectives for Part 3 of this study were the same as those outlined in Part 2. For management purposes, the coursework was once again divided into five modules, and students were required to identify and understand the inextricable links between the concepts that constituted these modules. In keeping with the principles of the DLE framework, collaborative group work was the primary pedagogical approach to teaching and learning. However, in contrast to the previous semester, these collaborations were centred around computers. For this reason, the entire unit took place in a computer laboratory where all activities were completed with the assistance of *Inspiration®*, a computerised concept-mapping tool.

Hurwitz and Abegg (1999) contend that the physical location of computers has a great impact on their use as both a learning and assessment tool. The chances of engaging students in learning opportunities with the computer are better when they are located in the classroom as opposed to being located in an external laboratory. In this instance, having the cognitive tools present at all times was paramount if they were to be viewed by the students as partners in their learning.

Concept-mapping software was chosen for its ability to facilitate students' explorations of the interrelationships between concepts and modules. More specifically, *Inspiration®* was chosen for its compliance with criteria defining effective cognitive tools, the characteristics of which were described in detail in Chapter 2 (refer to Anderson-Inman & Zeitz, 1993 in Table 2.2). Given that most of the students were first-time users of *Inspiration®*, basic instruction was provided from the first class onwards along with opportunities for unstructured use. Additionally, the third week was devoted to an *Inspiration®* workshop, where a more in-depth, structured exploration of the software was made. Each class thereafter was based on collaborative group work and whole class discussions, the understandings from which were built into a series of concept-maps that each group created for the five modules that made up the unit. Examples of the types of tasks used to facilitate this endeavour are available in the Lesson Plan presented in Appendix D.

Assessment for the unit consisted of three cumulative assignments (computer generated concept-maps) with each one contributing to the development of a student-portfolio. The students were also required to write a paper, the concepts within which were represented diagrammatically by an accompanying concept-map. The contents of this portfolio were formally assessed at varying times throughout the semester, the combined marks constituting the students' final scores.

- The classroom

As mentioned, the unit took place in a computer laboratory as opposed to a traditional tutorial room. There were at least 20 computers in this laboratory, placed around three sides of the room (approximately eight along the sides and four down the back). To avoid overcrowding, each group worked at every second computer. Whole class discussions (that did not involve the computers) often took place at a large common desk in the middle of the room. At the front of the class was a whiteboard, overhead projector, display screen and demonstration computer. Figure 6.6 illustrates the physical layout of the classroom. The participating students' computers are shaded in grey.

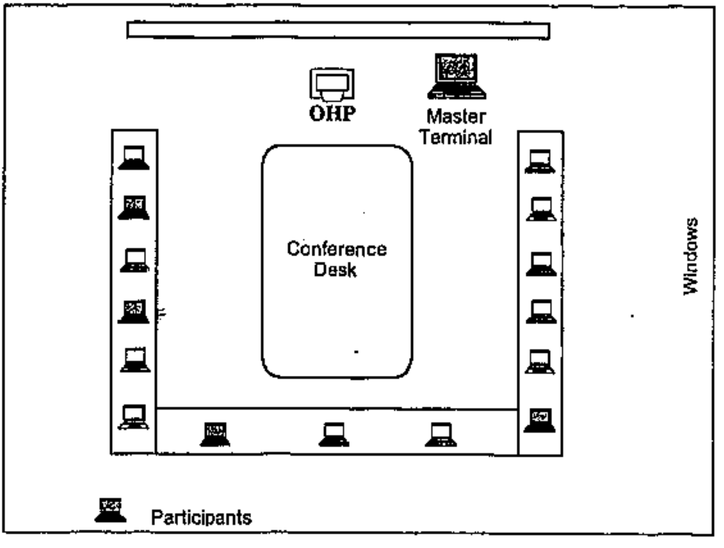


Figure 6.6 Physical arrangement of classroom for Part 3 of the study

Procedure

To give the students time to become familiar with their environment and *Inspiration®*, data collection did not begin until Week 7. The two subsequent data collection sessions occurred in Weeks 9 and 13. Once again, these data recording sessions occurred on the second week of the topic-module being studied, on the basis that students would be more comfortable with the language which defined it. The following matrix in Table 6.7 illustrates the types of data gathered for each group over the three data collection sessions:

Table 6.7 Data Collection Matrix for Part 3 of the study

	Group A	Group B	Group C	Group D
Data collection session 1	3 Class Activities	3 Class Activities	3 Class Activities	3 Class Activities
	3 Interviews	3 Interviews	3 Interviews	4 Interviews
	3 Journals	3 Journals	3 Journals	4 Journals
Data collection session 2	3 Class Activities	3 Class Activities	3 Class Activities	3 Class Activities
	3 Interviews	3 Interviews	3 Interviews	4 Interviews
	Journals	Journals	Journals	Journals
Data collection session 3	3 Class Activities	3 Class Activities	3 Class Activities	3 Class Activities
	3 Interviews	3 Interviews	3 Interviews	4 Interviews
	3 Journals	3 Journals	3 Journals	4 Journals

As indicated in this matrix, three data collection methods were used for each of the three data collection sessions. The first method was audio-tape recording students as they worked on activities within the classroom. While the whole lesson was recorded, only the collaborations that occurred during the three concept-development activities were subsequently transcribed and used as data.

Based on the problems identified during the data collection phase of Part 2, video cameras were not used. Instead, audio-tape recorders with sensitive desk microphones were placed beside the computer for each of the four participating groups. Ninety minute tapes were used which meant that recording could commence at the start of the class and finish at the 15 minute break, during which time tapes would be changed over ready to begin again for the second half of the lesson. This meant that the researcher could work the equipment herself, mitigating the need for a research assistant. The researcher's supervisor, however, did attend the beginning of each class to ensure that all the equipment was working successfully. There were a total of 12 class activity transcripts.

Although not the sole source of data, these class activity transcripts were the primary focus for analysis. In an effort to determine the extent to which the cognitive tool contributed to effective learning, it was necessary to assess the quality of the learning to emerge within the learning environment. In keeping with the principles of a DLE, this was done by examining the shared understandings that were socially constructed within the group collaborations. Therefore, while data was collected via the student interviews and journals, the dialogue that emerged during the class activities provided the most effective insight into the development of shared understandings. Consequently, the interview and student journal data were primarily used to inform the third and final research question which aimed to uncover the students' experiences of using the cognitive tool in a DLE.

The interviews were undertaken in similar method to those in Part 2 in that they were conducted following each class activity recording, they were semi-structured and the questions were developed based on Patton's (1990) classification of interview questions (refer to Table 6.5). They differed slightly however, in that the primary objective was to evoke responses regarding the *students' perceptions* of the extent to which the cognitive tool fostered effective learning within their learning environment. Consequently, many questions were based on the students' experiences with the software as a learning tool within the classroom. Each interview lasted approximately 45 minutes and was later fully transcribed. The principal interview schedule for Part 3 of the study is presented in Appendix E. Some examples of these questions, and their rationale, are provided in Table 6.8.

Table 6.8 Examples of interview questions for Part 3 of the study

Questions	Rationale
What are your thoughts on using *Inspiration®* as a resource to help you learn the unit material?	Determine the student's feelings about using the computer as a learning tool.
Looking at your concept-map, can you give me an overview of its meaning? If a friend asked you to explain to him/her what this map was about, what would you say?	Determine the type of learning that has emerged from using the cognitive tool.

If you had to highlight a particular component or aspect of this map in terms of its importance to learning, what would it be? Why?	
Can you describe the actions taken by your group to create this map?	Determine the extent to which the student has participated in DLE processes to learn.

Validity and reliability

Guba (1996) asserts that in human inquiry, it is not feasible to use conventional research rules such as reliability, validity, objectivity and generalisability. While these criteria are useful when measuring concrete, tangible concepts they are less useful in a study such as this where the focus is on intangible, social constructions of knowledge. Wolcott (cited in Creswell, 1998) concurs with this and contends that the traditional notion of validity and reliability actually detracts from the process of trying to construct plausible interpretations of social inquiry.

Nevertheless, action research projects should not be excused when it comes to establishing validity and reliability. To provide teachers and researchers with a sense of confidence that the outcomes of an inquiry are trustworthy, the researcher must show that the study has been carried out systematically and rigorously. In relation to educational research, Merriam (1998) writes, "To have any effect on either the practice or the theory of education, these studies must be rigorously conducted; they need to present insights and conclusions that ring true to readers, educators and other researchers" (p. 199). Consequently, strategies that advance this rigour must be operationalised throughout *all* stages of the action research project if findings are to be seen as credible and accurate.

The strategies used in this study were drawn from the literature supporting qualitative methodology, and are described in Table 6.9. While the actual terms for validity and reliability differ, multiple authors have described similar supporting strategies, thus strengthening their ability to defend the study's credibility.

Table 6.9 Varying terms of reliability and validity and their supporting strategies

Terms	Description	Strategies
Internal validity (Lecompte & Goetz, 1982; Merriam, 1998) **Credibility** (Lincoln & Guba, 1985) **Structural corroboration** (Eisner, 1991)	The extent to which the findings of the study are congruent with reality, that is, the context from which they first emerged.	Triangulation: using multiple sources and methods to provide corroborating evidence that confirms the emerging findings (Eisner, 1991; Lincoln & Guba, 1985; Merriam, 1998; Miles & Huberman, 1994). Long-term observation: gathering data over a long period of time in an effort to build trust with participants and access relevant data (Lincoln & Guba, 1985; Merriam, 1998). External review: asking colleagues to comment on the findings as they emerge (Lincoln & Guba, 1985; Merriam, 1998). Researcher biases: clarifying the researcher's assumptions, beliefs and theoretical philosophies at the beginning of the study (Merriam, 1998).
Internal and external reliability (LeCompte & Goetz, 1982; Merriam, 1998) **Dependability** (Lincoln & Guba, 1985)	The extent to which the results make sense and are consistent with the data collected, and the extent to which the study can be replicated by an independent researcher.	Triangulation: as above Investigator's position (researcher status): Fully outlining assumptions and theory behind the study as a basis for selecting participants and the social context from which the data were collected, including social relationship of researcher to participants (LeCompte & Goetz, 1982; Lincoln & Priessle cited in Merriam, 1998). Rich, thick description: making the process transparent by describing, in detail, the researcher, the participants, the context, data collection and analysis (Goetz & LeCompte, 1984; Lomax, 1994; Lincoln & Guba, 1985). Interrater reliability (check coding): Based on detailed descriptions of analysis, independent researchers code sections of the data to determine the extent to which they all agree on category meanings and data meanings. Peer examination: publicising results (e.g., in conference proceedings etc) for peer review and comment (LeCompte & Goetz, 1982).

Terms	Description	Strategies
External Validity (Lecompte & Goetz, 1982; Merriam, 1998) **Applicability** (Lomax, 1994) **Transferability** (Lincoln & Guba, 1985)	The extent to which the findings of one study can be applied to other similar situations. Through the detailed description of the procedure and the outcomes, others judge whether the research is relevant to their situation.	Rich, thick description: as above
Neutrality (Patton, 1990) **Confirmability** (Lincoln & Guba, 1985) **Impartiality and Intrinsic adequacy** (Guba, 1977)	The extent to which the researcher reports the situation 'as it happened'. That is, the extent to which mutual meanings exist between the researcher's interpretations and the participants' perceptions of the phenomena being studied.	Triangulation: as above. External reviews: as above Researcher biases: as above Asking contrast questions: Repeating questions during interviews to participants who are unsure about their meaning and objective. Paraphrasing responses in interviews to provide participants with opportunities to comment on their accuracy (Spelzman, cited in Guba, 1977).

Ethical considerations

In order to protect the rights of all participating students, and to ensure that the research was conducted in a fair and proper way, the Guidelines issued by the University's Ethical Committee were strictly adhered to. In following these Guidelines, a safeguard was implemented to ensure that the students were free from risk throughout the entire study. This safeguard was present in all facets of the study, but was primarily visible to the students themselves by way of an informed consent form. A copy of the consent forms signed by the students in Parts 2 and 3 of the study are presented in Appendices F and G).

Even though only a small percentage of each class contributed data for the study, the entire class participated in the implementation of the DLE framework and the computerised cognitive tool. It was necessary, therefore, to inform all students about the study, its background, aims and methods. This was done by way of discussion, and the provision of literature at the commencement of each semester. However, only those who subsequently volunteered to contribute data were asked to sign the informed consent forms. This form reiterated the aims of the study and also outlined the role of the participating students in terms of the ways in which they would be required to contribute data.

It was also made clear in this form, as well as at the beginning of each data recording session, that participating students were free to withdraw from the study at any time without penalty or sense of responsibility to the researcher and the completion of the study. This 'right to refuse' also extended to a) the interviews where students could decline to answer a question or questions, and b) the journals where students could refuse to submit a section or sections if they so wished.

Anonymity was assured through the use of pseudonyms for the duration of the study. While the participating students were aware that they would be given pseudonyms, they were not told what their pseudonym would be. Access to the data, both in its raw form and as a transcript, was confined to the researcher. Although a research assistant was employed for Part 2 of the study, all tapes were handed over to the researcher at the completion of each data recording session to be stored securely with the other data. Another individual was employed to assist with the transcriptions but, once again, all materials were stored safely when they were in her possession and when they had been returned to the researcher.

In addition to these general guidelines, ethical considerations specific to action research were also observed. In attempting to offset threats to the ethics of action research projects, Zeni (1998) proposes a set of provocative questions that encourage researchers to view their study with a sense of objectivity and impartiality. For example:

> Which of the research participants (and pertinent others) at your school have read your proposal?
>
> What do your students know of this project?
>
> What are the likely consequences of this research? How well do they fit with your own values and priorities?
>
> If you were a participant, would you want this research to be done? What changes might you want to make you feel comfortable?

These and other questions were adapted to fit the aims and objectives of this study and were consistently addressed by the researcher as a reminder that although the study arose from an issue specific to her own classroom, the findings could affect others involved.

Data analysis

As indicated by Tesch (cited in Creswell, 1994, p. 153), the process of data analysis in qualitative research is eclectic and there is no 'right way' to proceed. Nevertheless, this does not mean that there are no guidelines to follow and, indeed, the credibility of a study is strengthened if the researcher applies consistent and rigorous steps of analysis. As such, analysis was primarily an inductive process and the data for this study were explored using a systematic process based on the principles of Miles and Huberman's (1994) three-step process of data reduction, data display and conclusion drawing as well as Glaser and Strauss' (cited in Lincoln & Guba, 1985) constant comparative method.

Table 6.10 illustrates the nature by which these models informed the data analysis procedures for Parts 2 and 3 of the study, even though a different analysis tool was used to interpret the data for each separate investigation. For example, the analysis tool used in Part 2 (RQ1) was primarily drawn from the *process characteristics* component of the DLE framework, whereas the analysis tool for Part 3 (RQ2) was derived from models in the literature that describe varying levels and forms of conceptual growth. These analysis tools are described in greater detail in their respective chapters. A qualitative data analysis program known as Non-numerical Unstructured Data Indexing Searching and Theorising (NUD_IST) was used in both parts to organise and code the data.

Table 6.10 Fundamental data analysis procedure for Parts 2 and 3 of the study

Miles & Huberman (1994)	Glaser & Strauss (cited in Lincoln & Guba, 1985)	Data Analysis procedure
		Transcribing: Class activities, student interviews and student journals for all recording sessions were transcribed using Word, then imported into NUD•IST.
Data reduction: Transcripts are read to determine relevant data and superfluous data. Those that are not relevant are discarded. Condensing the data in this way requires preliminary sorting and organising thus sharpening the focus on possible themes and ideas.	**Comparing incidents applicable to each category:** Incidents (or units of meaning) are assigned to preliminary categories which have been derived on either a 'feels right', intuitive basis or drawn from the literature. Incidents are compared and contrasted to other incidents in the same and different groups, thus stimulating "thought [which] leads to both descriptive and explanatory categories" (Lincoln & Guba, 1985, p. 341).	**Preliminary Coding:** Transcripts were repeatedly read to gain an appreciation of the meaning attached to the participants' responses. Information not relevant to the study was deleted from all transcripts to refine the focus. Using NUDIST, units of meaning were coded by comparing and contrasting them to other units of meaning across all relevant data sources. The classification of these units of meaning was based on a combination of ideas that came from the data, related literature and the study's theoretical framework.
Data display: Data is organised, compressed and displayed in a form that permits conclusion drawing and action. "... [M]atrices, graphs, charts, and networks ... are designed to assemble organised information into an immediately accessible, compact form so that the analyst can see what is happening and either draw justified conclusions or move on to the next step ..." (Miles & Huberman,	**Integrating categories and their properties:** Incidents are judged according to the properties which define the categories. Coding, therefore, is more rule-based and less intuitive. This process also tests the properties of the categories in that disparate incidents encourage the researcher to either develop sub-categories, or redefine the primary category.	**Rigorous coding:** Having defined the preliminary categories, they were arranged on a table, against which supporting data was sorted. This tabular display of the categories and the data gave the researcher an intelligible overview of the nature of each category, thus making coding more fluid and rigorous. Participant responses that could not be assigned to any one category were placed in a 'miscellaneous' category for closer examination.

Miles & Huberman (1994)	Glaser & Strauss (cited in Lincoln & Guba, 1985)	Data Analysis procedure
1994, p. 11).	**Delimiting the theory:** As coding nears the end, the categories become so well defined that their characteristics are immediately identified in the data. This improved articulation of categories enables the researcher to integrate those that are alike, thus reducing the size of the original list.	**Merging categories:** In attempting to code idiosyncratic units of meaning, categories were redefined and merged or extended into sub-categories. Given that this stage occurred towards the end of data coding, the characteristics of each category were so well defined that units of meaning were smoothly assigned.
Conclusion drawing and verification: Decisions are made as to what the data means. The emergence of patterns, regularities, causal flow and propositions enable the researcher to draw possible conclusions. The validity of these conclusions is tested accordingly.	**Writing the theory:** Drawing conclusions based on the patterns and themes evident in the categories. Fleshing out and elaborating upon these conclusions by recording them.	**Conclusion drawing and verifying:** Once all the data was coded and categories refined and merged, conclusions were drawn in relation to the appropriate research questions. These conclusions were verified by referring back to the original data. Satisfied that they could be supported by the data, conclusions were elaborated upon for inclusion in the thesis.

Conclusion

Having described the methodology and design of the study in this chapter, the following four chapters provide an analysis of the data and discussion of the findings in response to the specific research questions. While Chapter 7 is not an analysis chapter as such, it acts as a precursor to the subsequent analysis chapters in that it verifies the appropriate implementation of the DLE. This verification process is now discussed.

-7-

Implementation of the distributed learning environment: A verification

Chapter Overview

Part 2 of this study entailed the implementation of the DLE in an effort to determine the extent to which students distributed their learning in this context. Before this analysis could be conducted, however, it was important to verify that the framework which emerged from the literature had actually been implemented in the classroom and that all its characteristics and features had been attended to. As part of this verification process, implementation of the *teaching context characteristics* was appraised throughout the semester given that this component was fundamental to the framework's overall success.

This appraisal served three main purposes. Firstly, it prevented the teacher from (unintentionally) returning to her typical teaching style. Secondly, it revealed aspects of the *teaching context characteristics* that needed a stronger focus in the classroom and thirdly, it exposed an additional feature of the *teaching context characteristics* that did not emerge from the literature. This feature did not change the overall objectives or structure of the framework. However, its inclusion was believed to have enriched it nonetheless.

This chapter, therefore, outlines the various means of appraisal and provides data from class activity transcripts, interview transcripts and student journals to support the assertion that the framework was successfully implemented in the classroom. This verification procedure was an essential phase in the analysis process of this study as it provided a solid foundation upon which subsequent discussions were based.

Implementation of the teaching context characteristics

The primary focus of this verification process fell on the first component of the framework - the *teaching context characteristics* - given that its features pertain to the more practical, teacher controllable aspects of the DLE. While this component interacts with the other components to form a state of equilibrium, its features set the scene for this prevailing balance of forces. These features, as they relate to the teacher, curricula, the tasks and assessment procedures, all define the teaching context, and to a large extent will also define the nature of other features within the second and third components (see Figure 7.1).

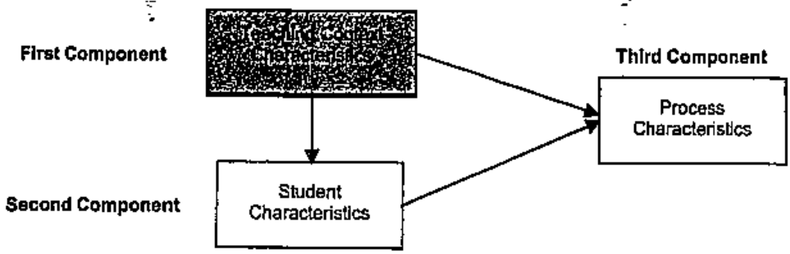


Figure 7.1 Teaching context characteristics: Primary focus of verification process

The verification process occurred each week where the teacher examined her lesson plan against criteria relating to the *teaching context characteristics* as featured in the DLE framework. This checklist, a sample of which is presented in Appendix H, enabled the teacher to address aspects of the teaching context that did not comply with, or fully support, the distribution of cognition. Also, the data which began to materialise after Week 6 was examined regularly for evidence that all features of the *teaching context characteristics* were visible in the classroom context. Class activity and interview recordings were reviewed, and journal entries were read in an attempt to confirm the presence of check-listed criteria in each lesson.

The findings from this verification process are presented below. The attributes of each feature of the *teaching context characteristics* are revisited then followed by excerpts from the data which corroborated (or disputed) its presence in the classroom.

Findings from the verification process

Teacher Features

- *The teacher is committed to a DLE and models distribution in his or her own actions.*

The teacher, in this instance, was fully committed to the design and implementation of a DLE as she was also the researcher. In keeping with the principles of action research, the study materialised from the teacher's desire to improve an aspect of her teaching. Whitehead (cited in McNiff, 1994) likens this desire to improve practice to a force within the teacher/researcher that has arisen when his or her educational values and beliefs have been denied and/or questioned. In other words, the teacher experiences a sense of dilemma when current practice conflicts with, or does not fully reflect, his or her educational values.

The force behind this study then, is the dilemma experienced by the teacher/researcher when her strong social constructivist views and interest in cognitive tools were not adequately reflected in her own practice. The aims and objectives of the study grew out of this dilemma and, as such, the very act of investigation can be construed as a strong commitment.

While students were not questioned directly on their thoughts about the teacher's commitment in this study, aspects of it have emerged in the student interviews. In the following excerpt, teacher-commitment is intimated in relation to teacher-motivation. The teacher's motivation, it seems, is a by-product of her commitment which also has a direct influence upon student-motivation. It can be inferred from this finding that the teacher's commitment to a DLE will ultimately affect the students' commitments to a DLE also.

> Q: Is this assistance provided by me important?
> A: ...it shows also that you are involved in the whole thing...that you're interested in what we're doing and are motivated too. We won't be motivated if you're not motivated [laughs]. (I1/10) ***Note: Coding references explained in detail in Appendix I.***

- *The teacher is responsible for the development and implementation of a participation framework, that is, facilitating students' learning of the skills of collaboration, using resources and being strategic learners.*

For knowledge and expertise to be distributed effectively across the classroom, students must be inducted into the rituals of distribution (Brown et al., 1993). As outlined in Chapter 5 (where the features of the DLE were explored), induction is the process of 'enculturation' whereby participation in routines and practice joins students together in a common goal and mind-set. These routines and practices are the catalysts that enable specific discourse patterns and belief systems to be learned and accepted as the norm by all students.

The routines and practices carried out in this study were based on an infrastructure that supported and promoted distribution through a) collaboration, b) using resources and, c) thinking strategically. The following excerpts, which have emerged from the students' conversations in class, their interviews and journals, can be construed as evidence that these three vital elements were present in the classroom, and that the teacher made concerted efforts to continuously help the students develop these skills. In the interests of optimising space, only one example from the data is included for each attribute, even though there were numerous supportive claims.

The first excerpt, and many others like it, confirms that the physical environment was designed to promote collaboration:

> Q: The class is always arranged in the 2 x 2 desks. How do you feel about this arrangement?
> A: I really like it. For the type of thing we're doing it's great. One of the worst things I find is trying to discuss in classes where the [classroom] is not set up for it, you know where there's rows of desks or something and the teacher says "Now discuss this". If it's not set up for it then it's terribly distracting. I also got to know people better; in depth; their perspectives. When you sit down like that, you know, before the class almost starts, you can't help but talk and I find that ... [facilitates] discussion in class. (I3/1A)

However, arranging desks appropriately, in itself, does not ensure collaboration. As discussed in Chapter 5, students also need a range of skills that will enable them to cope with the social and intellectual demands of collaborative group learning. Consequently, the collaborative skills required for this study were modeled and encouraged by the teacher throughout the semester. Each week the teacher focused on one skill in particular (e.g., week one - setting group goals) and would observe each group as they practised this skill in the class activities. As the semester progressed, and the students' repertoires of skills increased, both new and old skills would be discussed and practiced in the context of collaborative group activities. The following excerpt is indicative of many, where the teacher would use given opportunities in whole class discussions to review aspects of collaboration. This particular example is in relation to cognitive conflict which had been addressed in the class some weeks before:

> Tr: Gill just said that he thinks that it's all down to the teacher to get a student to use a certain approach. Do you all agree with that?
> V: Yeah mostly...
> D: Yes and no.
> Tr: Okay, good Dick. You think it is and it isn't. I want you to hold your reasons for a minute and we'll talk about them after but first I just want you to think about this for a minute. When someone says something that you don't quite agree with or you don't quite get what they were saying, what do you think you should do?
> V: Get them to repeat it.
> Tr: Yeah okay. Anything else?
> D: Say what is on your mind and get everyone to compare.
> V: Ask them about what they mean.
> Tr: Yeah, okay. Ask them some questions about it... (CA2/1WC)

Although not regular, there were references in the data suggesting that group collaboration was not successful and, as such, opportunities for the distribution of cognition were adversely affected. In the following example, the student offers the notion of 'group dynamics' as one possible reason:

> A: ... Just group dynamic. Some groups just click and fly and soar and others, you know, the questions are asked and their heads go down...so I think we missed out on a fair bit.
> Q: Discussions could have been richer you think?
> A: Could have been richer, could have been a bit more enthusiastic. (I3/1G)

Learning within a DLE is also resource-based. A range of different types of resources should be present in the classroom with easy access available to the students. The following excerpts suggest that social resources, physical resources and symbolic resources were available and readily accessed by the students during this study:

- Social resources

> Q: Did you use any resources within the classroom to help you learn the concepts?
> A: Yes. I find that when you ask a question, I don't come up with the answer straight away. I like to listen to about three different responses and that will trigger my thoughts as to what I think the answer is. So I definitely use the other people's responses to feed my own. I might use a combination of them to help me understand the question more so I use other peers. (I1/1K)

- Physical resources

> Q: Did you use any resources in the classroom to help you learn?
> A: We used textas, the big paper, my book, the others, each other, my own notes, my journal, and the overheads. (I2/1R)

- Symbolic resources

> Q: Ok, last night did you use any resources to help you learn?
> A: The people around me primarily. The textbook was good, especially the table which organised it in the way that I liked very nicely. There was a table which listed motive and strategy...Once I had that, I really had something to hang my discussion off ... (I2/1A)

Although these and other resources were available, the students frequently commented that there should be more visual resources on hand:

> Q: Do you have enough resources within the classroom to help you learn - to satisfy your learning needs?
> A: No not really. I like lots of charts, pictures, boxes of equipment. I'm a visual learner, and I'd like to see more diagrams...videos, concrete things are good. I like the video we saw a few weeks ago and more like it would be good. Sometimes the concepts are very hard to grasp and it would be good to get support from other concrete aids. (I1/1D)

The data also revealed that, although social resources were widely encouraged through discussion and collaboration, practical constraints (e.g., time) often hindered their ultimate usefulness. For example:

> I wish we had more time to talk on things. Sometimes I feel that we're just getting to the answer and we've got to go on to something else. That's our fault to a degree - we go off on tangents that are really interesting and about our teaching, but when we finally get on track we have to stop. (I2/1V)

While resources need to be readily available within a DLE, students also need to know how to gain maximum results from them and why they are necessary. Just as collaboration requires skill and know-how, resource-use is also skills based. As such, the skills associated with using resources as partners in learning in this study were modeled by the teacher, practiced frequently and constantly promoted through feedback and discussion. For example, the next excerpt has been taken from a whole class discussion on effective ways to extract the meaning in journal articles:

> Tr: ...just think about how you do read the articles though – especially the ones that you find particularly difficult. What do you do?
> S1: Well to be perfectly honest with you, I get totally cheesed off because the way that some of these yokes write it's like they're trying to do their absolute best to hide the meaning in the longest words that they can pull out of the dictionary and then that makes them feel real good because they think they're really academic in front of their colleagues.
> Tr: Like the Marton et al. (1993) article I guess. A lot of you said you found that one hard to get through.
> S2: Yeah, I read it about three times and I still don't really understand it.
> Tr: Did any of you use any particular strategy to read it that helped you understand it ...?
> S3: I just read it lots too.
> Tr: How many times?
> S3: Probably twice...I gave up after that.
> Tr: That would have taken some time... You've got other units to read for don't you? You've got lessons to prepare for school too don't you? Can you afford to waste time reading these sorts of articles lots of times and still not get the gist of it? [general consensus from class is 'no']. So what can you do to make these articles more manageable, make them work for you rather than try to intimidate you ... they can help you if you use them properly. What sorts of things can you do here? (CA3/1WC)

The students, with the teacher's guidance, went on to identify a range of strategies they could use to help them cope with academic articles.

The idea that "what is learned depends on what is already known" (Biggs & Moore, 1993, p. 22) was emphasised as being an integral intellectual resource within a DLE. With this in mind, students were encouraged to view 'prior knowledge' as a rich resource for their own learning; a wealth of information that could be used to learn new concepts. This influence is evident in the following excerpt:

> Q: Do you do that in these classes? Do you always think about the new concepts in relation to what you already know about them?
> A: Yes. I can definitely answer yes because you make us do that.
> Q: How's that?
> A: Um, I'm trying to think of an example ... well just when we start a new lesson, we always begin it by looking at what we think it means before we find out what it really means. (I2/1G)

Interestingly, some students also discussed their prior knowledge as being a social resource, as the following excerpt indicates:

> Q: ... do you feel that you as a learner bring resources to the learning environment?
> A: Yes I do. I can see now that I bring my things that I know...the prior knowledge I have about things and share with the others - because I think they will gain from me and I will gain from them ... because we've been looking at the importance of prior knowledge, I see that as a resource that is mine and that I can share. (I1/1D)

As indicated in Chapter 5, learning strategies are also an integral facet of an student's intellectual resources. These mental tactics and techniques, however, must be learned through teacher modeling, coaching and constant encouragement. In this study, students were introduced to the notion of learning strategies as part of the coursework and as part of the DLE framework. A primary objective of both the unit and the study was to encourage students to be strategic learners themselves, to see value in using learning strategies for their own learning objectives and for the students that they teach. While the different types of strategies (cognitive, metacognitive, resource management) were not introduced until Week 6, the notion of metacognitive learning and thinking about *how* to learn was encouraged from Week 1. This occurred by way of:

- Teacher modeling, coaching and constant encouragement:

> Q: Why did you use these [learning strategies] specifically? How is it that you are aware of these resources?
> A: I don't know, habit maybe, at the beginning. You use them all the time. You use them and you get us to. (I1/1A)

- Opportunities to practice and use the strategies:

  A: I'm more aware of them [learning strategies] now that I've done this unit.
  Q: Why?
  A: Cause it's all about how to learn. We've learned how we learn, and we've put it to practice, or at least I have ... (I3/1R)

Curriculum and task features

In a DLE, curricula must emphasise depth of understanding over the accumulation of information. There is little need for resources and social discourse when the objective is to soak up as much information as possible. On the other hand, if the objective is to understand and make sense of concepts, then students will need a range of tools and resources to help them achieve this. This latter goal will also be achieved more effectively if the curricula is arranged and presented as a series of themes which are progressively discussed and disseminated.

The teacher in this study held a conception of curricula that was in keeping with the evolution of deeper understandings in preference to memorisation and recall. As such, the unit's objectives were viewed through this philosophy and tasks were designed accordingly. For example, certain key facets of concepts were focussed upon to give students opportunities to make thorough explorations. However, the objectives were complex and the teacher on occasions did feel as though more time should be spent on specific topics. Nevertheless, the attributes of curricula as they define a DLE were generally adhered to, as is indicated in the following excerpts:

- *Curricula emphasises depth of coverage over breadth and understanding over memorisation and recall.*

  I wrote something. You know when we first came into the first lecture [in this unit] I was very superficial, you know I read the stuff and I took notes using all the cognitive strategies, but when I come in here and I listen to others speak and where they're at, they might make it clearer for me, or you might bring that focus back. So I feel that if the module goes over two or three weeks, I feel that by that third week I have grown in my understanding, so my approach has slipped from that surface, superficial level - because sometimes I don't have time to read all that information but by listening and talking the links grow and the desire, the motivation grows and changes to more of a deep approach. (CA2/1GA)

- *Task features should be based on objectives that emphasise understanding as opposed to the accumulation of facts.*

> Q: What are the main things that you've learned about Learning Strategies?
> A: I keep thinking about yesterday. The big debate we were having about the particular component of resource management, you know the 'effort' component that was something that stood out to me.
> Q: What in particular?
> A: Just that it's the most important part of Resource Management and it's probably one of the most important strategies. Because the amount of effort you put into something is more important than the time or what cognitive strategies you actually use. Your attitude is a significant factor, an attitudinal thing. (I1/1R)

- *Task features are situated and authentic.*

> Q: ... how do you feel about your understanding of the concepts encountered?
> A: ... I think I understand the main concepts mainly because I'm looking at my teaching at school and also the way I learn ... I'm more...aware of what I do and how I teach.
> Q: How has that come about?
> A: I use learning strategies with my students to help them build links with new information and old information, and also, I was talking to the group today and I mentioned in my basketball class there was a student who couldn't play. He just didn't know what to do, yet I teach the same student soccer and he's got the perfect skills for the game. He told me that he didn't enjoy basketball because he couldn't do it. So I asked him what he does on the soccer field when he wants the ball, and he said that he runs towards it, into a space, and calls for it. So I said that that is exactly what he should do for basketball. He thought that that made sense and yesterday he tried it and it worked...through that I thought that my own understanding was achieved. (I1/1K)

The data revealed, however, that the tasks were considered more authentic for those students with teaching backgrounds. As is suggested in the following example, they were less 'real' for the one student who did not have an education background:

> Q: And do the activities lend themselves to that sort of transferability?
> A: Not always directly. But that's mostly because I'm going to be the guy probably writing software rather than teaching. So usually it's a matter of kind of extracting and removing the concepts and taking the essence of what you are doing in the classroom situation. That can take a bit of thought sometimes, but generally I find that it is there. (I2/1A)

- *Task features are conducive to collaboration, using resources and learning strategies.*

Given that collaboration, resource use and strategic thinking constitute the participation framework for engaging students in distributing their cognition, it was essential that the tasks in this study facilitated this need. The following excerpts are evidence of the teacher's attempts to design tasks that encouraged:

- Collaboration

A: I don't know. I just know that every week I get ready to think. We have to participate in discussion. There's no way out of that.
Q: Why?
A: Well because that's the way the activities go ... you can't just sit there. You've got to say something. It's not a chore either. It's a good feeling to share and listen to others and learn from them. (I3/1V)

- The use of resources

Q: The activities that we did - just to remind you of a few, there was the group recall of concepts, there was the journal writing, there was the 3P model, the study guide...were those activities relevant to you?
A: ... I agree with the group exercises. The journal in this case was very relevant for me because I dived straight into it because it was a chance to write down in some concrete fashion what I had, I suppose the conception I had arrived at in terms of approaches. So yes, it helps to sort of crystallise that. (I2/1G)

- The use of learning strategies

Q: The class is always arranged in a particular way for this unit. Is it accommodating for your learning, or has it been a hindrance?
A: It teache. us about resource management. About using the set-up in our own classroom. Using the television, the overhead, the board, maybe you are modeling the kind of strategies that we should be using for our students, it makes us more metacognitive. (I1/1K)

Assessment features

- *Assessment features should be consistent with the process of learning.*

Assessment procedures within a DLE should reflect all the criteria that define learning tasks. Assessment tasks therefore, should be consistent with the actual process of learning. In this study, assessment for the unit consisted of one assignment and one end of semester examination. The purpose of the assignment was to encourage students to apply the main concepts encountered in the unit to their own learning. Students were asked to reflect on their learning in a formal learning situation (such as their learning at university), analyse it in terms of the ideas presented in the first four modules, and then write an essay explaining the *what* and *why* of their learning. Because the assignment was heavily weighted (60% of the final mark), students were encouraged to submit part of it for preliminary feedback. This submission was to include an introduction to the assignment, a plan outlining the intended structure of the paper and a draft of one section.

Criteria for assessing assignments was based on the students' ability to:

- adhere to feedback, that is, their ability to use the teacher's comments on their preliminary submission as a resource to further their learning.
- draw on the relevant ideas in the unit to analyse their own learning.
- explain their ideas clearly and present a thoughtful argument.
- integrate the four sections together to present a cohesive, well-supported argument.

The examination consisted of two essay questions, which students were required to answer in a three-hour period. Typical examination conditions require students to answer three essay questions and sometimes five to six short essay questions within this time frame. Responding to only two questions gave the students in this study more time to provide in-depth answers. Students were asked to answer the questions in relation to contexts that were meaningful to them, draw on relevant concepts only and integrate them in an effort to construct a cohesive, well-structured paper.

The examination was also 'open book', and students were encouraged to bring resources into the examination room which they felt would help them respond to the questions. Because few students in the class had sat 'open-book' examinations before, they were given opportunities in class to complete 'mock examinations'. Towards the end of the semester, the teacher gave students essay questions from previous semesters, which they had to respond to under examination conditions. During these times, students were encouraged to:

- make a plan and structure their response.
- concentrate on demonstrating their understanding of concepts rather than their ability to regurgitate facts.
- use their texts, notes, journals as resources.
- draw on personally meaningful contexts upon which to base their essay.

Responses made by students from previous semesters were critiqued by the whole class during these times in an effort to give students some feedback as to the sorts of things they should be focusing on in their own essays.

- *Assessment features should evaluate student understanding, not recall.*

The outline of the examination and assignment requirements above are indicative of the teacher's efforts to ensure that assessment procedures encouraged student understanding. The following excerpt also reflects this:

> S1: I think the assignment was a metacognitive task. It forced us to think metacognitively about our own learning.
> S2: Did it ever. It made me see where I need to improve. (CA3/1GB)

- *Assessment features acknowledge other 'containers' of knowledge not just 'in-the-head' knowledge.*

Designing an 'open-book' examination also communicated to the students that, in a DLE, an individual's mind is not the only retainer of knowledge. Throughout the semester, students were encouraged to acknowledge that, apart from their intellectual resources, other resources within the learning environment reflected the knowledge that was constructed each week. This is evident in the following excerpt:

> Q: Has the journal affected your learning?
> A: ...I think it's been very useful...I like to think of it as a concrete version of my mind. What's in my mind is in my journal, and what's in my journal is also in my mind. (I1/1F)

- *Assessment features should look for partial understanding as well as complete understanding.*

There was no evidence in the data that reflected this feature. This oversight was noted and considered in the design of the teaching context for Part 3.

- *Assessment features should use methods (e.g., portfolios) that emphasise the process of learning as well as the product.*

While a portfolio, as such, was not used in this stage of the study, the structure of the unit (assignment and examination inclusive) did emphasise the process of learning as well as the product. In the data, students frequently made statements suggesting that their learning had developed progressively and that they were aware of the processes that contributed to this. Discussion and collaboration were the main processes students identified as determinants of their learning, as indicated in the following example:

> Q: If I told you the exam was tomorrow, how would you feel responding to exam questions not having a chance to study?

> A: Fine...I feel like I've done most of my learning already rather than just stuffing it into my head for an exam. Normally I'm a real crammer, but I feel that I could discuss just about anything...I will [study] nonetheless because I want to refresh on some particular points, but I think my understanding is there. In fact I think it's pretty good actually.
> Q: Why is that?
> A: I guess it's because for me it always comes back to the discussion. If I can express it to someone verbally, then I understand it. That's usually my definition of learning. We've done that all the way through the semester. Each week...talk about it to the people and they've talked back and we've kind of come to a negotiated agreement on that. We've talked about the same things, and I think that I can understand it. (I3/1A)

Affective features

In reviewing the data as part of this verification process, the 'affective state' of the classroom has emerged as a significant issue. Throughout all data sources, whether it was the interviews, the student journals or the class activity recordings, students frequently referred to the importance of the mood of the classroom in relation to their willingness to distribute their cognition across the learning environment. For example:

> Q: Can you describe the learning environment as you see it in our class?
> A: ...Very supportive, I find. Everything that everyone says is generally considered to be valid. And there's no criticism so it's quite supportive. It's quite okay to take risks. You can say something that you think might be true. It's fairly safe in that you know people are not going to throw books at you or shout you down or make you feel completely inadequate. You might get a few blank looks or shaking heads, but that's the worst you get. So...most people feel able to just go out and have a go. (I3/1A)

Students repeatedly commented on the need for a relaxed sense of security in order to confidently share and construct knowledge. A precondition for the effective distribution of cognition, it seems, is the development of a positive classroom climate. Schmuck and Schmuck (1992) describe a positive classroom climate as one where:

> ... the students support one another; where the students share high amounts of potential influence – both with one another and with the teacher; where high levels of attraction exist for the group as a whole and between classmates; ... where communication is open and featured by dialogue; where conflict is dealt with openly and constructively; and where the process of working and developing together as a group are considered relevant in themselves for study. (p. 39)

In identifying the key characteristics of a DLE, the notion of a 'positive classroom climate' did not emerge from the literature as a distinct and separate feature. Given that it is an important attribute of any learning environment, it was inferred that once all the identified features were put into practice, a supportive learning environment would automatically ensue. While this is a possibility, the importance placed on class cohesiveness by the students has led the researcher to believe that this feature must be added to the framework and, as such, proactively engineered by the teacher.

Discussion

In reviewing these findings, it can be concluded that all features of the teaching context characteristics of the DLE framework were operationalised and introduced appropriately into the classroom context. Justification of this conclusion will be made by briefly looking at the overall outcomes for each feature as presented earlier in the chapter.

Teacher features

The teacher was totally committed to the development of a DLE and modeled distribution throughout the course of the semester. She also implemented a participation framework into the design of the classroom context where students were able to participate in the act of distributing their cognition through collaboration, using resources and thinking strategically. Even though some collaborative attempts were unsuccessful, these were infrequent and due to unhealthy group dynamics rather than a lack of collaborative know-how and skill.

There were a wide variety of resources available to the students and multiple opportunities were provided for them to maximise the affordances offered by these resources. However, even though attempts were made to integrate a range of visual resources into the environment, a few students commented that they would like to have more available to them - wall charts and videos in particular. This finding was used to inform implementation of the framework in Part 3 of the study.

Curriculum and task features

Based on a qualitative conception that teaching is the facilitation of understandings, the teacher's program for the unit had a strong emphasis on encouraging students to find meaning in the content rather than simply memorise it. In pursuing this objective, the curricula focused more on penetrating concepts deeply and thoroughly as opposed to achieving a broad and shallow coverage. Most students found the coverage of the topic modules adequate and rewarding, although some did mention their frustrations at having too little time during discussions to delve into ideas as deeply as they would have liked. Due to time constraints, which are typical in most classrooms, this unfortunately was unavoidable.

The tasks also emphasised understanding over recall of isolated facts. The design of the tasks was conducive to collaboration, using resources and using learning strategies and therefore, complemented the students' attempts to participate in a DLE. Tasks were authentic and applicable to real life experiences which, at times, proved to be a shortcoming for one student who did not have a teaching background. Although the teacher made attempts to broaden out application possibilities, discussions were inevitably pulled back to more specific issues and situations in relation to teaching (given that the majority of the students were teachers).

Assessment features

Assessment features were consistent with the processes of learning and as such both the assignments and the examination required students to demonstrate their understanding of the unit's concepts and their applications to real life situations. The examination was 'open book' thus encouraging students to use the same resources that they had accessed when initially learning the concepts. Given that the process of learning is a large feature of learning within a DLE, students were encouraged to focus on the processes they used as well as the concepts they were learning about.

Affective features

This feature was not intentionally attended to in the implementation of the DLE. While the students' comments suggest that the mood of the classroom was conducive to the distribution of cognition, the frequency of these references has prompted the researcher to incorporate it into the DLE framework for future implementations.

Conclusion

This verification process has shown that the elements of a DLE framework, as they were defined in Chapter 5, were present in the context of this study. Apart from a few minor findings to the contrary, all features of the *teaching context characteristics* were thoroughly embedded into the teaching context. Those issues that were not attended to, or were not included in the original framework, were taken into consideration during implementation of the DLE in Part 3. On the whole, this verification process has ensured that the findings to emerge in the following analysis chapters are based on sound foundations.

The Students' Distribution of their Learning

Chapter Overview

Having confirmed the presence of the DLE, data were explored to establish the extent to which the eight participating students distributed their learning within the classroom. If students were to maximise the learning benefits afforded by cognitive tools (and resources in general), then it was necessary to thoroughly explore the extent to which the DLE framework encouraged this endeavour. Therefore, this chapter presents the findings that have emerged from the first research question:

> *To what extent do students distribute their learning within a distributed learning environment?*

To gain a comprehensive insight into this question, it was initially looked at from the point of view of the resources that the students accessed in the learning environment and subsequently distributed their learning to. Analysis was carried out in four distinct stages and in response to the four resource categories - social, physical, symbolic and intellectual. This analysis process is described in detail in this chapter and acts as an 'advanced organiser' for the subsequent presentation and dissemination of the findings. While these findings are initially discussed in relation to each resource category, they are subsequently examined collectively and summarised in relation to the main research question above.

The analysis process

Determining the extent to which students distributed their learning within a DLE is synonymous with examining their approach to learning, that is, the processes they engaged in when completing assigned tasks. Therefore, the *process characteristics* component of the DLE was used as a framework for organising, coding and analysing the data that was gathered during the class activities, student interviews and student journals. Consequently, (and in keeping with the specific features of this component), the first research question was readdressed and examined according to the following four subsidiary research questions:

To what extent did students distribute their learning to *social resources* within the distributed learning environment?

To what extent did students distribute their learning to *physical resources* within the distributed learning environment?

To what extent did students distribute their learning to *symbolic resources* within the distributed learning environment?

To what extent did students distribute their learning to *intellectual resources* within the distributed learning environment?

Each of these subsidiary research questions was individually addressed and the transcripts scanned on four separate occasions to uncover examples where the students distributed their learning across all four resource categories. In doing this, it was discovered that there were distinct instances where the students either distributed, or did not distribute, their learning to a particular resource category. Preliminary coding, therefore, involved using NUD_IST to segment the data into 'yes' or 'no' categories for each resource group (social, physical, symbolic and intellectual). For example, Appendix J contains data that represents instances where learning *has* been distributed to social resources, whereas Appendix K represents instances where learning *has not* been distributed to social resources.

Following this pre-analysis, the data analysis procedure outlined in Chapter 6 was used to systematically examine the segmented data for patterns and themes. During this process, the transcripts were repeatedly read to synthesise the data for each resource group, and to gain an appreciation of the meaning attached to the students' responses. In doing this, it was apparent that while students clearly accessed the various resources, the extent to which they actually distributed their learning to them varied considerably.

For example, in relation to the extent to which learning was distributed to social resources, there were instances where students took turns in making surface comments about the subject matter, as well as instances where they engaged in deep conversations that challenged their existing ideas and pushed their understandings to new levels. Consequently, the qualitative differences between these and other emergent categories were defined by constantly comparing and contrasting them to each other across all relevant data sources. The outcome of this process was a series of categories (and in some instances, sub-categories) for each resource group that clearly illustrated the varying degree to which students distributed their learning within the DLE. These qualitatively different categories are described for each resource group as follows.

The distribution of learning to social resources

While the data showed that students did interact with each other, the extent to which they used each other as a resource varied. For example, the following excerpt is characteristic of a rich collaboration where, with the help of the teacher, the students reached new understandings about the differences between cognitive and metacognitive learning strategies:

> S1: Do you think metacognitive tasks are different from cognitive ones...?
> S2: Cognition is goal setting. See this might be our problem.
> S1: But you can't set goals without thinking about it.
> S3: See most [metacognitive strategies] are tools to think with ... So it's what to control ... how you're going to save time ... Saying to yourself "Do I understand this"?
> Tr: Yes there are... two aspects of metacognition ... one aspect is the regulation of your learning, like self-testing. The other is knowledge ... about cognitive [learning] strategies.
> S1: So the metacognitive strategies are like the ones that help you think and learn and the cognitive strategies are the ones that get you thinking about what you're learning
> Tr: Yes, right.
> S2: Really then metacognition should accompany all of the different types of learning strategies...
> S4: They are not as effective otherwise. (CA1/1GB)

The quality of distribution in this example, compared to interactions where students made isolated comments to one another, was clearly richer and more comprehensive given the extent to which the comments were being challenged, extended and abstracted. In fact, a range of five qualitatively different categories was identified in an attempt to discern the extent to which students distributed their learning to social resources. These categories form a continuum ranging from instances where there was no distribution evident, to instances where quality distribution was apparent. This continuum is presented in Figure 8.1, the varying levels of which are then described in detail.

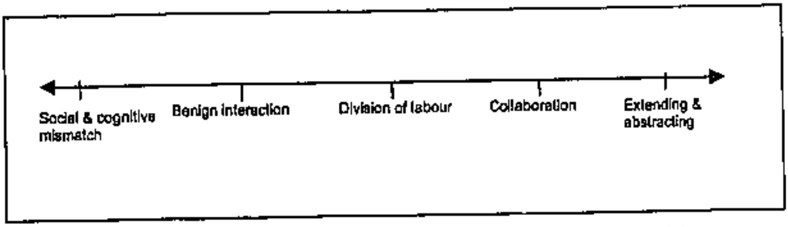


Figure 8.1 Continuum of the extent to which learning was distributed to social resources

Social and cognitive mismatch

There are various aspects to this category, all of which are characteristic of behaviours that appeared to stifle the distribution of cognition. The position of this category on the continuum (Figure 8.1) indicates that, while students did interact with one another, it was usually in a non-productive way. There appeared to be an inability to keep conversations flowing smoothly and a general lack of group cohesiveness. Several causes have been identified and are outlined in Table 8.1:

Table 8.1 Sources of social and cognitive mismatch

Cause	Description	Example
Social conflict	A degree of animosity has formed between members of the group. This feeling of ill-will appeared to emerge from frustrations directed at one or more members of the group who were either not contributing to the discussions, or were taking paths that others disagreed with. In the given example, the third student's lack of commitment to the conversation stops it from developing into anything meaningful.	S1: Well I think it's very important …that lecturers don't assume that because we're at university that we all know about strategies; that we can cope with all of the information they give us. S2: I feel the other way actually … by the time students get to university they have a good grasp of strategies …what do you think Gill? S3: I think I'll just go down the pub and have a drink. I'm just sitting here and saying nothing. S2: Oh, Okay…we're up to the next one. (CA3/1GA)

Cause	Description	Example
Cognitive conflict	A lack of understanding and basic knowledge about the concept being studied, has led to misconceptions and poor communication skills. Often cognitive conflicts embedded in social situations are the catalysts for deep understandings to develop (Katz & Lesgold, 1993). However, it is possible for unusually high or low level conflicts to militate against productive discourse (Hewitt & Scardamalia, 1998). In the given example, ideas appeared to be speculative rather than substantive, thus resulting in an interaction that was uncertain and plagued with low level cognitive conflicts. Based on their private study, students were to identify aspects in the teaching context that led to deep approaches to learning. They focused, unnecessarily, on the notion of 'hidden curriculum' and eventually arrived at the misconception that the teacher does not influence approaches to learning.	S1: Well do you agree with it? [comment that quality learning is associated with a deep approach] S2: Yes, yes. S3: Yes. S1: Why? S4: If you're only ... taking the shallow approach then you're only achieving points being made in the curriculum, which may not be everything in that subject ... S1: [and not] the hidden curriculum. S4: Yes exactly. S1: ... it says "explore the relationship between what happens in the classroom and the approaches to learning that students adopt". So...a teacher sees her object to work to the curriculum very closely so that all the checklists are met. S3: ...They're not talking about teachers' teaching habits. S1: No [reads sheet again] S4: It's more about student willingness to go outside the guidelines rather than teacher willingness to go outside the guidelines. S2: And um... S4: Well they are both the same thing. S3: But they're not saying the teaching will change the approaches to learning. (CA2/1GA)
Disbelief in the value of social resources	In the event that peers may not be reliable sources of information and knowledge, students displayed a reluctance to rely on others students as a sole resource. This was believed to be a dangerous and risky endeavour. Students who voiced these sorts of concerns said that they typically enjoyed group discussions, but would always consult the text independently to ensure that concepts presented by other students were correct and accounted for.	Q: There are always a lot of ideas, thought, comments and opinions being circulated in group activities. Did the comments shared today in your group affect your learning? A: They did but not 100%. I might be going in one direction and I like to stick to what I know. I don't always take on board what I hear. I'll listen and make a judgment. Q: [you] don't think it enriches what you are thinking? A: Yes it does – if I agree with it. (ID1/1)
Lack of common objectives and goals	While the students did interact, conversations were carried out in parallel to one another and appeared uncoordinated and without direction. This is evident in the given example where students discussed the types of learning strategies they have used in their learning. At first glance, this conversation resembles a brainstorming session where one idea leads to another. A closer examination shows however, that the students are largely pursuing their own ideas with little regard for what the others are saying. Although not common, these sorts of parallel conversations occurred when groups did not identify what they intended to achieve in an activity.	T: ...I want you now to question yourselves about the three types of learning strategies you've used over the past couple of weeks [in these classes]. S1: Highlighting key points. Try to pull them together. S2: Are we to do all of them or just the first one [cognitive strategies]? S3: I kept looking over my notes that I wrote about the readings, all the time. S1: ...I just highlighted. I have great trust in my ability to highlight the really...actually what I did was that I highlighted my highlighting. S2: I always ask myself questions. (CA3/1GB)

Nastasi and Clements (1992) claim that cognitive gains from social interactions occur when members of a group synthesise their own and each other's actions. This means that in the pursuit of common objectives, each persons' ideas are considered in the light of what has already been said and is then fused into the overall picture. This process can be likened to the joining of puzzle pieces to achieve a whole picture.

The notion of 'synthesis of ideas' is the antithesis of comments classified in the social and cognitive mismatch category. Whether it was due to social or cognitive conflict, a lack of trust in social resources or an inability to form group goals, the groups' failure to blend together a range of thoughts has opposed the distribution of cognition. Findings in the next category differ in that they represent cognition that has been distributed, albeit in a rather benign way.

Benign Interaction

Interaction in this category was more cohesive compared to the previous one. Students listened to one another and used shared ideas as springboards for subsequent ideas. However, this was typically in relation to issues that were either off-task, technically related to the task or that simply scratched the surface of the task. For this reason, interaction in this category was described as 'benign' in that it generally did not encourage cognitive growth, or if it did, it was usually only to a small degree. While there was evidence that cognition was distributed across individuals, it was only ever at a level that provided students with a one-dimensional understanding of the topic. The three primary classifications of benign interactions are presented in Table 8.2:

Table 8.2 Classifications of benign interactions

Classification	Description	Example
Benign off-task	Off-task interactions emerged periodically in discussions that lacked depth and direction. This is apparent in the given example, where (as a group) the students were attempting to identify instances in their lesson plans where they actively encouraged their students to use learning strategies. Only two students brought in lesson plans for this activity, which seemed to prevent the group's conversations from gathering momentum.	S1: ...When you teach science where I come from, you have to teach in groups because the classes are big and there's not much resources. It's how I learned. S2: Where do you come from again? S1: Seychelles. S3: This looks great. It's very much like the lesson we viewed on TV, the constructivist one – on energy. S4: Look. It ran for 80 minutes. S3: What! 80 minutes? Was it with a break? S1: No. It was a double period. No breaks. S2: If they offered me a job like that I'd say "Forget it. Give me another school"...I mean even asking a Year 11 or 12 to sit in one room for 80 minutes is ridiculous. (CA1/1GB)
Benign technical	While it is expected that technical aspects of tasks are attended to, it is not necessary for discussions about them to take a long period of time. It is anticipated that issues of 'what to do' and 'how to do it' are dealt with alongside conceptual discussions. When students do extend discussions about technical issues, it could be that they a) are unsure about the task, b) are not motivated, or c) do not have the prior knowledge needed for discussions to be based on. In these instances, talking technically can be a useful 'avoidance' strategy, providing students with an opportunity to sidestep the conceptual issues. The given example of 'technical talk' continued for approximately 60 seconds. In the context of the surrounding conversation, and the quality of the diagram that was eventually produced, it is believed that group did not have a sound grasp of the concepts they were trying to illustrate.	S1: This is rotten. I'm not a terribly good artist. Seeing as I'm the volunteer artist and I'm not an artist you'll have to put up with it...The subject matter and the teaching of the strategies is integral. S2: Integral? S1: Integrated...We need a label don't we? I'll put it up here. I think I might hand this over. It's just not happening for me. Do they call it 'programs'? S2: So you've got that, now put features of it. S1: So features comes next. S2: You've got a circle, an oval and now a rectangle. This is very mathematical. Are you maths-minded? S1: If I was to do this diagram again, I'd do it very differently, but anyhow. So... (CA3/1GA)

Classification	Description	Example
Benign on-task	Instances where students have moved on from the technical talk, but in essence have been just 'talking', have also been categorised as benign. Even though there was evidence that cognition was being distributed across members of the group, the level to which this occurred was low in the sense that concepts were just being touched upon and not developed in any depth. This is evident in the given example, where the group focused solely on the 'physical environment' aspect of resource management learning strategies without consideration of its other equally important facets such as time management, effort management and/or support from others.	S1: In this lesson though, the activities are all material-centred. S2: Well, it takes a lot of time setting it up then? S1: The students have assigned roles for doing that. S3: So your resource management strategies are very well developed. S1: Yes mine are but so are the students. They were part of that. They had to be taught how to be organised and how to use the resources that were available and the routine of setting them up and packing them away. It's all part of the lesson. S2: Here you have a science technician that does all that. S1: Oh yes, but you still need to get the students involved. It's all part of the role of a scientist. (CA1/1GB)

Division of labour

Interaction classified in this category was more robust and on-task compared to the previous one. Students conversed with one another in an effort to discern the tasks' requirements, identify group goals as well as methods of achieving these goals. There was a mutual desire to attend to all of the task's specifications and, as such, the group worked together cohesively and in a cooperative manner. This typically occurred through a division of labour, where components of the task were identified and then delegated to group members. This is evident in the following group's response to the teacher's request to diagrammatically illustrate concepts which had been encountered in the previous class:

> S2: [as S1 is beginning to draw something] We should be doing something else while you're doing that.
> S3: I was just going to suggest that Dick. Let's get learning resources management...I'll just write down the main points. You two discuss what that means as if you were presenting it to the whole class. By the time we're all finished, two jobs are done for the price of one.
> S4: All right, so we need to get into the features because the others will need to know that. So what about the subject matter? (CA3/1GA)

At a glance, this appeared to be an effective collaboration based on the mutual desire to learn with and through one another, and had the goal been to achieve mutual understandings, this possibly would have been the case. However, in examining this example more closely, it was apparent that the groups' intention was to distribute the thinking load for practical gains rather than conceptual ones. Even though there was a sense of group unification in this and other similar examples, the objective was primarily to reduce the cognitive demands of the task and complete it in a time-efficient and effortless manner.

While Brown and Palincsar (1989) assert that a clear division of labour can result in valuable cognitive consequences, Salomon (1993c) argues that thinking collaboratively about a problem can lead to even more impressive learning outcomes. Rather than a tendency to individually separate aspects of a task, the collective intelligence of the group is distributed across all members as they address the task together. This type of distribution was evident in the following category.

Collaboration

This category contains the most solid evidence that cognition was distributed across individuals. Statements categorised here were typically segments of, or whole conversations where groups of students negotiated and shared meanings relevant to the tasks they were studying. These collaborative exchanges were the very kind referred to in Chapter 5 that provided the communicative links for knowledge to be propagated from one individual to another. They were part of the fabric that sustained the distribution of cognition and which enculturated students into the mindset that learning is a social endeavour.

Discourse classified as 'collaborative' differed from discourse classified in the previous categories in that its flow, content and structure was conducive to and supportive of the ongoing development of understandings. Conversations usually began with students trying to identify goals that they as a group were eager to achieve. Following this, there was typically a successive flow of knowledge being introduced and accepted into the discussion. Activity was regularly monitored for evidence of divergences in meaning, and attempts were made to repair those divergences that threatened the overall progress of collaboration.

Goal identification was never as precise as "What are our goals for this activity" but was evident in a more subtle, conversational way. For example, the following excerpt was from a group's attempt to design a tutorial on how learning strategies should be taught to students:

> S1: Well we've been saying all along that you need to give them a variety of strategies. Teach them the strategy then give them the opportunities to do them and to use them so they become more skilled at it.
> S2: [thinking aloud] Why do students not use strategies – how to get students to...
> S3: Yeah.
> S1: So should we put that question up there [on a diagram]? Kind of sum it up...So what do you reckon Andy?
> S2: [Why don't we put] 'why don't the students use learning strategies', and then 'how to get them to use them'?
> S1: But even when they do use them, they don't maintain them, so maybe we should put 'use and maintain'.
> S2: Mm.
> S1: Should I put that question here and then we can answer it [later]?
> S2: Yeah do that one first then we can address the other later. I would put 'Why don't students use learning strategies' then pull out a few reasons. [S1 records this on the overhead transparency].
> S3: Yeah sounds good. You also have to talk about the use of the strategy. [S1 continues to write]. (CA3/1G8)

This conversation continued for over seven minutes during which time Student 4 joined in the conversation and together each student contributed to the identification of how they could present a simple but cohesive tutorial about how learning strategies should be taught in class.

The introduction and acceptance of knowledge into the group followed what Teasley and Roschelle (1993) call a cooperative 'turn-taking' process. One student would say something while the others listened. This initial comment would then be accepted by other members of the group who would take turns to either confirm, question, elaborate upon or challenge it. Each contribution would build upon the previous one, thus taking the conversation deeper into the concept being studied. The next excerpt, for example, was from a conversation that emerged from the third stage of a jigsaw activity where each member of the group had to explain his or her section to the others, with the intent of helping them understand it. In this conversation, students consecutively commented, questioned, confirmed and elaborated upon the leading person's explanations until a convergence in meaning began to form:

> S1: And then monitoring strategies – an example is self-testing. Now I was saying to the group back there that funnily enough when I got to reading that down here, I found myself self-testing. Did you hear the lecturer next door talking about 'x' and 'y'?
> S2: Yes, the algebra.
> S1: Well, I got sidetracked and I was listening to him, so I was thinking "Hang on. Get back on this". So I did what they say here, monitoring strategies called 'tracking your attention when you read'...

> S3: And I had to re-read sections...
> S1: Exactly. And then I had to do the other things like testing by re-reading, especially what I highlighted to see why I did highlight it in the first place.
> S2: So you're using cognitive strategies with the added angle of knowing when, and knowing why you're using them.
> S1: Yeah, I guess so, but the metacognitive is the thinking – more the awareness and being in control of your thinking. So I guess metacognitive strategies are the engines that drive the cognitive ones. They control them, and which ones you use and why you're using one over the other. Would you agree with that Dick?
> S3: Yes.
> S4: It's like a cognitive person wanting to get to 'A' and asking a metacognitive person how to get there. (CA1/1GB)

Teasley and Roschelle (1993) also emphasise the collaborative power of 'turn-taking' where one student's turn begins a sentence or an idea, which is subsequently finished off by another student. This was evident in the following example:

> S1: I was thinking about the difference between these three, or the similarities between these two [points to achieving and surface] and the end product is quite important in all. For example, for the surface just passing is important; that's the end product, and the achieving is also focussed on the end product in terms of the best marks. But the deep tends to...
> S2: ...not worry about the end product.
> S3: The deep person is more worried about the process...
> S1: ...about understanding.
> S2: So the deep learner focuses on the processes of learning, so does the achieving focus on the process and the end product? (CA2/1GA)

These types of interactions are useful for observing the ways in which knowledge is spread over collaborating individuals and how interpretations of concepts come to be shared. As is evident in the above example, an idea is introduced by one student, which is then elaborated upon by other students until the idea has been articulated in a more complete form. By the end of the conversation, the conception which was initially the belief of the first student, has not only been refined but has come to be shared by all those contributing to the conversation. Due to the spiral-like nature of distributed cognition (Salomon, 1993b; Salomon & Perkins, 1998), it can be hypothesised that this shared understanding was then appropriated (internalised) by individual students. Interestingly, internalisations developed through communicative exchanges have been found to be richer and more transferable compared to those that were formed through individual study (Henderson, Eshet & Klemes, 2000).

There was also evidence that students monitored their discussions and attempted to resolve divergences in meaning whenever they surfaced. In contrast to the irrevocable conflicts that were characteristic of discourse classified in the first category, cognitive conflicts categorised here were typically due to incompatible thought processes and ideas rather than a breakdown in the collaborative process itself. As stated by Teasley and Roschelle (1993), these 'mutual intelligibilities' contribute towards the consolidation of shared understandings and, consequently, are important characteristics of collaborations. In the following excerpt, Student 2 held the misconception that the achieving approach to learning is associated with a qualitative conception of learning. Student 3 disagreed with him and explained why. Student 4 supported this explanation which Student 3 subsequently elaborated upon. Student 1 and 4 then diverged slightly from this original discrepancy in relation to other similar concerns. Student 2 attempted to resolve these and in doing so came around to Student 3's way of thinking:

> S1: You know with the achieving learner, what sort of conception of learning do you think they would hold?
> S2: They'd be qualitative, don't worry. But the...meaning is not important. In their process they are deep but they're not doing it for the love of it, they're doing it because they want to be number one...
> S3: Don't you think their conception of learning would be more quantitative then?
> S2: Ah ...
> S3: If they're not interested in the meaning then why do you say they would have a qualitative conception of learning?
> S2: Because they have a very qualitative approach, I mean a deep approach, which is more or less the same thing.
> S4: You're talking more about a deep-achiever I think.
> S3: Yeah because the achiever takes whatever approach that is necessary to get to his goal. So he might use deep approaches or he might use surface ones but it's just to achieve his ultimate goal which is getting lots of marks and that's very much a quantitative conception don't you think?
> S2: Mm...their strategies are very much time management...
> S1: This is confusing because with me I'm a surface learner cause I'm extrinsically motivated to study to get my BEd...But in the meantime things I find interesting I think I'm learning quite deeply. I want to learn and I want to understand...And I also want to do well...
> S4: Sounds like maybe you're an achiever.
> S1: But I don't want to be the best.
> S2: But as was just established, we can move around in between all of these, even within the unit it seems.
> S3: Quality learning is learning for meaning isn't it? And that's what you achieve when you learn deeply.
> S4: Do you always need a deep approach to understand things?
> S2: Possibly not depending on ability maybe. I think what this question is getting at is if a student walks into the classroom ... and gather[s] up ... one handout after the next... that style of teaching did not motivate me to do well...All I could see was this mountain of information...that I had to remember so I took a surface approach to try and help me get through it. But in other lessons where we discuss things...that to me is much more quality learning. So has that answered your question...?
> S4: I don't know, I still don't know.

The teacher noticed the conflict and approached the students to guide them through it. Towards the end of the conversation a convergence in meaning began to emerge:

> Tr: Are you guys having trouble? What's the discrepancy?
> S4: I'm just having trouble trying to understand whether you can understand without taking a deep approach...If someone takes a deep approach to learning is their understanding going to be different from someone else who doesn't? Will everyone else be unsuccessful?
> T: It depends on how you define success I think. Is success getting 100% in your exam, or is success being able to demonstrate you understand and can apply a concept...
> S4: Well some may and some may not.
> Tr: If the person took a surface approach in attaining that top mark would they also have attained understanding?
> S4: Probably not.
> Tr: Would, therefore, that person have attained a quality learning outcome?
> S4: No. So quality learning is understanding and being able to make links between concepts and apply that understanding to different tasks.
> Tr: That's right. And do you think it's possible to achieve that level of understanding if you use an achieving approach?
> S4: Probably not.
> S2: Yeah right. So I'd agree with that.
> S1: I'd agree too.
> S3: Mm.
> S4: So there's a difference in the quality of understanding depending on the approach that you take. (CA2/1GB)

The previous excerpt is also indicative of the students' attempts to repair divergences which threatened to impede the progress of the collaboration. Student 4 was unsure as to why deep learning was the only approach associated with quality learning. Her consistent outbreaks of confusion could have thrown the others off course, who themselves were trying to grasp the idea, but instead they offered her alternative explanations, suggestions and justifications. For example:

> S4: I don't know, I still don't know.
> S2: Can I use another example? If say you had a video to say teach kids how to bake as opposed to say getting them to actually bake a cake ... where they feel the texture and get right into the activity of actually baking a cake ... (CA2/1GB)

Although a satisfactory collective understanding was eventually achieved with intervention from the teacher (also a social resource), distinct attempts were made by the students in this group to coordinate their partner towards a convergence in meaning.

Each of the examples in this section constitutes collaboration and, by way of definition, also constitutes the distribution of cognition. Each interaction was indicative of peers working together towards the construction and verification of shared knowledge. There was evidence of students supporting each other and assisting those who clearly were experiencing difficulty understanding the concepts on their own. Students were representative of resources for one another, modifying and adapting their language, explanations and suggestions to fit within their peers' knowledge status, that is, their zones of proximal development (Vygotsky, 1978). Furthermore, these collaborations (along with many others within this part of the study) are prime examples of the communicative exchanges that induct students into the culture of distributing their cognition. It is through these types of conversations that the conventions of distribution are spread over students in a group and participation frameworks come to be known.

Extending and abstracting

This category is similar to the previous one in that there was strong evidence of collaboration and the distribution of cognition. The outcomes of these collaborations, however, were qualitatively different to the previous category hence its more extreme position on the continuum in Figure 8.1. In the 'collaboration' category, students worked in partnership to negotiate and re-negotiate the meanings of concepts. When one or more students experienced difficulty in comprehending a concept, others would provide scaffolding that would ultimately guide all students towards a shared conception. The outcome, as such, was the construction of meaning that was collectively held by all members of the group.

In this category, interactions were still collaborative however the students appeared to be more deeply engaged in their conversations and adept at articulating their knowledge. Having established sound understandings of certain concepts, the students toyed with each other's perspectives and interpretations by distributing them across the group in a type of mental interplay. This process enabled the introduction of a variety of related concepts which were steadily integrated together in a logical and meaningful way. These interrelationships were subsequently applied to real-life contexts, the implications of which were critiqued and extended into new, more abstract understandings:

> Tr: Where does competition fit into all of this?
> S1: It'll be a promoter of the achieving approach.
> S2: It's sort of an extrinsic motivator.
> S1: I personally don't believe in it.
> Tr: In competition? Why not?
> S1: Because children don't learn how to learn, they just learn how to compete. It's usually based around the recalling of facts and that means lessons are assessment driven...
> Tr: I guess that goes back to what you were saying earlier, you either value the process or you value the product. And what does competition teach students to value?
> S1: The product.

> S2: Competition feeds the achievers. That's what they want – to compete and to win. Without that competition they can't really fulfill their desire.
> S1: Competition defeats the purpose or aim of constructing knowledge. The stress that competition causes encourages strategies to learn the material in whatever way and that's usually not the constructivist way.
> S3: In fact, it encourages surface learning because you just gloss over the details to get that product.
> S1: And at the same time you de-motivate the low ability students because they feel no good.
> S4: And when you engage in that negative self-fulfilling prophecy that will make a huge difference.
> Tr: We all know how detrimental competition is yet it is in the classrooms. I wonder why?
> S1: We encourage it because that's what you need for the real world.
> S4: So you think it's healthy now?
> S1: No but that's what our society is based on. (CA2/1GA)

In summary, the extent to which students distributed their learning to social resources, ranged from no distribution at all to the distribution of abstract understandings. Instances indicative of no distribution were infrequent and often due to unfavourable group dynamics. Also, some students' disbelief in the merit of social resources was clearly detrimental to distribution. Students will be less inclined to commit to the joint construction of knowledge if they are wary of the resources' credibility. However, this commitment is essential for a DLE to prosper.

A rather benign process of distribution was apparent when students discussed the technical aspects of tasks and when ideas were verbalized but seldom integrated and developed. The amount of time devoted to technical aspects of tasks appeared to decrease as the groups became more familiar with class routines. Similarly, conversations became more integrated as the groups' collaborative skills grew. The need to divide cognition rather than distribute it also declined alongside the development of collaborative skills, although certain students had a propensity for this approach throughout the semester.

Effective distribution was most noticeable when students created what Teasley and Roschelle (1993) describe as a Joint Problem Space (JPS). Participation within a JPS is collaborative and involves the joint identification of goals, integration of ideas and collective monitoring and repairing of divergences. As these collaborative processes grew in proficiency, they enabled the groups to establish a common language and develop mutual understandings. In some instances, these understandings were extended and abstracted through the 'dialectical interplay of minds' (Goodman, 1986, cited in Stage et al., 1998) although this happened infrequently. In keeping with the claim made in Chapter 5, collaborative groupings are certainly complementary to the distribution of cognition.

The distribution of learning to physical resources

There was widespread evidence that students used physical resources such as their texts and set readings, the blackboard, their own notes and in-class videos. This evidence is presented in Table 8.3.

Table 8.3 Physical resources to which cognition was distributed

Physical Resource	Supporting Statement
Text	Q: What are the most important resources for you when you tackle the tasks I give you in class? A: Generally the text. I like to underline and get key points out of that. And it's sort of the framework that everything kind of hangs on. (IA3/1)
Blackboard	A: ...I like it when [information] goes on the board. I would much prefer it than just discussing it because once it's on the board you can kind of move on. You don't have to worry about not getting the point. (IA3/1)
Student notes	Q: Did you use any resources within the classroom to help you learn the concepts? A: I was writing things down while others were talking. I put things in my own words. For me, I think it will trigger things off in my head when I come back to it. (IR1/1)
Video	I viewed [the second viewing of the video] very much as before, noting the attention-gabbing exercise, prior knowledge through to final construction. The detail of the video I saw slightly differently and there's a noted change in use of language. When I talked about it to the others in my group, I was definitely surprised at the words I used to explain myself compared to the last time we talked about it. Maybe I am learning something after all. (J1G)

These (and other) examples, suggest that students were aware of resources within the learning environment and accessed them in pursuit of their learning goals. However, one cannot conclude that the students distributed their learning to these physical resources simply because they were accessed. In fact, this insight was generally difficult to glean from the interview and class activity data given that the students mostly talked 'about' resources rather than 'how' they used resources. Conversely, the student journals were valuable in that the students' written reflections permitted insight into the extent to which this resource mediated cognition. Consequently, the journals were the primary data source in analysing the extent to which students distributed their learning to physical resources within the learning environment.

A number of researchers have espoused the importance of journals in learning (McCrindle & Christensen, 1995; November, 1996; Dart, Boulton-Lewis, Brownlee &

McCrindle, 1998; O'Rourke, 1998; Woodward, 1998). They are forums for *reflection*, which Vygotsky (1978) argues is integral to the construction and reconstruction of learning experiences. When individuals reflect, they consciously contemplate situations and things, and make inferences about then in the light of stored knowledge. Jonassen (1993) writes, "Reflective thought is the careful, deliberate kind of thinking that helps us make sense of what we have experienced and what we know" (p. 13). He goes on to say that reflection usually requires some sort of external support such as books, computers and other people.

The journal, in this instance, supported three types of reflective thought which ranged in depth and richness. The first type was characteristic of spontaneous thought about concepts and cognitive processes. The second was deeper, in that reflections were more critical and analytical, and the third was deeper again in that reflections were abstracted and extended to other contexts. Within each of these three types of reflections it was generally possible to identify student ruminations about the knowledge they had constructed or the cognitive processes that fuelled these constructions. Where possible, therefore, each reflection is described in terms of its content and process.

General reflections

General reflections on content were those where the student endeavoured to explain, in his or her own words, the meaning of a concept. For example:

> My understanding of constructivism (as it is developing) is that fundamentally learning is personal and unique for every individual. The teacher should not act as a dictator [but] rather pupils should be encouraged to use their preferred and most effective learning strategies. I do not believe this lessens the role of the teacher but shifts teaching towards facilitating knowledge... (J1A)

Sometimes entries were opportunities for students to off-load thoughts about concepts as they materialised in their minds. For example:

> The ideas of looking at 'how I learn' made me think quite consciously about 'how I teach'. (J1Gy)

General reflections on process were metacognitive in that students articulated their learning intentions. Identifying goals gave substance to students' endeavours, and provided them with a point from which learning could begin. The following excerpt is an example of the types of goals that were evident in the journals:

> I want to know how, as a cognitive thinker, I can become more balanced in relation to metacognitive learning strategies – to become more familiar with learning strategies to assist me in my teaching and my own learning as well. (J1Gy)

Other metacognitive reflections were those where the students considered the cognitive processes that either facilitated or constrained their learning. Entries where students questioned the types of learning strategies they did or did not use were indicative of this. As is evident in the following example, however, there is nothing to suggest that these revelations were used to inform further learning experiences. This is an important action if students are to learn anything about and/or from their learning (Dunlap & Grabinger, 1996):

> I am a shallow achiever. Need recognition. Poor time management and low motivation for intellectual effort requires shallow approach. Can only focus on one deep thing at a time. Everything else must be shallow. Intellectually interested but lazy. (J1A)

Critical reflection

Critical reflections on content were indicative of students' inner thoughts that emerged as a result of interactions with peers, the teacher, text or other resources. While these resources sparked the reflection initially, interaction with the journal was the fuel that gave the reflection substance. That is, in the act of making the journal entry, the reflection grew in depth, as did the students' understanding of the concept. As students became more confident with the concepts, their reflections resembled attempts to integrate and synthesise these understandings into a coherent whole. For example:

> Another understanding of constructivism I have is that it is entwined with Marton, Dall'Alba & Beaty's (1993) – and other's – levels of learning, particularly the upper qualitative levels of D, E and F... (J1A)

There was also evidence of understandings being developed further by being applied to the students' own lives and circumstances. For example:

> ...I believe as a child, teenager and possibly young adult, I held a quantitative view of learning. However, now I am leaning more towards a constructivist view. I am constructing knowledge for myself. I'm looking for new things to learn; to challenge me.

> For example, taking on this new...teaching position (Italian immersion at XYZ Primary School)...What I already knew about teaching, that is my previous experiences in a normal classroom situation ... helped me make valuable links with new information in the Italian immersion program. (J1V)

Students also used these sorts of reflections to critique concepts in reference to their own beliefs. For example:

> I think the constructivist approach works great with practical subject areas like science, design and technology, art, maths [and] possibly some language areas, however, I do think there is also a need for time where there can be individual learning. This does not mean to say that it ceases being an approach where the focus is on the understanding and meaning, but simply that...the social interaction is excluded. [It] can still be an active process of learning, only it would be the child interacting with the learning tools. (J1V)

Critical reflections on process were similar to those classified in the previous category in that students self-evaluated their methods of learning. A defining difference in this category, however, was that students attempted to identify solutions that would potentially ensure achievement of goals in subsequent learning situations. In essence, the journal provided the students with an opportunity to articulate problems associated with process and techniques that could be used to refine and adjust future performances. For example:

> I couldn't help but reflect on my assignment and where I partially confused learning strategies with conducting learning. Although I see them as being linked I need to be more direct in my explanation, e.g.., "I conduct my learning through rehearsal and elaboration, employing various cognitive and resource management strategies which will be discussed in greater depth later". Learning is...understanding and the learning strategies help us to get to this understanding. I think I need to make that clear in my assignment on this section. (J1G)

The journal was also a gauge by which students could trace and monitor the progress of their own learning over the course of the semester. For example:

> ...I feel during this unit, I've grown in my learning and shifted my approach to learning from surface learning to deep learning. I believe this has contributed to the interest/motivation I have for the learning material, possibly because its about myself, analysing my learning... (J1V)

Reflecting and abstracting

Although the frequency of these types of reflections was limited, those that were evident deserve recognition due to their rich level of abstraction. In the same way that Hatton and Smith's (1995) most sophisticated level of reflection entailed the provision of reasons for decisions or events which recognised broader historical, social and political contexts, reflections in this category were generalised across wider contexts. For example:

> Interesting discussion about misconceptions which helped clear up my misconceptions about 'misconceptions'. Apart from some of the obvious examples, pressure and heat, I believe my misconceptions are primarily incomplete conceptions. I don't think that it's because I have the wrong idea, I think it's more that I haven't got the whole idea yet. Like with conceptions of learning, I wasn't sure what they were all about but the more we looked at them and what conceptions we all had then I got the fuller picture better, I think. Interesting to note the strong response in class on religious subjects as being a strong source of misconceptions. Once again, have we misconceived these ideas or have we maybe just got only part of the picture? I tend to think that our religious beliefs are not necessarily misconceptions, but knowledge of what we were told to believe as children. Interestingly, it is hard for me to let go of these beliefs, even though I can't justify them. They are well and truly part of my stored knowledge and now, if I want to, I have to reconstruct these beliefs - if I want to. It has to be a conscious effort. (J1G)

Within this category, there were no examples of reflections on process. Furthermore, while these three reflection-types suggest cognition was distributed between the student and the journal, there were also entries that exemplified no distribution at all. These entries have been classified as non-reflective recordings.

Non-reflective recording

Non-reflective recordings are indicative of entries that are in no way reflective or representative of inner thought. Entries in these instances are typically short statements written in point form. For example:

> Information processing keywords – mnemonics, elaboration, short-term memory...(J1A).

Other non-reflective entries are those that are purely descriptive, usually explanations of terms as derived from another source such as the text, the teacher, or the overhead projector. For example:

> Learning strategies according to Weinstein and Mayer (1986) include rehearsal strategies (basic and complex), elaboration (basic and complex) organisational (basic and complex), comprehension and affective. (J1Gy)

When there is no attempt to elaborate on recordings such as these - to interpret the author's meaning or to identify the relationships between terms - it can be inferred that cognition has not been distributed between the students and the journal. . The affordances offered by journals have not been realised, rendering them little more than pieces of paper upon which superficial notes are recorded. In their research of university students' journal writing, Hatton and Smith (1995) identified a similar type of entry which was ultimately descriptive in nature, non-reflective and simply referred to literature or events.

Given that these non-reflections did not appear to suppress the students' desire to make reflective recordings, the journal has emerged as a support for reflective thinking - a physical resource to which cognition was distributed. While not consistent across all journals, the richness and depth of reflections appeared to develop as students became more comfortable with the process of keeping a journal. Some journals therefore contained all three levels of reflections ranging from brief reflections at the beginning, to in-depth ones towards the end. Others, on the other hand, contained similar reflections throughout.

The distribution of learning to symbolic resources

By and large, this question has already been addressed. The findings that have emerged in exploring the extent to which students distributed their cognition socially and physically also encompass the distribution of cognition symbolically given that symbol systems of various kinds are the medium of interaction and exchange between individuals and artefacts. For example, when collaborating, students draw on symbolic language systems to communicate with one another. When writing in their journals, they employ a range of symbols to either display, interpret or extend their thoughts. In a sense, distributing cognition symbolically is synonymous with distributing cognition socially and physically. The following section examines the specific *types* of symbolic resources accessed in this study, and the extent to which cognition was distributed across them.

The data reveals students accessed six specific types of symbolic resources. These resources were: content-specific language, concept-maps, diagrams, tables, blackboard inscriptions and models. Concept-maps, diagrams, tables and models were accessed both on an individual and group basis and were either student drawn, or contained in a text. Blackboard inscriptions were those that the teacher made while discussing or summarising concepts with the class as a whole and content-specific language was primarily used in small group collaborations but was also evident in whole class discussions. Each of the six resources is now examined more closely.

Content-specific language

Content-specific language used in this study constituted the terms, phrases and words that defined the unit material, and which enabled meaning to be exchanged between individuals. In keeping with the claims made in Chapter 5, content-specific language was essential for learning to occur as it was through articulation of phrases and terms that students were able to ask for explanations of concepts, negotiate meanings and ultimately construct understandings. Pea and Gomez (1992) explain this process, "Meaning negotiation takes place using diverse interactional procedures such as requests for clarification or elaboration; gestural indications of misapprehension; explicit paraphrasings ... [and] commentaries, repairs and other linguistic devices for signaling and fixing troubles in shared understanding" (p. 80).

In the following example, students used content-specific language to interpret a model given to them by the teacher, and to navigate their way through the concept of deep approaches to learning:

> S1: Essentially it's [the 3P model] saying the same thing that the deep approach is a willingness to not focus totally on where the marks are.
> S2: But when I look at what happens in the classroom...you know the interaction between the teacher and the students and the consequences of that relationship in the curriculum.
> S3: Do you think the student can be a deep learner if the teacher isn't teaching with expertise in a deep way?
> S2: No. That's why I...do you think they can?
> S3: Well I'm sure there are children out there who have deep approaches and have bad teachers.
> S2: They're the high achievers.
> S1: I think that self-motivation is required in that environment...much more so.
> S4: I think I'd put more importance on the learner. Yes the teacher influences but once you take that journey to school it's self-motivation. You haven't come to school to do nothing.
> S2: But if you talk to secondary students in relation to their learning, they'll say it's very different.
> S3: So what are we saying here, does quality learning and teaching result in the deep approach?
> S4: Yeah.
> S3: Sounds like we're doing a debate on whether teaching affects the quality of our learning... (CA2/1GA)

The quality of these types of interactions has been extensively reviewed in the section exploring the extent to which students distributed their cognition socially. The categories of communicative exchanges to emerge in this section were also indicative of the extent to which students distributed their learning to content-specific language. As such, a similar examination will not be repeated here. It is worth noting, however, the importance the students' themselves placed on content-specific language as a powerful learning resource. The following interview excerpt was one of many, where students expressed their understanding of the intricate relationship between using content-specific language and effective learning:

> Q: So did you use the specific terminology in your group discussions?
> A: Yes I think so.
> Q: Did that help?
> A: Yes...I quite enjoy collecting jargon and technical terminology because using the words sort of gets you more into it. The more you use the phrases, the more people will bounce those same phrases back to you in discussion. The more you get into what you are talking about, you don't have to worry so much about communicating what you mean because if you have mutual understanding of a term, you kind of clear the ground a bit to talk about what that means and how that links to other things. (IA2/1)

Pea and Gomez (1992) argue that traditional classroom settings often undervalue the impact of communicative exchanges on learning. Typically, few opportunities arise where students are able to draw on the technical jargon of a subject to interpret its meaning and use this interpretation as a vehicle to develop shared knowledge constructions. In a DLE, it is essential that students are given opportunities to 'talk technically' with one another. Not only do these communicative exchanges enhance learning, they also contribute towards the development of a learning community where a shared language base enables all members to a establish common ground upon which the rituals and formalities of distributed learning are mastered. This was captured in the following interview excerpt:

> Q: Did you use the specific terminology in your group discussions today?
> A: Yeah, you have to. You have to use them to make yourself understood. It's impossible to talk about this stuff without using the words that make it up.
> Q: What do you mean?
> A: Um, I'm not sure. It's like...you can't talk about cars without using car-related words. And so, you can't talk about learning strategies without using learning strategy words, you know. (IG1/1)

Markings on the blackboard

In Chapter 5, Pea and Gomez (1992) were quoted as saying that inscriptions on the board, and other symbol systems, were important features of DLEs. Whether they are words, diagrams, pictures or formulae, the visual or explanatory nature of these symbolic resources can be used by students to index their developing understandings of concepts. In the following interview excerpt, the student talks about using the teacher's inscriptions on the board as a symbolic resource to support her learning:

> Q: Did my questions and the discussions we had as a whole group help?

> A: Oh yeah, absolutely. Especially when you were talking on the board. That was really good. It reinforced everything. Put it down on the board and I could get it off and it backed up what we were talking about at the time. (IK3/1)

Diagrams, tables, concept-maps and models

Throughout the class activities and student journals there were numerous examples of students distributing their learning to diagrams, tables, models and other pictorial representations of the subject matter. In transforming information into symbols, students are encouraged to engage in the material at a deeper level than had they viewed or verbalized the concept only (Lowe, 1996). This was the impetus behind the following example where students were asked to review previously encountered concepts by diagrammatically representing them:

> S1: Yeah, how about we do a symbol for surface, deep and achiever?
> S2: Yep.
> S1: What about a pond...I'm thinking maybe an ocean.
> S2: Yeah, ocean, let's settle on the ocean shall we?
> S1: Yeah, a boat on the surface, something underneath the surface...
> S3: A fish.
> S1: A fish and what about the achiever...a dolphin going through a hoop.
> S2: Okay. Let's let that develop.
> S3: A shark maybe. [S2 continues to draw...] What about a deep-sea diver?
> S1: Yeah, and maybe a pirate for the achiever cause remember he doesn't care how he gets to where he's going as long as he gets there.
> S2: And the achiever...
> S1: They've got their eyes on the goals don't they? How about someone standing there with a prize - medal or something.
> S2: We need an ocean floor. Now maybe we have our second diver who is deep but has got a big bag full of pearl shells or something like that.
> S1: Do you think they'd be a diver? (CA2/1GB)

Similar exchanges were recorded as students collaborated to interpret tables and models found in their text and readings. There were also moments of private reflection about other students' diagrams and concept maps, as recorded in the following journal entry:

> During the small group discussion about our individual concept-maps, two of us...failed to mention...the concept of...Executive Control Processes. But [for] one member of the group, it was on the top of the page of his map and...he explained how it affected the whole model. Metacognition [as it relates to the Executive Control Processes] and my personal utilisation of it in my own learning is quite weak. I realise it needs some improvement...(J1A)

The student journals, in fact, were a significant medium for students to engage with symbolic resources. Frequently, students accessed their journals to construct tables, diagrams, models and concept-maps. These designs were highly idiosyncratic and dependent upon the intention and perspective of the student creator. Some diagrams appeared to be representative of spontaneous thought and reflection, for example:

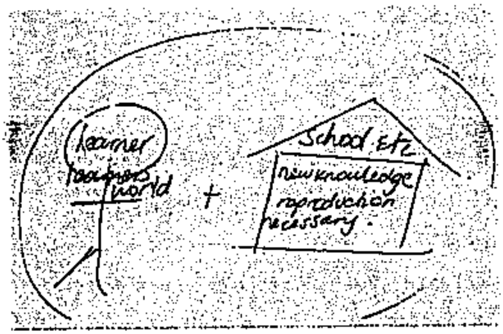


Figure 8.2 Student's symbolic representation of spontaneous thought

The tables were generally used to graphically organise thoughts and ideas, for example:

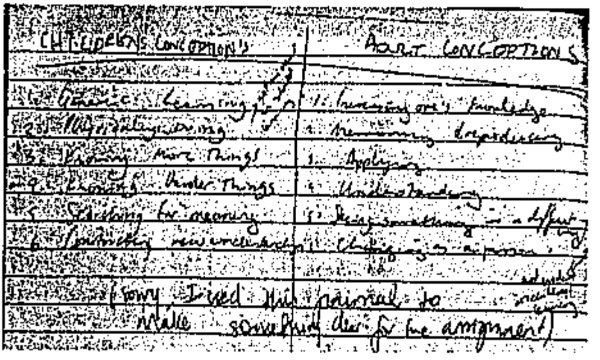


Figure 8.3 Table created by student to organise thoughts

Simplistic models, similar to the one below, appeared to be the beginnings of students' new knowledge constructions and personal theories:

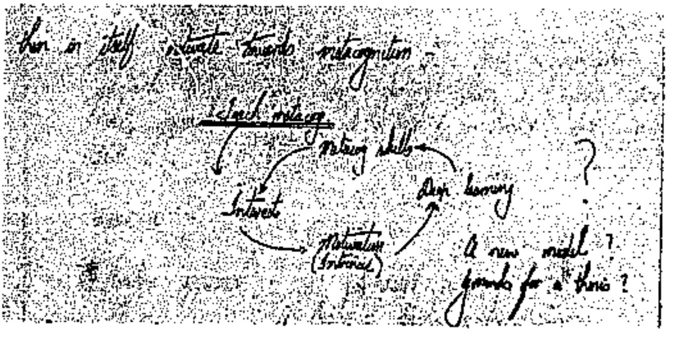


Figure 8.4 Student's symbolic representation of a theory

The concept-maps, all of varying shapes, sizes and depths, were essentially representative of the students' understandings of concepts and the structural relationships between these concepts. The following concept-map, for example, reflected the student's developing knowledge structure about how individuals process information:

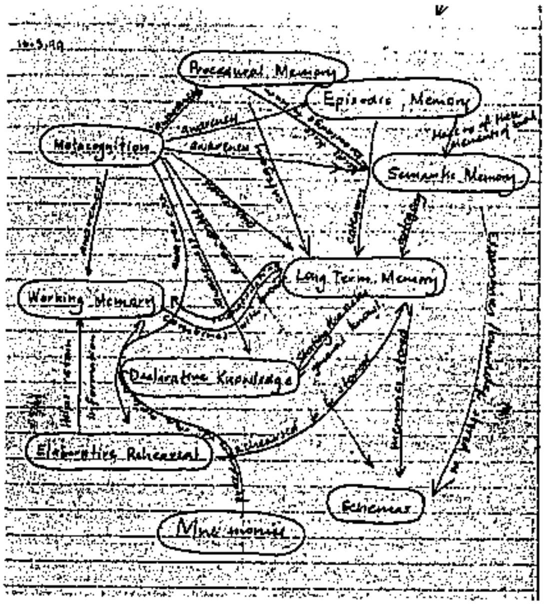


Figure 8.5 Student created concept-map

It can be inferred that cognition was distributed to these diagrams, tables, concept-maps and models to the extent that they enabled students to visually represent their interpretations of the subject matter. Most of these visual representations were well-defined reflections of the students' knowledge. Even those that were less elaborate, however, could still be considered useful learning resources in that their deficiencies provided insight into what the students didn't know and consequently needed to develop further. Jonassen et al. (1997) argue that concept-maps are particularly useful in this regard as they provide opportunities for students to reflect on their incomplete understandings as to what concepts mean and how they relate.

In summary, content-specific language enabled students to develop a common language base as well as a method of negotiating concept meanings. Inscriptions on the board, student notes and other language symbols were used by the students to index meaning, that is, to support, reshape and strengthen understandings. In terms of which one of these symbolic resources was the most frequently used, content-specific language was by far the most prevalent. Given that verbal exchanges are the primary means through which meaning can be negotiated and knowledge can be constructed, this finding is not surprising. However, the importance the students themselves placed on the content-specific language is interesting and perhaps indicative of the DLEs endorsement of this symbolic resource's inherent value.

Nevertheless, while the other types of symbolic resources were accessed less frequently, their learning benefits were by no means inferior. The findings indicate that the whiteboard inscriptions and student-created visuals supported both private and collaborative thought processes. Given that most of the student-created diagrams, concept-maps, written reflections and tables were recorded in their journals, it can be inferred that the presence of this resource in the DLE was crucial. One wonders whether these symbolic resources would have been recorded elsewhere (or at all) had the students not been encouraged to maintain a self-reflective journal.

The distribution of learning to intellectual resources

Given that the knowledge an individual possesses constitutes his or her intellectual resources, this subsidiary research question was explored in terms of the extent to which the students distributed their learning to their own internal knowledge structures. Furthermore, because knowledge has two major planes, conceptual knowledge and metacognitive knowledge (Hedberg et al., 1993), the data was analysed to determine the extent to which both of these types of intellectual resources were utilised.

Earlier in this thesis, conceptual knowledge was described as the facts, figures, understandings, experiences and perspectives individuals hold in their memories – the existing knowledge structures they have pertaining to interpretations they've previously made about their world. From a social constructivist perspective, this prior knowledge is the base to which new information is linked and given meaning and structure. As such, it is an invaluable resource for the continuation of new learnings and the development of sound understandings. Because the notion of 'prior knowledge' was part of the unit material, as well as being an integral part of the DLE framework, the students in this study were continuously encouraged to view it and use it as a resource for the support and development of their own learning. This is evident in the following example:

> Q: Does revising concepts help your learning at all?
> A: Oh yes. That's how I learn. In the first week you just listen and gain some insight to trigger your thoughts, to activate them. In the second week you use what you learned in the first week to learn some more and by the third week you've got the foundation, a good grounded understanding to learn even more.
> Q: So how does revision help that?
> A: Well...at the beginning each week makes you think about the things you know, that foundation, and then you just add to it the new stuff, and it makes sense because you're building onto what you already know.
> Q: Can you explain what you mean?
> A: ... It's to do with constructivism and I know that now. I didn't have the word for it before ... you know, you build to what you've already got up there [points to head]. (IF1/1)

Prior knowledge isn't only useful for advancing and developing sophisticated knowledge structures. It is also useful for generally making sense of things - even concepts that have not been encountered before. The conceptual knowledge an individual holds is made up of a wealth of experiences and perspectives that can be called upon at any time to be compared to, distinguished against, likened to, and dissected, in the light of a concept or a situation that has not previously been experienced. Dunlap and Grabinger (1996) explain this process, "Students want to understand and make the connections between existing and new knowledge not only because it facilitates new learning but because in general, students are more comfortable with what they are familiar with (p. 74). This is evident in the following interview excerpt where a student discusses her familiarity with deep and surface concepts as they relate to an 'ocean' perspective. This student had been absent the week before when deep, surface and achieving approaches to learning were initially explored:

> Q: As a person who didn't have that background knowledge, did that picture [of the ocean with boats on the surface and deep-sea divers below etc] help your evolving understanding?
> A: Yes, it did because I didn't have the background knowledge of all these terms. They were foreign to me so naturally if they're foreign to me they're gonna go in one ear and out through the other, whereas the picture I could relate to more. I had prior knowledge on the boat being on the surface and the diver being underneath, so in that sense I did understand it more. It's got to do with prior knowledge doesn't it?
> Q: Do you think it does?
> A: I think so. I'm relying on my existing understanding of levels – you know the boat on the surface of the water, the person being a deep-sea diver and relating that to the surface and deep approaches and orientations to learning. (IK2/1)

The other aspect of an individual's intellectual knowledge is their metacognitive knowledge which, according to Hedberg et al. (1993) "firmly underpins learning" (p. 161). As outlined in Chapter 3, this knowledge is typically operationalised when students engage in a range of learning strategies which have been described by

McKeachie et al. (1986) as cognitive, metacognitive and resource management. There was evidence throughout the data to suggest that students distributed their cognition to cognitive learning strategies in an effort to complete the set task:

> Q: Do you remember using any learning strategies yourself to help you learn the information yesterday?
> A: ...I pretty well skim read then I read [in a] more detailed [way] and made notes at the same time to have a bit of a break. And when I was writing my notes, I was looking for key words. Then I would also run it through my mind...The connections were coming to me and then that got me to look for further connections...starting [with] the qualitative/quantitative view, through to looking more at the six levels [and] then through to...the information processing model - the strategies related to it - and so yes, it was imagery I suppose - writing, reading (different types of reading approaches)...and then of course ... discussing it. (IG2/1)

There was also evidence that metacognitive learning strategies were used. The following example was evidence of this but also emphasised the student's awareness of his own intellectual knowledge as resource to be used in the development of his learning:

> Q: ....What I'm trying to get at is to see if you are a metacognitive learner (in this unit).
> A: I am, yes.
> Q: How do you know that?
> A: Because I'm always watching my progress and how I'm going. If I don't understand it then I'll do what I have to do to understand.
> Q: Like what exactly?
> A: Read more, ask more questions, go to the lecturer and ask for help – whatever it takes.
> Q: So you watch your learning progress. You are a guide, a facilitator for your ownself, as well as the teacher?
> A. Yes. More so than the teacher? I can't rely 100% on the teacher. I have to do my own facilitating. I think that's what makes a good learner ... when someone can rely on themselves for learning something. (ID2/1)

The last example is indicative of the resource management strategy being employed in a class activity where the group was planning a mini tutorial to present to the whole class:

> We should also plan our time management here – how long to spend on each section. (CA3/1GA)

While there was widespread evidence in the data to suggest that all three types of learning strategies were employed regularly, it is not possible to discern if each of the eight participating students used a combination of these strategies themselves. It is difficult to substantiate, therefore, a claim that each student distributed their learning to a large extent to all three types of learning strategies. When working collaboratively, however, the data suggests that each group employed all three types of learning strategies, even though there was a greater emphasis on cognitive learning strategies.

Passive versus active learning

When students are distributing learning to their intellectual resources, it can be said that they are mentally attuned to the process of learning – they are actively involved with the material. Conversely, when students do not distribute learning to their intellectual resources, it can be said that they are participating in a passive capacity, that is, they are not consciously linking new to old knowledge nor calling upon appropriate strategies to deal with task demands. While it appears that students were actively involved in their learning most of the time, there is also evidence in the data indicating the students' passive involvement. These incidents were often due to students feeling overtired and unmotivated, as the followig example indicates:

> Q: When you were completing the activities, were you monitoring and checking your understanding of the concepts?
> A: No. Maybe. I don't know. I was so tired last night that I doubt it. If I was, I wasn't aware of it. (IR3/1)

In light of the next example, this passive involvement also might be due to a conflict between learning styles and the desire to engage in aspects of intellectual resources. For example:

> Q: How important is it to you to set yourself goals?
> A: I hardly ever set goals. I'm almost anti goal setting. I generally find people who are great goal setters to be abrasive, annoying and egotistical. Going through the 1980's when there was a lot of hype on motivational, self-help seminars etc I could see that it was a waste of time except for those who were making the money out of it. What a gimmick. It was all this goal setting stuff to fill auditoriums and get charged $80 per head. So I have a real strong thing about that. (IG1/1)

Finally, distribution of cognition to intellectual resources must be intentional – a conscious effort on the part of the learner. So, even when students identify strategies they've used but in an unintentional way, then it can be said that distribution has not occurred. For example:

> Q: You've been learning about learning strategies in this module. What sorts of strategies did you yourself use today?
> A: Took notes, wrote down the main ideas. Read a section of the article...highlighted etc.
>
> Q: Was a conscious effort to use them?
> A: No. It just happened. It's a habit. (IK1/1)

The data suggests, however, that learning was largely active and students distributed their learning to their intellectual resources to the extent that they employed a range of learning strategies and made concerted efforts to learn the material by connecting new information to existing knowledge structures. Dunlap and Grabinger (1996) claim that teachers rarely allow students sufficient time to determine the connections between new information and prior knowledge, largely taking that responsibility on themselves. This type of practice is detrimental to a DLE where students are encouraged to explore a range of resources, including their prior knowledge for themselves.

Discussion

In synthesising these findings it was found that the extent to which the majority of students distributed their cognition within the DLE was extensive. The findings showed that social, physical, symbolic and intellectual resources were not only accessed but were incorporated in class activities as partners in learning. While there were varying degrees to which the resources were accessed as partners, the data suggests that the majority of students relied heavily on all four resource categories to support and strengthen their developing understandings.

Some of these resources were accessed more frequently than others. For example, learning was distributed more often to social resources in comparison to physical, symbolic and intellectual resources. Given that the DLE promoted a high degree of collaboration, this finding was anticipated. Symbolic and intellectual resources appear to have been less frequently accessed although this cannot be fully discerned from the data. While the reason for this disparity might be related to a deficiency in the DLE framework (in that it did not sufficiently promote the potential of these resources), the abstract nature of symbols and knowledge also offers some explanation. Because symbolic and intellectual resources are typically more obscure compared to their social and physical counterparts, their affordances were perhaps less apparent and, consequently, less accessible to the students in this study.

While an uneven distribution of learning to the four resource types is inevitable, a significant imbalance could adversely affect the success of the DLE framework.

Distributing cognition solely to social resources, for example, could preclude the mediating affordances offered by a range of other resource types. Conversely, precluding social resources due to a preference for resources that facilitate individual learning (as was the case in some instances in this study) impedes the path of distribution generally, but also eliminates the invaluable support typically provided by others in the social construction of knowledge. Notwithstanding the fact that all resource-types vary in their mediational support (depending on their specific affordances), cognition is most powerful when it is distributed across a range of resources (Derry et al., 1998; Hewitt & Scardamalia, 1998; Lebeau, 1998) rather than one only. In other words, thinking with a peer is valuable but no more so than thinking with a peer in conjunction with paper for recording ideas, a calculator or even a concept-map that externalises mental models and concepts.

In trying to discern why varying degrees of distribution were evident within the four resource categories, the temporal nature of the DLE may provide some insight. Given that the DLE gradually encourages students to distribute their learning to social, physical, symbolic and intellectual resources, it is feasible to expect that the proficiency with which students use resources at the beginning of a semester will be less effective compared to their use of resources at the end of a semester. In this investigation, many instances of the more extensive, qualitatively richer distributions occurred towards the end of the semester (although not a consistent finding). It would appear from these findings, that prolonged participation in the DLE facilitated this outcome. Had the investigation focused on data collected in the first recording session only, the conclusions would potentially be very different to those outlined.

Finally, this analysis explored the general distribution of cognition to resources within the classroom. It did not investigate the extent to which each individual student distributed his or her cognition specifically. Had the data permitted this type of analysis, a greater insight into the effects of the DLE on student learning would have been gained. While this was not the aim of this particular investigation, further research in this regard would potentially enrich the DLE framework by providing a deeper understanding of the factors that influence distribution, why some resources are preferred over others, and how reluctant students can be transformed into enthusiastic members of a knowledge building community.

Conclusion

The findings from this investigation suggest that the mental activity that occurred in the classroom was performed in the context of tasks that encouraged cognition to be distributed over the students, the teacher, physical, symbolic and intellectual resources. Arguably, these tools both supported and expanded the students' mental powers. The next chapter is an analysis of this mental activity in the context of activities that were centred around the cognitive tool. It explores the extent to which this resource contributed to student learning when accessed within a DLE.

The cognitive tool as a partner in cognition: The effects

Chapter overview

The two previous parts of this study were devoted to the design and implementation of a framework that would ultimately facilitate the integration of the computer as a cognitive tool. Described as a distributed learning environment (DLE), this framework encouraged students to spread their cognition over contextual resources as though they were partners in learning. The aim of this part of the study (Part 3), therefore, was to explore the outcomes of this integration in terms of the extent to which the cognitive tool contributed to student learning. Consequently, this chapter presents the findings that emerged from the second research question:

> *How does a cognitive tool contribute to student learning when implemented in a distributed learning environment?*

In an effort to facilitate a meaningful dissemination of these findings, it is necessary to firstly establish the grounds upon which any contribution to student learning can be qualified. Therefore, the chapter begins with a discussion which draws upon Pea's (1985) portrayal of the cognitive tool as a resource that can augment and enhance cognition through the development of rich representations of knowledge. Moreover, because learning within a DLE is centred on *shared* constructions of knowledge, this discussion is based on conceptual growth and changes in knowledge representations as they pertain to cognitive systems.

The principles to emerge within this discussion are at the core of the analysis tool which is subsequently described in detail, along with the analysis procedure. Following this, the findings are presented and discussed.

Conceptual growth: The development of rich networks of knowledge

Pea (1985) argues that a cognitive tool's strength is evident in its ability to restructure and reorganise students' thoughts. In this regard, learning outcomes can be qualified as the extent to which existing representations of knowledge have been re-shaped, extended and meaningfully integrated with other knowledge representations. Therefore, quality learning outcomes can be equated with coherent and extensively connected knowledge structures, whereas poor learning outcomes can be equated with knowledge structures that are tenuous, thin and lack meaningful integration.

This latter learning outcome is often associated with novice learners (Jonassen, Mayes & McAleese, 1993) where inadequate existing knowledge structures obstruct attempts to make sense of new knowledge. On the other hand, expert learners possess elaborate, multilevel knowledge structures (Bereiter & Scardamalia, 1986) which enable them to integrate new information more efficiently and manipulate it into complex understandings. While it is feasible for students to remain as novices indefinitely, there is consensus in the literature that those who are experts in a particular field possess knowledge structures that have gradually evolved over a series of stages (Biggs & Moore, 1993; Jonassen et al., 1993; Rumelhart & Norman, 1978; Shuell, 1990; Vosniadou & Brewer, 1987).

Although varying terms and phrases are used, these theorists contend that, at the novice stage, students encounter a large array of bits of information that are more or less isolated conceptually. Due to insufficient prior knowledge, support and guidance from others is required to enable these students to develop foundational knowledge structures. Once this occurs, the students are then able to look for the similarities and relationships between these previously isolated pieces of information, thus enriching their fundamental understandings of the concepts. Furthermore, "As these relationships become better developed, they are formed into higher order structures and networks" (Shuell, 1990, p. 542) which opens up opportunities for the students to participate in more complex problem solving activities. However, the automation of these advanced knowledge structures does not occur until the final stage where previously formed schema become so intricately connected and coherent that students can respond to problems in a more effortless, expert way and knowledge can be easily transferred to a broad range of contexts.

Consequently, quality learning can be described as an extensive, well-connected and complex set of knowledge structures. More specifically, and in keeping with the fundamental principles of social constructivism and distributed cognition, quality learning is synonymous with extensive knowledge structures that have been constructed *collaboratively* and, as such, are representative of *communal understandings.* In a DLE, for example, representations of knowledge are evident in the minds of individuals *and* supporting resources. They are embodied in the discourse that emerges as students interact with each other and available tools, and they are embodied in the tools themselves (e.g., a concept-map). And as is the case with individually constructed knowledge structures, collaborative knowledge structures have the potential to evolve into deep, richly interconnected understandings of the subject matter.

However, some theorists dispute the notion of collaborative representations of knowledge and question what it actually means for a group to know something. For example, because a group has reached a consensus about something, does it mean that each member has attained the same level of understanding (Nikerson, 1993)? Based on the constructivist view that meaning cannot exist independent to an individual's subjective point of view (Jonassen et al., 1999), this is probably not a likely outcome. In fact, in a study conducted by Jeong and Chi (1999), only a small portion of knowledge constructed during collaborations in dyads were actually represented by both students (cited in Fischer & Mandl, 2000).

From a social constructivist perspective, however, each member will take from a collaboration what is appropriate to his or her ZPD. While this may mean that all members of a group share the same understanding (albeit to a varying degree of abstraction) it might also mean that some students will form (or refuse to let go of), completely opposing views. Interestingly, this is no different to an individual's internal knowledge constructions where, as Hewitt and Scardamalia (1998) point out "individuals ... can accommodate two or more sets of ideas that, under analysis, reveal themselves to be mutually incompatible" (p. 78).

Consequently, defining what it means for a group to know something is not altogether different from defining what it means for an individual to know something (Hewitt & Scardamalia, 1998). In this vein, Derry et al. (1998) draw on the cognitive theory of information processing to conceptualise collaborative cognition. Similarly, Hinsz, Tindale and Vollrath (1997) describe an emerging view of groups as information processing systems. For example, during collaboration, students' privately held views are shared, rejected, reintroduced and so on. These views are combined, built upon and transformed into knowledge structures that are stored in the 'collective memory' of the group, which is embedded in the activity and the learning context (Holland & Cole, 1995). Jonassen et al. (1999) argue that a 'collective memory' (or to use their term, 'distributed memory'), is far more capacious and dynamic than individual memories.

While these collaborative cognitions may or may not be appropriated by all group members, the fact remains that they have evolved through the process of co-construction and therefore constitute group thought. "Shared information thus provides potential bridging relationships among otherwise privately held knowledge stores, linking all data in collective long-term memory" (Derry et al., 1998, p. 30). As has been argued in Chapter 5, however, recall of this knowledge depends on access to all contributing resources (social, physical, symbolic and intellectual), not only those internalised constructions that have been appropriated by individual students within the group. Given that these resources have collectively mediated the group's evolving understanding about something, it is feasible to expect that the group's cognition is embodied in and spread over these resources.

This point is integral to the analysis of group cognition within a DLE. Given that knowledge representations are largely embodied in the groups' interactions with each other (and with resources), the extent to which quality learning has occurred would necessarily be evident in the discourse that emerged through their collaborations. While it might be difficult to discern the actual structure of groups' knowledge representations, discourse analysis would unearth the sorts of cognitive processes that support, and are characteristic of, varying levels of understanding. This was evident in Hogan's (1999) study where she analysed both the socio-cognitive and interactional processes in group collaborations. Although she did not assess knowledge structures per se, she explored group discourse for evidence of the types of processes that presuppose deep, extensive and well-connected understandings.

This was also the aim of analysis within this investigation and so an analysis tool was devised that facilitated the examination of socio-cognitive processes in an effort to determine the extent to which the cognitive tool augmented and enhanced learning.

The framework that supported the development of this analysis tool is discussed as follows.

Framework for analysis

Models that describe varying forms, levels and phases of conceptual growth are evident in the literature. The descriptive categories within these models represent the evolving nature of student knowledge and are useful for assessing, among other things, the cognitive and metacognitive processes that are characteristic of particular knowledge structures. Given their endorsement of the ideals that subsume social constructivism (and subsequently distributed cognition), three of these models were identified as being potentially useful analysis tools for this study. Biggs & Collis' (1982) SOLO Taxonomy, Marton et al's (1993) conceptions of learning, and Jonassen and Tessmer's (1996) learning taxonomy each contain rich descriptions of learning outcomes which can be applied to both solo and socio-cognitive processes. A brief overview of each model follows:

- SOLO Taxonomy (Biggs and Collis, 1982)

The SOLO Taxonomy (Structure of Observed Learning Outcomes) is a set of five statements that reflect students' growing understandings of concepts in relation to particular tasks. These statements are indicative of the evolving nature of knowledge constructions – each one characterises a particular level of schematic growth which can be evaluated in terms of its structure and sophistication. As such, the SOLO Taxonomy complements ZPD theory (Vygotsky, 1978) in that it can be used to trace students' transitions within and between various zones. Prestructural responses, for example, indicate that the task is perhaps too abstract for a student requiring him or her to operate outside his or her ZPD. Given appropriate support, however, unistructural, multistructural or even relational responses may be possible. While these three levels are typically the target mode in any given task, extended abstract responses are indicative of students pushing beyond the level of abstraction at which the task has been set. Some teachers may misconstrue these responses as being irrelevant (or maybe even prestructural) rather than modal shifts between ZPDs (Biggs & Collis, 1989).

McAlpine (1996) has identified the SOLO Taxonomy as a useful tool for measuring depth of learning in computer assisted learning environments.

- Conceptions of learning (Marton et al., 1993)

These six levels of learning have emerged as a result of questioning university students about their personal interpretation of what learning means. As previously discussed in Chapter 5, Marton et al. (1993) found that students' conceptions varied in complexity and so described them as a hierarchy ranging from basic, low-level understandings where learning is seen as something that happens to students, to more sophisticated views where learning is seen as the result of an active effort on the part of the learner to abstract meaning from the material. Given that conceptions of learning have been found to influence students' approaches to learning, and subsequently their learning outcomes (van Rossum & Schenk, 1984), it is feasible to perceive Marton et al's (1993) hierarchy as a taxonomy of potential learning outcomes.

- Learning taxonomy (Jonassen & Tessmer, 1996)

This taxonomy was primarily designed in response to Jonassen and Tessmer's (1996) contention that traditional taxonomies (e.g., Bloom and Gagné), do not adequately address important principles evident in current learning theories. They write:

> [Current] views of learning believe that knowledge is distributed throughout the environment in which we work and is embedded in the artefacts and tools that we use to engage in meaningful work, as well as in the dialogue and social relations that bind communities of learners as they reflect on that work. (p. 28)

As such, their taxonomy is indicative of meaningful learning outcomes where active learners:

- interact with, explore and strategically manipulate their learning environment,
- intentionally try to achieve learning objectives,
- engage in dialogue with other active learners and instructional systems,
- reflect upon and articulate the processes of learning in relation to their experiences,
- generate assumptions, attributes and implications of what they've learned.

The three models were compared and combined to develop a thorough set of learning characteristics. This merger is presented in Table 9.1 along with a more detailed description of each model.

Table 9.1 Merger of learning characteristics

SOLO Taxonomy (Biggs & Collis, 1982)	Conceptions of Learning (Marton et al., 1993)	Learning Outcomes Taxonomy (Jonassen & Tessmer, 1996)	Merger of learning characteristics
Prestructural: Students engage the task but have difficulty in interpreting its requirements. Responses are illogical or irrelevant.	**Increasing One's Knowledge:** Students accumulate or absorb pieces of unrelated knowledge.		**Prestructural knowledge:** Students are engaged in the task but have difficulty in interpreting requirements. Responses are often illogical or irrelevant. If they are relevant, then they are usually isolated facts that either lack structure or are inadequately structured. These facts are typically rote learned or 'absorbed'.
Unistructural: Students are able to interpret task requirements, but only in terms of a 1:1 relationship between a selected concept and the information supplied by the task.	**Memorising and Reproducing:** Students rote learning information in order to recall pieces of knowledge.	**Declarative knowledge:** Students can recall, recognise and paraphrase declarative knowledge, albeit unstructured or inadequately structured knowledge.	
Multistructural: Students successfully relate task requirements to a number of appropriate concepts. However, interrelationships are not usually made.	**Using Knowledge for a variety of purposes:** When required, students use knowledge and skills that have been accumulated. Application, in this sense, does not presuppose understanding.	**Structural knowledge (basic):** Students can identify the relationships between one or more basic facts related to a task.	**Foundational knowledge:** Students have sufficient information in relation to a concept and can apply it to certain task related situations. There is a growing understanding of relevant concepts and the relationships between these concepts are beginning to form.
Relational: Students successfully select a number of concepts and identify the relationships between them. These interrelationships are used to form generalisations, which are consistent with the task data.	**Understanding:** Students use strategies that enable them to search for the meaning inherent in concepts.	**Structural knowledge (complex):** Students demonstrate that they have acquired a range of diverse and interrelated semantic networks in relation to tasks.	**Relational knowledge:** Students have acquired a highly developed understanding of a concept which is demonstrated in the way they are able to multi-link it with other concepts and topics. Learning strategies are adopted to enable students to develop understandings of the material which are often on a par with experts. Transfer to other similar contexts is possible.
		Mental models: Knowing what, when and why of a particular concept. The foundations for ampliative learning.	

SOLO Taxonomy (Biggs & Collis, 1982)	Conceptions of Learning (Marton et al., 1993)	Learning Outcomes Taxonomy (Jonassen & Tessmer, 1996)	Merger of learning characteristics
Extended Abstract: Students are able to select a wide range of concepts appropriate to the task requirements, and to interrelate these through the use of abstract universal principles not directly detailed in the task data. Students can formulate hypotheses and deduce from these that certain events are likely to follow. They can successfully introduce analogues not embodied in the data to explain principles.	**Seeing things in a different way:** Having understood the inherent meaning of a concept, students are able to look at it from a number of different perspectives.	**Situated Learning:** Students can successfully transfer knowledge of concepts and problems to authentic and diverse contexts.	**Extended abstract knowledge:** Students' understandings are so advanced that they can extend them to other similar and dissimilar circumstances. Application to authentic situations is automatic. There is evidence of understandings being abstracted to new constructs that are logical, imaginative and unique. As a result of these learning experiences, students grow and change within themselves.
	Changing as a person: As a result of learning experiences, students grow and change within themselves. These experiences lead to new understandings and appreciations.	**Ampliative Skills:** Students can use rules of logic and imagination to draw conclusions, explain implications and imagine a range of plausible possibilities.	
		Self-knowledge: Students use reflection and self-knowledge to identify cognitive and affective strengths and weaknesses.	**Metacognitive knowledge:** Students demonstrate their ability to control their learning by adopting a range of learning strategies. These strategies include those that can be used to manipulate the learning material, as well as those related to self. Self-reflection is adopted to monitor and control motivation, attitude and effort.
		Executive control: Students demonstrate their ability to control internal and external learning problem solving processes.	
		Motivation: Students demonstrate the willful manipulation of task attention, effort, and enthusiasm. They consistently display willingness, persistence and effort.	
		Attitude: Students demonstrate a healthy attitude towards tasks. They make choices in keeping with appropriate behaviour.	

These merged learning characteristics were subsequently converted into a workable analytical tool by translating the five levels of knowledge into corresponding discourse. Each level of discourse was described in terms of the types of socio-cognitive processes which were characteristic of the knowledge category it was derived from. However, not all dialogue within the transcripts could be classified according to these five types of discourse. There were instances where statements were made, or conversations were held, about issues that were either socially or technically oriented and in keeping with Herrington and Oliver's (1999) findings, these instances have been classified as either social or procedural discourse. Together, these seven types of discourse constituted the fundamental analysis tool, the descriptions of which are provided in Table 9.2.

Table 9.2 Analysis tool: Types of discourse

Type of discourse	Description
Social discourse	*On-task*: Any statement or question which is on task but relates more to the social interaction of the students than the task itself. *Off-task*: Any statement or question which is off-task.
Procedural discourse	*Equipment*: Any statement or question which relates to procedures of the equipment. *Software*: Any statement or question which relates to procedures of the software. *Task*: Any statement or question which relates to procedures of the task.
Prestructural discourse	Statements that are illogical, irrelevant, incorrect or incoherent. Statements about related declarative knowledge that are isolated from any other information. Statements that are indicative of memory recall or recognition of isolated declarative knowledge.
Foundational discourse	Statements that are indicative of a developing understanding – groups can identify more than one relevant concept and will endeavour to (either successfully or unsuccessfully) relate these concepts together. Statements show consistency and congruence with expert perspectives.
Relational discourse	Statements are indicative of the formation of a diverse, complex semantic network of interrelated concepts. Knowledge of these relationships is articulated freely and effectively to others. A range of strategies is employed to facilitate deep level understandings of material and explanations are logical, coherent and speedy.
Extended abstract discourse	Statements indicate the group's ability to apply concepts to a range of situations using learned operations. There is a sense of emerging originality and confidence to experiment with concepts in diverse contexts. Analogies are being drawn, abstract inferences made, as well as personal theories, all of which are highly plausible and sophisticated. As a result of these newly formed appreciations, changes are apparent in the way the group perceives concepts about certain phenomena.
Metacognitive discourse	Statements reflect knowledge about the group's ability as a learning entity - its strengths and shortcomings. There is an awareness of the learning context - what the task requirements are, what resources are available, how these resources can be used effectively, and what skills and processes will facilitate successful completion of the task. This incorporates knowledge and application of appropriate learning strategies (cognitive, metacognitive and resource management). Groups are able to articulate, monitor and regulate their effort, and demonstrate persistence and a willingness to learn. Choices are made that indicate a healthy attitude towards learning in general.

Data analysis procedure

This analysis tool was not used to assess a final product as such (e.g., an examination, assignment, presentation or concept-map) but instead, each category was used to determine the socio-cognitive processes that facilitated the development of group understandings. Because these processes were reflected in the dialogue that occurred during collaborative group work, the transcripts of class activities were the main focus of analysis (as opposed to the student interview and student journal transcripts).

These transcripts were coded in chronological order according to the class activities from which they were taken. The unit of analysis was based on the collective contribution of cognition in relation to a particular *theme* (or idea, or challenge etc). For example, the following excerpt is a theme about gaining student attention that has been built up across multiple students within one group, and has been coded in the 'foundational discourse' category:

> S1: What's first?
> S2: Well you need to consider how you're going to gain and maintain the students' attention if as Woolfolk says you need to get the lass's undivided attention because of the sensory register. If you don't attend to what's to be learned then you don't learn it.
> S3: Yes you need to have all their attention. It needs to be undivided as you say.
> S1: So I'll just put [types] "gaining undivided student attention" (CA1/2).

While many *themes* were relatively brief (as in the example above), they did vary in length. Within those that were lengthy, a number of different types of discourse were evident. In these instances the *theme* was divided up into *sub-themes*, each of which were coded according to the category it most closely represented. Appendix L is an extract from a transcript that is indicative of a *theme* that has been segmented into *sub-themes* based on the multiple categories evident within it.

Using NUD_IST as an organising tool, themes and sub-themes within all 12 class activity transcripts were explored using the data analysis tool and by following the data analysis procedure described in Chapter 6 (Table 6.9). Although the data was constantly compared and contrasted to ensure that classifications accurately reflected the attributes of the categories within the analysis tool, this process did not force the data into an *a priori* framework. Rather, it simply enabled the author to explore the data in greater detail. Schumacher and McMillan (1993) contend that this would still be considered inductive analysis as "Any starting point begins an inductive, generative, and constructive process because the final set of categories are not totally predetermined, but are carved out of the data according to their meaning" (p. 487). Furthermore, this process contributed to the fundamental definition of each category as the supporting data enriched and extended their specific features.

To ensure that confidence could be held in these categories, as well as the coding process, two independent coders were asked to conduct separate interrater reliability checks, otherwise known as 'check-coding' by Miles and Huberman (1994). These coders were given the analysis tool, the coding scheme (developed with NUD_IST) and 2 pages from each groups' transcripts for the first two recording sessions. The following formula (recommended by Miles and Huberman) was used to discern the extent to which the independent coding was consistent with the researcher's coding.

$$\text{Reliability} = \frac{\text{Number of agreements}}{\text{Total number of agreements + disagreements}}$$

A reliability rate of 90% was reached with the first coder, and 85% with the second coder. Given that Miles and Huberman (1994) recommend a reliability rate of 90% or better, the exercise was completed again with the second coder. This was a collaborative effort between the coder and the researcher, during which time the meaning inherent within a certain category (metacognition) was clarified. Following this exercise, a reliability rate of 95% was achieved, thus providing confidence in the overall coding process and, consequently, the findings.

Findings

One would expect that for the cognitive tool to have contributed to effective learning within the DLE, the students' discourse would be consistent with the sophisticated, more structurally oriented types of discourse. In reality, all categories were represented in the students' discourse - some to a greater and lesser extent. A summary of the nature and extent of this discourse is presented in Table 9.3. Accompanying this summary is a short definition of the particular category and an example of discourse taken from the transcripts.

Table 9.3 Summary of findings: Discourse evident in student collaborations

Discourse category	Characteristic	Summary of findings	Example from transcripts
Social (on-task)	Any statement or question that is largely social in nature but somehow related to the task.	Evident (intermittently) in all transcripts. Mostly occurred when students were explaining a concept and would go off on a tangent to a related but not very relevant issue.	S1: That's like with my daughter who was told ... she needed to vary her reading by the librarian ... she hardly reads anything anymore and ...(CA2/2G1)
Social (off-task)	Any statement or question that is off-task.	Evident (intermittently) in all transcripts. Usually in the form of one-sentence remarks that generally would not affect task progress. Comments often related to students being tired.	S1: What're we doing? S2: Can we have a break? S1: I'm going to the Royal Show Saturday. S2: Are you? (CA2/2G1)
Procedural (equipment)	Any statement or question related to the computer hardware.	Evident mostly in transcripts taken from the first data recording session where groups delegated control of the mouse and keyboard. Other comments were in relation to hardware and system problems.	S1: You type Deb. You're faster than us. S2: No probs ... (CA1/2G1) S1: ... our computer has just crashed again. S2: Quick start it up ... (CA3/2G3)
Procedural (software)	Any statement or question related to the computer software (*Inspiration®*).	Prevalent throughout all transcripts, but most significant in the first data recording session. Many comments, questions and exclamations made about how to use the software, and its various functions. As groups became more proficient users, these comments transformed into statements in relation to their desire to perform more complex and creative functions.	S1: Oh don't forget we have to ask [the teacher] about that little square we hit last week. (CA1/2G1) S1: I'm going to flick through the pictures here to make this look a bit better. (CA3/2G1)
Procedural (task)	Any statement or question related to the specific task which groups were completing at any given time.	Prevalent throughout all transcripts, albeit to a greater or lesser extent between groups. Those groups who didn't understand task requirements at the beginning of lesson spent much time trying to grasp the objectives throughout the rest of the class.	S1: So what are we doing here? S2: We're just doing implications of this – how we're going to organise our classroom to use this best. S1: I see. S2: So [typing] 're-cap what was learnt in the previous lesson'. (CA1/2G3)
Prestructural	Any statement or question that is illogical, irrelevant, incorrect, incoherent or isolated from any other relevant fact.	Mostly apparent at the introduction of topic modules where groups encountered concepts for the first time. Comments made would be based on misconceptions previously held or simply stating facts that lacked meaning.	S1: Actually you know constructivism seems to work really well in my art classes because ... it's outcomes based. You've got to think of the outcome first before you can write the program. (CA1/2G1)

Discourse category	Characteristic	Summary of findings	Example from transcripts
Foundational	Any statement or question that demonstrates a developing understanding of a concept. Students can identify more than one relevant concept and will endeavour to integrate them.	The most prevalent type of talk throughout the semester and across all groups. Evident when groups were trying to come to terms with concepts and their interrelationships. Questions were frequently posed and in relation to uncertainties about concepts. In most cases, these uncertainties were resolved with assistance from the teacher. Discussions occurred in conjunction with the concept-map, where its image was used as a visual prompt to activate conversations.	S1: Yes I know that but how do you actually control that? S2: ... I've had enough. S3: But hang on, we've already got it here [referring to map]. That's part of what we were talking about before with elaboration and ... rehearsal and those things that you do to learn something. S2: No that was levels of processing. S3: Yeah I know but ... S1: So if you're really thinking about how you're going to learn it and trying to be in control, you would try to elaborate like in a deep level way and not rote learn ... (CA2/2G1)
Relational	Any statement or concept that indicates the formation of a diverse, complex semantic network of interrelated concepts. Explanations are logical, accurate and speedy.	Prevalent in all transcripts but diversity between groups in terms of who exhibited this type of talk the most - some groups were more consistent than others. In attempting to explain or justify links made on concept-map, there was a sense of ease and automaticity that consisted of integrated and relevant ideas. Authentic contexts were often drawn on for explanations.	S1: Well the concept of constructivism to me is that it's a form of learning and teaching where teachers, instead of being the expository type ... who stands out the front and says "blah, blah" ... the constructivist teacher designs experiences where they capitalise on what the students already know, and goes from there. So on the video ... the first thing [the teacher] did was to get the kids to discuss the kinds of energy they already knew about ... (CA1/2)
Extended Abstract	Any statement or question that indicates the groups' ability to apply concepts to similar and dissimilar situations as well as authentic contexts. A sense of originality is emerging. Analogies are being drawn and sophisticated inferences made.	A few, but not many instances of this talk and only in one group. Comments made in these instances were rich, creative and on a par with an expert's definition. Attempts made to construct own theories about aspects of concept-maps.	S1: ... so like for the qualitative conception for reading you'd look for personal interpretations ... So like the person plus the text would give you the interpretation ... what I do with my students. Like I'll give them this little diagram of a stick person, a book and a light globe and this means that the person plus the text gives you your own meaning of the story. S2: ... you're letting them form their own opinions. (CA1/2G3)

Discourse category	Characteristic	Summary of findings	Example from transcripts
Meta-cognitive	Any statement or question that reflects knowledge about the groups' ability as a learning entity. There is an awareness of the learning context and the processes that will facilitate completion of the task.	Evident throughout all transcripts. In many instances, the concept-map was used as a metacognitive prompt. Based on the formation of the map, groups would identify areas that needed clarification. Maps were used to indicate the progress being made by the group. Evidence that groups would monitor each student's effort and give encouragement to keep on task.	S1: Guys, I'd really like to know a bit more about levels of processing. Where's the note card for it? (CA1/2G4) S1: Why haven't we got anything about prior knowledge here? S2: We do it's in the note card for ... no its not. S3: What should we put it with? What about ... (CA1/2G3)

The findings summarised in this table are further elaborated below.

Social - on-task

In many instances, groups were in the midst of explaining or commenting on a concept but their explanations took them off on a tangent to a related, albeit not very relevant, issue or point. At times, groups were attempting to draw on authentic examples to explain points but they quickly digressed and lost sight of specific task requirements. This mostly happened when concepts were applied to family members or personal classroom experiences, as in the example in Table 9.3.

Initially these instances were misconstrued as a type of structural knowledge in light of the groups' attempts to apply concepts to a range of contexts. However, in keeping with the intention of the analysis framework, classifications were made on socio-cognitive processes in relation to task requirements. Because these groups deviated off the topic, their dialogue became more social than structural.

Other types of social on-task dialogue were those where groups discussed their experiences of learning within the unit. Often, these instances were in relation to, a) the collaborative learning process or, b) using *Inspiration®* as a learning tool. For example:

> S1: You know I'm quite impressed that we remembered so much from last week.
> S2: Because there was so much visual representation it made it easy – don't you think?
> S3:...But you know I'm amazed how well we've tuned into each other's thoughts about this. We've only been working together for three weeks and already we're thinking alike. (CA1/2G1)

Social - off-task

Statements classified as social off-task were those which were completely unrelated to the task requirements. These comments were usually in relation to groups' social lives, student lives or their physiological state, for example:

> S1: Can I just go to sleep?
> S2: No you can't. You can do some typing now.
> S1: I couldn't. I've got a headache coming on. (CA1/2G3)

Because these comments were relatively rare and intermittent, they did not appear to disrupt the groups' thought processes.

Procedural - equipment

Statements classified here were those that related to the groups' interactions with the computer hardware – their feelings towards the types of computers being used, who should work the mouse and/or keyboard, disk issues and computer breakdowns. For example:

> S1: What are we doing?
> S2: I don't know. I'm trying to copy stuff onto my disk.
> S1: If this was an IBM it would be so much easier.
> S3: Just click off it. (CA3/2G3)

While these sorts of statements were generally rare, they increased when hardware and system problems occurred.

Procedural – software

Given that none of the groups had used *Inspiration®* before, there were many discussions about how to navigate the interface, what the many functions did, how they could perform certain functions, and more. For example:

> S1: And what's this red box here all about?
> Tr: That's just telling you that you've created a note-card for that concept. So if you double click on it you can open up the note-card. Oh there's nothing in it.
> S2: No we haven't done that yet.
> S1: The other thing we want to know is how you bring in pictures?
> Tr: You can bring them in from this symbol library over in the margin but you can actually see that there's hundreds of pictures in the library so you click these arrows. (CA1/2G1)

While this type of discourse was particularly prevalent in the first few weeks of the semester, it became less noticeable once the groups became more skilled users. With this proficiency, however, came comments in relation to the groups' desire to perform more creative and sophisticated functions (e.g., how to make the map more aesthetically pleasing, how to make the map more complex in terms of multilinks, how to merge maps, how to take short cuts etc). There were also complaints made about what the software could *not* do once the groups became familiar with what it *could* do.

Procedural – task

Discussions about the tasks (e.g., what they mean, how to do them, how to involve *Inspiration®*) were prevalent throughout all activities and in all groups, albeit some more than others. These discussions typically took place at the commencement of a new activity and intermittently thereafter in an effort to monitor progress. For example:

> S1: Okay, number two 'what approach to learning would you like to encourage in your classroom'?
> S2: We talked about that.
> S1: Okay 'Explain the presage, process and product characteristics that would typically be applicable to a surface learner'. So we can do some things from each of these too [pointing to concept-map].
> S2: Yeah, like stress and anxiety.
> S1: Competition. Why don't we do a rapid fire off the surface learner?
> S2: Yep. [types].
> S1: No that's not what we're doing. We're looking for the types of things the surface learner exhibits. Like they only do the minimum to survive. (CA3/2G1)

In contrast, those groups who did not fully understand task requirements to begin with were constantly trying to do so throughout the remainder of the lesson and devoted a considerable amount of discussion to this cause.

Prestructural

Discourse coded here was generally a consequence of discussions classified in the previous category. When groups were unable to grasp task requirements, they often embarked upon conversations about concepts that were irrelevant. This mostly occurred when groups attended to trivial aspects of the task at the expense of the more significant ones. For example:

> S1: Okay maintenance rehearsal is basically - it's by the articulatory loop. It's where you only store it for a while, for like 1.5 seconds for all that you can remember and then it goes into the memory. So like I said before, a phone number for example. And that comes out by forgetting, by interference and by decay. But the main bit which we are very similar about [comparing her map to Bronte's] is the rehearsal...
> S2: Elaborate rehearsal, articu ... what? Stop, stop, stop, stop. What did you say about articuplanctory hoop? Were we meant to know this?
> S1: [laughing] No. I don't think so. I don't think it's important. Yeah but I thought it was interesting how the prior knowledge is what we call constructivism. Isn't that interesting how we've both linked that?
> S2: Yeah. I can't remember why though. What are we supposed to be doing again? (CA1/2G4)

Prestructural discourse was also evident when students witnin groups skimmed over communications with one another without attempting to actively process the information. Comments were vocalized and then blindly applied to the concept-map with few attempts to transact meaning. For example:

> S1: But do you know the term 'cognition' will never change.
> S2: Put that in the map - very profound. What is cognition [laughs]?
> S3: What is cognition? Type that in too...that's profound too. Like "what is knowing"?
> S1: Like you cognise over something when you think about it.
> S2: We never used that word twenty years ago when I did my teacher training. (CA1/2G1)

Low-level socio-cognitive processes, where groups recalled information in a form which was unchanged from its original source (usually the text), were coded here also. These facts, which were copied verbatim onto the concept-maps, were isolated from other relevant pieces of information or meaningful links. For example:

> S1: Oh look [reading Woolfolk] "Extrapolate is when you take the idea further". Add that in as a um, as a bit of, as a tidbit.
> S2: Thank you. To it's nth degree. (CA1/2G1)

Often, the identification of these isolated facts was a necessary starting point upon which meaning could be later attached.

Foundational

Compared to the other categories, discourse characteristic of foundational knowledge was the most prevalent throughout the three recording sessions. In these instances, the groups' prior knowledge about concepts were pooled, evaluated, questioned and challenged. There appeared to be a genuine commitment towards understanding the material which was evident in the students' attempts to explain concepts, relate them to personal experiences and fit them into their concept-maps in logical and meaningful ways. For example:

> S1: We were saying that...it goes to the working memory first so whenever you need it, you bring it out and then it goes into your long term [pointing to map]. Do you know what I mean? Because it has to go through the working memory - every thing has to go through the working memory.
> Tr: All your knowledge is housed in your long-term memory, but when you activate it for whatever reason, you bring it back into your working memory to deal with it.
> S1: That's what we should put here 'activation' because it's a strong term that makes you know...
> S2: It is. I like that word 'activation'. [typing it in to note card]
> S1: Cause your activating the software - opening up a file.
> S2: And in the book it says you've got to concentrate on it and put effort into it to make it work.
> Tr: What's effort?
> S2: Concentration. Focus.
> S3: Time.
> S2: Understanding it.
> S3: Basically working it through.
> S2: And you're trying to transfer it into your long-term memory.
> Tr: Tom you say you're working it through. What's that?
> S3: You're thinking about it, trying to make sense of it.
> S2: And we're trying to link it to what we already know about that to build on it...
> S1: To fit the puzzle. (CA1/2G4)

In this example, it is possible to see how a thought, which has been distributed across a group, has become a reasoned view co-constructed by multiple members. While the group has not attained a particularly deep understanding, they have laid the structural foundations of the concept upon which more elaborate, complex understandings can be built later.

Given that the groups were grappling with largely unfamiliar concepts, there was much uncertainty and indecision. While students brought a range of relevant ideas to the activities, it was their attempts to fit these ideas into meaningful schemata (both on the concept-map and in their heads) that fueled discussion and argument. The visual appearance of the concept-map, in particular, often led to a sense of dissatisfaction as to the meaning of certain concepts in relation to other concepts. If one or more students within a group opposed the spatial placement of a concept, then a discussion would follow where perspectives would be explained, argued, questioned and challenged. For example:

> S1: Yeah. It's not new. Those [pointing to map], don't they go under...
> S2: Declarative and conditional...
> S1: Don't they go under metacognition? I wouldn't put them there.
> S2: Metacognition is thinking about thinking.

S1: Yeah. Knowledge about knowledge and procedural, conditional and declarative are all different types of knowledge.
S2: Right. But that's - they're kinds and types of knowledge but metacognition is knowing about this knowledge.
S3: It's a different type of knowledge - it's not any of them.
S1: No it's all of them.
S3: Declarative knowledge is just trivia and facts. How can that be metacognitive knowledge?
S1: Because it's...
S2: If it's not any of them then what kind of knowledge is it?
S3: It's not really a kind of knowledge like those three. It's just being able to think about those different kinds of knowledge when you're trying to learn them. So say you're trying to learn how to shoot a basket, that's sort of like a procedure, instead of just going up to the ring and throwing the ball, you would think about how far you are away from the ring, how heavy the ball is, how hard to throw the ball and stuff like that. So you're always thinking about how you're going to do it and the best way to do it.
S1: If they don't go there then where? (CA1/2G3)

These differences were mostly resolved within the lesson but typically in conjunction with the teacher. Having recognised that a group was experiencing a type of circular conflict where resolution seemed unlikely, the teacher would intercede and encourage all members to articulate their concerns. Through teacher-questioning, students were encouraged to reflect on, justify and defend their positions, a process which not only fostered the development of joint understandings, but also guarded against the degeneration of conversations into irrevocable conflicts (as was evident in some collaborations held in Part 2 of this study).

There were numerous attempts to draw on real life examples (albeit simple ones) to explain concepts and how they might relate to other concepts. This process authenticated the activity for the group and consequently was an important step in strengthening their understandings. This is evident in the following example where the group has simplified terms and ideas as they have become more comfortable with their meaning. The complementary partnership between the group and the cognitive tool is also evident in this example as the students incrementally build on shared ideas which emerged from the concept-map:

S1: Do you know what I'm thinking right at this point in time?
S2: What is that?
S1: These are different types of memory we have right and memory is prior knowledge, so these must some how link up...with the declarative, procedural and conditional knowledge right?
S3: That's what I'm trying to figure out. Can you just go back to see what we've got? [on concept-map]
S1: [reading concept-map] So procedural is just procedural. Episodic and semantic are - semantic is everything we know, all the facts and figures that we know. Episodic was more images.

> S3: Semantic is where we store knowledge about things. It's the schemata, isn't it? It's presented as a scheme of things that link on and relate to one another if they're common - like the concept-map right?
> S1: Memory is knowledge so is it a type of knowledge?
> S3: Yeah but I think they're just trying to show you where different types of knowledge is stored. Different store houses for different knowledge.
> S1: So it's like a big envelope for semantic memory, one for episodic memory and one for procedural. (CA1/2G2)

Relational

There was a greater diversity between groups in terms of the transition to relational knowledge. While all groups did conduct conversations characteristic of relational knowledge, some groups did so more consistently than others. Characteristic of this type of knowledge was the ability to make logical and coherent inferences based on the integration of new ideas with concepts already displayed in the concept-map. For example:

> S1: [pointing to parts of concept-map] Ah okay we've rehearsed it, we've acquired it, we've done all that sort of stuff so now we're going to stick it in to the long term memory here.
> S2: How are we going to do that?
> S1: Link it to something.
> S2: How do we do that?
> S1: Make it meaningful.
> S2: Oh yeah, that's a good one. Apply it to real life situations so they can see it has application. But ... that's in the rehearsal yeah?
> S3: Well it depends - no. Rehearsing can just be 2 x 2 = 4 ... and you just say it over and over.
> S2: You're right it's what Sean said about linking it. Don't worry about me.
> S1: It's make meaning and try to understand the subject, your times tables and everything by linking it to your prior knowledge.
> S3: That's elaboration isn't it - linking the known to the new? (CA1/2G2)

As concepts became firmly embedded in existing knowledge structures, there was an obvious ease and automaticity with which they were discussed and explained. Because there was less uncertainty and indecision, conversations were more fluid and there was a greater acceptance of, and interest towards, multiple perspectives. For example:

> S1: ... But just think about it. If you were more aware of how you learn, do you think you would be a better learner? If you set yourself goals and monitored your understanding and did what you had to do to learn it well, do you think you get better marks?
> S2: Probably. I don't think it could get much worse anyway.
> S3: Have your piano students improved?
> S1: They seem to be more organised and more into it. It's like you give them some responsibility for their own learning and they lap it up.
> S3: So what did you do?
> S1: Well rather than tell them to do this exercise or play this piece ... I ask them what they would like to do, why they want to do that particular thing and how they are going to do it and it's like they're thinking about these things for the first time. And I don't know

> maybe I'm imagining it but they seem to play better when it's because they decided to do it rather than me telling them to do it as part of the lesson.
> S2: Well I know that's true of me when I play jazz and it goes back to making things relevant to you because I play atrociously pieces I'm told to that I loathe but do really well with the ones that are favourites.
> S3: Yeah but you probably practice those more.
> S2: Oh yeah I do but I also practice them with meaning and feeling and I listen with edge and...
> S1: But that's it - that's the question [reads] "to what extent can students learn without deliberately controlling their learning processes"? You disagreed - no you said you don't have to be deliberate in learning and now you're saying the exact opposite ...
> S2: I still think you can. But what I'm saying is that you probably learn better when you do think about it. (CA1/2G2)

This skillful distribution of ideas facilitated the groups' articulation of abstract concepts and their evolving understandings. While conflicts and discrepancies were still evident, they were handled in a more proficient manner. The teacher still mediated most of these instances but it was generally to facilitate a more advanced understanding of a concept rather than a foundational one as was the case in the previous category. For example:

> S1: [teacher comes over] ... See up the top you said metacognitive and I really agreed with that because it's so connected. But I was thinking that what you were saying is that that was the executive control processes which links it back to the processing in the information processing model. So I was thinking you put metacognition under the executive control processes so that's how we're linking it to that. Does that make sense...?
> Tr: Yes sure. It makes good sense because it shows that you're thinking about this in relation to the IPM ... You're saying "How do these learning strategies fit in to the IPM". That's great. And yeah you're right that your metacognitive processes are ... the same as your executive control processes because they both oversee learning don't they?
> S1: Okay cool. I just thought rather than go on I'd check first because it was confusing us at first. (CA2/2G4)

Interestingly, relational knowledge often emerged in conjunction with a groups' decision to reorganize the layout of their concept-map. As their understandings developed so too did their confidence to experiment with a range of spatial possibilities. In justifying these rearrangements, groups articulated thoughts and ideas that were representative of well-connected knowledge structures.

Extended abstract

In keeping with Biggs and Moore's (1993) contention that the presence of extended abstract learning outcomes is a rarity in classrooms, groups in this study engaged in conversations representative of these types of cognitive processes infrequently. In fact, there was only one incident across all three data recording sessions where a conversation within a group made the transition from relational discourse to extended abstract. In this instance, the group was attempting to integrate information processing ideas into constructivist-oriented teaching contexts. Having previously reflected on these ideas in relation to his own class, one student shared a diagram he constructed that would encourage his students to search for meaning in film genre based on their previous experiences. For example:

> ... so like for the qualitative conception for reading you'd look for personal interpretations wouldn't you? So like the person plus the text would give you the interpretation ... [it's] what I do with my students. Like I'll give them this little diagram of a stick person, a book and a light globe and this means that the person plus the text gives you your own meaning of the story. So meaning is the focus of the ... the objective. (CA1/2G3)

This student not only transferred an abstract concept to an authentic situation but did so in a particularly unique and creative way. The diagram (stick person + book = light globe) may appear simplistic but, in essence, it effectively captures the core of constructivism in relation to his own area of teaching. Based on understandings developed in previous collaborations, he has personalised a theory which, having shared with the group, was used as the basis of more abstractions.

One or two extended abstractions were also evident in whole class collaborations. While these discussions were not the focus of analysis, the following thought was shared by a participating student in response to a previous comment that learning strategies are not taught in schools:

> I think that it's not just that we don't teach students those strategies, it's the consequences of not teaching them. They are not taught them so they're not aware of them so they don't use them not only in the present but in the future so it's like a cycle of ... And it's a cycle for the teachers too ... [teachers] have to know about them themselves before they can get the students to know about them. We're caught in a cycle and unless we recognize that then the students are going to remain unaware. It's really ... up to the teachers I think. (CA2/2WC)

In this example, it can be inferred that a higher level of abstraction has been reached in that the student has encouraged the class to look at the *consequences* of a concept as it is applied to a particular context. Rather than take the concept and its relationships at face value, she has looked beyond the information given and proposed an hypotheses that has taken the discussion to new heights.

Metacognitive

Throughout the semester, there was evidence that the concept-mapping tool encouraged the groups' use of their executive control. Clearly, the concept-maps were not only visual records of what the groups understood, but also a suggestion of what they didn't understand fully. Missing links, incomplete note cards, or the absence of concept bubbles would serve as prompts for groups to reconsider their progress. For example:

> S1: I think we need to include the 3P model in our map somewhere.
> S2: How, where? (CA3/2G2)

There was a group awareness of knowledge construction procedures, for example:

> S1: Is the map helping you understand the concept a bit better?
> S2: Yeah I think so. It's pictorial – what is it?
> S1: Visual.
> S3: Yeah visual, so you can see it all better and see how it all links. (CA1/2G3)

There was a group awareness of changes to their conceptual structures, for example:

> S1: And I'm confused about the one we did last week now.
> S2: Why? How does [it] differ to what you've talked about today?
> S1: It's not making sense to me now because I think we've done these in the wrong places. We've put this [levels of processing] over here as software when actually parts of it are the working memory and parts of it are ... the long-term memory and parts of it are the procedure ... that's got to change I reckon. (CA1/2G4)

There was a group effort in monitoring and regulating learning, for example:

> S1: [looking at placement of levels of processing on concept-map] Yeah I think it would go somewhere else too ... that's not right.
> S2: What?
> S1: Levels of processing. Isn't that what we're talking about? You've confused me now. Don't we want to ... I think ... I don't think it should go in there. It's linked but it's not the same as ...
> S3: You've confused me as well [laughs]
> S2: Can we just get on with the note cards? Let's just move on and maybe it will come to us. (CA1/2G3)

And there were general reflections made in relation to feelings, attitudes and physiological states about the task and their evolving knowledge, for example:

> S1: This is actually starting to all fall into place ... shall we add that one to our map? (CA1/2G1)
> S2: I think it's looking quite good. You can get the overall gist of what the IPM is all about by looking at how the concepts flow. (CA1/2G2)
> S3: This is the first time I feel confident that I know what we're doing ... ? (CA2/2G4)
> I'm taking in so much. I'm listening and going "Wow this sounds so right and familiar to me". It's funny actually because this class relates to all my other classes. (CA3/2G4)

These examples are indicative of the varying functions and levels of metacognitive reflection. For example, groups practiced basic metacognitive knowledge when they identified what they did or did not know, as well as more complex metacognitive knowledge when they acknowledged changes in their conceptual understandings. In a way, the concept-maps enabled the students to observe the changing state, or the 'runability' (Henderson & Tallman, 1998), of their mental models whereby the identification of incomplete schema led to the assimilation of new information and/or the deletion of irrelevant information.

While these varying levels of metacognition emerged throughout the semester, and in all groups, they appeared to coincide with the quality of collaborations that occurred at any one time. Prestructural discourse, for example, was supported by basic metacognitive learning strategies, whereas relational discourse was supported by more sophisticated learning strategies and metacognitive awareness.

Discussion

Each category above represented a type of conceptual discourse that contributed in its own way to the groups' learning outcomes. Social discourse allowed group members to gauge each other's commitment to, and perceptions of, the learning situation while procedural discourse operationalised the task and computer demands. Prestructural discourse enabled the students to pool their knowledge resources and foundational discourse provided the basic infrastructure upon which relational discourse could take place. With sound understandings of the intricate relationships between concepts in place, extended abstract discourse allowed some students to attain higher levels of thought while metacognitive discourse mediated the entire collaborative experience.

However, even though each type of discourse was essential to the overall learning process, the socio-cognitive processes behind each one varied in complexity. For example, social, procedural and prestructural discourse was generally representative of lower-order socio-cognitive processes whereas structural discourse (foundational, relational, extended abstract and metacognitive) was representative of higher-order socio-cognitive processes. Therefore, for the cognitive tool to have augmented and enhanced learning, it was hypothesised that structural-oriented socio-cognitive processes would prevail within group collaborations.

The following graphs in Figure 9.1 provide an overview of the extent to which structural socio-cognitive processes were evident in comparison to the other categories during the three recording sessions and for each group.

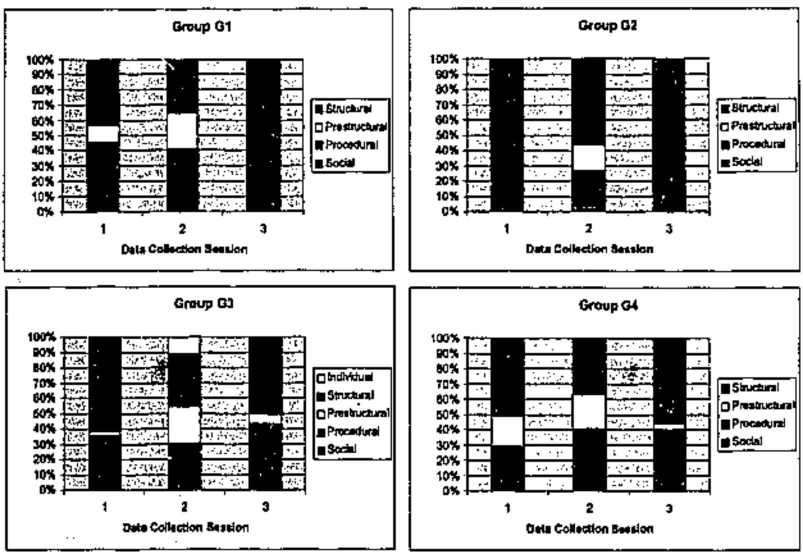


Figure 9.1 Comparison of discourse within groups across the three recording sessions

Given the temporal nature of DLEs, along with the fact that conceptual change is evolutionary and involves the gradual adjustment and reorganization of central concepts (Tyson, Venville, Harrison & Treagust, 1997), a considerable degree of prestructural discourse was expected to prevail in the first recording session as the groups grappled with largely unfamiliar subject matter. Similarly, it was expected that procedural discourse would dominate initially given the groups' inexperience with *Inspiration*® and computers as learning tools. These types of discourse were then expected to subside as a stronger focus on structural discourse emerged alongside the groups' growing proficiency with the concepts and the computer software and hardware.

This scenario was partially evident in that substantial structural discourse was apparent in the final recording sessions for each group. During this class, between 50 and 70 percent of all four groups' discussions featured discourse which was indicative of either structural, relational, extended abstract or metacognitive knowledge. There was a definite sense of group solidarity where collaborations between the computer and the students facilitated the development and consolidation of conceptual relationships. However, this relationship with the computer was not automatic. At the beginning of the semester, discussions were held *at* the computer, where thoughts and ideas were developed first then recorded in the concept-map. Eventually, students began to incorporate the computer more into their groups and, as such, discussions were held *around* and *with* the concept-map (Crook, 1994).

There was no prestructural discourse evident in the third recording session for Groups 1 and 2, and only a small amount for Groups 3 and 4, which perhaps is suggestive of the groups' attainment of higher levels of understanding of concepts, or at the very least, their efforts to reach higher levels of understanding. The presence of approximately 20 percent of procedural discourse in all groups was largely in relation to technical problems with the computer hardware which occurred that day. While still relatively low, social discourse was at its highest for most groups during the third recording session. Interestingly, this social discourse was largely in relation to on-task discussions that were so in-depth that the groups often lost focus and direction.

There is no consistent pattern, however, across the first two recording sessions, nor across all four groups. For example, in the first recording session, Group 2 participated in structural discourse almost 80 percent of the time. Their explanations and challenges were firmly grounded in existing knowledge which facilitated discussions that were comprehensive and typically situated in authentic situations. This finding is believed to be an outcome of both the group's previous knowledge of the topic (information processing), and the DLE within which this collective memory was nurtured into well-connected knowledge structures.

Although still relatively high (approx 55%), structural discourse for the same group decreased in the following recording session. Given that there were four students in this group, this decline may be due to Hurwitz and Abegg's (1999) assertion that computer-based learning is most favourable in groups of three.

Prestructural discourse, on the other hand, was higher indicating the group's efforts to come to terms with new concepts. This was the case for all groups during the second recording session within which the topic of Learning Strategies was being tackled for the second consecutive week. This suggests that this topic was perhaps a little more complex than the others. Consequently, each group devoted between 15 and 30 percent of their time trying to understand individual facts before integrating them into meaningful, interconnected conceptions.

Procedural discourse was also prevalent in the second recording session, particularly for Groups 1 and 4. In looking at the specific breakdown for these two groups, most of the procedural-oriented discussion was in relation to the task. In both instances, these groups misinterpreted the task requirements and consequently spent up to 40 percent of their time trying to rectify the situation. Upon reflection, the task may have been too ambiguous for the students, which is in contrast to the specifications of DLE framework. Had the task purpose and requirements been more transparent, it is assumed that procedural discourse would have been less prevalent during this recording session.

Group 3 also experienced some degree of difficulty in their efforts to collaborate during the second recording session. The outcome was a patchwork of various types of discourse that did not really dominate in any one area. Furthermore, there were times when this group entered into dialogue that was more individually oriented than collaborative. In these instances, there was a disconnection between group members and so attempts to distribute their cognition to one another were unsuccessful. Although they spoke to one another, it was not to build upon each other's thoughts, and aspects of tasks were largely completed independently. This is evident in the following example, where one member of the group worked on the concept-map as he spoke aloud to himself:

> S1: Maybe we need to create...what we can do is um...
> S2: It would be easier to just start again for this one (Pablo takes the keyboard and starts typing without saying what he's thinking about. After a while he says...)
> S1: I suppose metacognition. (CA2/2G3)

Interestingly, the concept-map enabled the other two members to see (to an extent) what he was thinking as his thoughts became visual on the screen. More inferences about this group are discussed in Chapter 10.

On the whole, however, it can be said that structural discourse had a strong presence in each recording session. When presented with a task or concept, there was consistent evidence in the data that groups reflected on their combined prior knowledge, made inferences about it, determined its implications in relationship to other concepts and made attempts to fit it into a coherent explanation. This was typically done in the presence of the concept-mapping tool, which clearly provided the group with visual representations of their developing understandings. Given that the socio-cognitive processes needed to construct these understandings were complex and required a higher level of thinking, it can be inferred that the learning context was conducive to this type of learning. In other words, the cognitive tool within the DLE, promoted higher level socio-cognitive processing and kept 'low-level directive interaction' (Henderson et al., 2000) to a minimum.

Conclusion

The findings suggest that the characteristics that presuppose the development of foundational knowledge, relational knowledge, metacognitive knowledge and (possibly) extended abstract knowledge were present due to a form of socially organised intervention with the computer. Collaborative group work with and around the computer fostered the conditions that lead to quality learning outcomes in a DLE. Interaction with the cognitive tool appears to have mediated the groups' attempts to place structure in their dialogue, identify gaps in their understandings and take the appropriate steps towards integrating knowledge.

Due to the prevalence of foundational discourse in the data, it appeared that the cognitive tool was particularly useful in supporting students in their endeavour to make sense of the material and work it into some form of logical structure upon which deeper understandings could be developed. In terms of the phases of learning addressed earlier in this chapter, foundational discourse can be equated with the intermediate phase where students are neither novices nor experts but are attempting to arrange an isolated set of facts into coherent, integrated and memorable understandings. This endeavour can be challenging, frustrating and, at times, difficult to accomplish. However, the cognitive tool appears to have successfully supported and perhaps even promoted (given the prevalence of foundational discourse) the cognitive processes that facilitate learning within this phase.

Given the prevalence of metacognitive discourse throughout the semester and across all groups, it appears that the cognitive tool can be a useful resource in encouraging students to become self-directed, self-motivated and skillful learners. The value attached to this finding increases substantially in light of theorists' claims that these skills can be transferred to other learning situations - even those where the cognitive tool is not present (Salomon et al., 1991; Salomon & Perkins, 1998; Underwood & Underwood, 1990). While cognitive transfer was not the focus of this study, the fact remains that learning *with* the cognitive tool promotes metacognition, which enables students to become increasingly adept in their field of study (Jones, Knuth & Duffy, 1993) is integral to effective learning in general.

The visual component of the computer clearly served a useful purpose. The images produced by *Inspiration®* provided a basis for discussion amongst the groups. Conversations held about the meaning and interpretation of these images enabled the groups to uncover their partial understandings of concepts. This metacognitive facility was prominent throughout the semester as a means for groups to control and regulate their learning.

Additionally, it was apparent in this study that the teacher's role in this collaborative environment was of central importance. Whereas some approaches to computer-based learning threaten to remove the teacher from active participation in student learning, teacher intervention in this study was crucial. By participating in the groups' conversations, the teacher was able to determine the appropriate times at which she could share a level of expertise about the topic that would resolve cognitive disputes or extend understandings. This was particularly evident when the groups were engaged in dialogue representative of the more structurally-oriented socio-cognitive processes. In these instances, the teacher was also able to monitor the groups' collaborative abilities and model techniques that facilitated the students' efforts to transact meanings and develop a common knowledge base.

Ferry, Kiggins, Hoban and Lockyer (2001) also found teacher-input to be essential to computer-mediated communications. In their attempts to provide teacher-education students with a general view of the professional habits and obligations associated with primary-school teaching, they devised a knowledge-building community within which students communicated with each other using a range of collaborative computer technologies. They found that providing the appropriate conditions for this type of learning environment, as well as frequently monitoring student progress, is only half the battle. Regular contributions from the teacher are also integral to the development and maintenance of rich student dialogue and, subsequently, the construction of shared understandings.

Perkins (1992) asserts that, within a DLE, input from the teacher is initially extensive but then decreases gradually as the students become competent, independent distributors of knowledge. While the temporal span of this study did not permit such findings to be confirmed, it was apparent that the need for the teacher to explicitly model the distribution of cognition lessened towards the end of the semester. Nevertheless, her mediating contributions to the student collaborations were clearly valuable throughout the semester.

In an attempt to explore these collaborations further, and to discern the nature of the relationships between the cognitive tool, the students and the learning environment as a whole, the following chapter explores these experiences from the perspectives of the students. In response to the final research question, Chapter 10 focuses on the students' feelings towards computer-based learning and the DLE, the outcome of which is an insight into the ways in which the cognitive tool effectively mediated learning.

-10-

Students' Perceptions of Cognitive Tools and Distributed Learning Environments

Chapter Overview

In the previous chapters, the DLE framework was explored, implemented, analysed and then used as a catalyst for the implementation of a cognitive tool. The compatibility between the DLE and the cognitive tool was then assessed in terms of the socio-cognitive processes this environment encouraged. In an effort to gain a greater insight into the ways in which the cognitive tool supported these socio-cognitive processes, the final phase of the study sought to examine the students' experiences of using the computer as a cognitive tool in a distributed learning environment. Consequently, the third and final research question was posed:

> *What reactions typify students' responses to the use of computers as cognitive tools in a distributed learning environment?*

This affective aspect of the study not only provided insights into students' perceptions of how cognitive tools contributed to their learning but also the extent to which they were prepared to adopt computer technology into their learning culture. Given that student commitment to resource-based learning is a key component within a DLE, rejection of the cognitive tool would potentially adversely affect the overall success of this type of learning environment.

Therefore, the student interview and student journal transcripts were examined using the data analysis procedure described in Chapter 6 (Table 6.9). This analysis procedure is briefly described followed by the findings.

Data analysis procedure

Analysis of the interview and journal transcripts was once again an inductive process where patterns in the data led to the development of four primary themes which the students identified as being significant in relation to their experiences with the cognitive tool in a DLE. The coding process was carried out over three integrated stages using the data analysis procedure presented in Chapter 6. Due to the large volume of data collected for this research question (39 interview transcripts and 13 journal transcripts), coding was carried out in four batches. The first three batches were the interview transcripts (13 per batch) and the fourth batch was the journal transcripts.

Using NUD_IST, student statements within these transcripts were segmented into units of meaning by constantly comparing and contrasting them. The classification of these units of meaning was based on a combination of ideas that came from the data, related literature and the study's theoretical framework. These initial categories were tentative and were used as flexible working tools for making sense of the numerous pages of data. Moments of confusion were usually overcome by writing anecdotal notes which enabled the researcher to uncover the properties of the emerging themes. Lincoln and Guba (1985) have recognised this as a very significant stage in coding, not only in the identification of a category's attributes, but also in the identification of rules by which assignment of segments occurs. Thus the initial and somewhat intuitive process of classification was replaced by a more concrete, rule governed judgment system.

Having defined the preliminary categories, they were then arranged on a table against which supporting data was coded. This tabular display of the categories and the data gave the researcher an intelligible overview of the nature of each category, thus making coding more fluid and rigorous. Finally, these categories were refined, merged and sorted into four primary themes and their respective sub-themes. These themes are presented as follows.

Themes

The first two themes were in relation to the students' perceptions of how the cognitive tool contributed to their learning. For example, there were numerous references made about the various ways in which the cognitive tool was a partner in their learning. The collaborative, visual, metacognitive and motivational components of the concept-mapping tool rendered it an important member of group negotiations. In addition to this, the students identified the learning environment as one that promoted a deep approach to learning. Mindful involvement with the cognitive tool and authentic activities encouraged learning for understanding as opposed to the accrual of meaningless information.

The third theme was in relation to the students' perceptions of computer technology as a learning tool and its role in education in general. There were widespread references throughout the interview transcripts and student journals to the computer as a requisite tool in their teaching careers. Based on the belief that most schools expect teachers to be computer literate, the students voiced a strong desire for a heavier emphasis on computer-based learning in all education units.

The fourth theme was in relation to negative feelings the students held towards both cognitive and practical aspects of the cognitive tool. Although these perceptions were not typical of the data in general, their existence provided insight into some of the findings in the previous chapters. A more detailed description of these four themes is provided in Table 10.1 along with examples from the data.

Table 10.1 Themes to emerge from the students' perceptions of the cognitive tool

Theme	Sub-theme	Description	Example
Partner-ships	Collaborative partner	According to the students, the process of developing concept-maps with others generated group discussions. Students stated that discussing ideas and building them into the maps were interdependent elements that enhanced their understanding of the concepts.	S: [*Inspiration*® is] great. It helps us a lot with what we're thinking and talking about. It's not like they're two separate activities, you know talk then go to the computer... It happens at the same time (IM3/2).
	Visual partner	According to the students, the visual component of the concept-maps enriched their understandings by allowing them to comprehend concepts and their relationships pictorially. It provided them with a visual representation of internal schemata.	S: ... If anything ... [*Inspiration*® has] helped us see what things mean. It's like a visual picture of what the concepts mean and it just makes more sense when you can see it (IB2/2)
	Metacognitive partner	According to the students, a keen awareness of resources (cognitive tool, peers and learning strategies in particular) was fostered by the learning environment. Students recognised their concept-maps as important metacognitive tools. Also, the goals set were generally indicative of higher-order objectives, which were realistic and oriented towards understanding.	S: ... I think the computers have been good as tools – tools that have helped us learn ... tools that have gotten us talking and thinking (IN3/2). JE: My expectation of *Inspiration*® is to help me map out what I've learnt in the unit and hope it will be a ... useful organization tool to help me understand and organize the information I've gathered (JBr).

Theme	Sub-theme	Description	Example
	Motivational partner	According to the students, the ease and flexibility of the software made learning an enjoyable experience. Following the maps' progressions was motivating. As they grew in size and complexity, so too did the students' desire to develop them more. The relaxing, communal nature of the learning environment fostered a willingness to share ideas and take risks with the design of the concept-maps.	S: ... I enjoy trying to get each concept and make them relate ... Looking back over the concept-maps has been amazing. There's so much work there and you can see the thinking that's gone into them and they trigger off thoughts by just looking at them (IN3/2).
Deep approach to learning	Active pursuit of understanding concepts	According to the students, the pursuit of using the cognitive tool in a DLE fostered a desire to understand the material, the process of which was mentally demanding and required effort.	S: ... I think the whole idea of linking things, of being forced to find ... lots of different links – that really gets you looking ... You have to develop a better understanding, a deeper understanding, a clearer understanding by seeing how the relationships are developed (IN3/2).
Computer as an integral tool for teacher-education	Computer-literate teachers	According to the students, schools expect teachers to be computer literate if they are to cultivate prospective students' computer literacy. It is paramount, therefore, that teacher-education students be exposed to computer-based learning environments if they are to fulfil they job expectations.	S: ...Computers are in the schools so ... they should be in the universities too so we can learn about them and not be so technophobic anymore (IB1/2). S: Students are going to be using them in the future. As a teacher, if you're not computer literate ... you're going to be in trouble. (IT3/2)
	Education courses too conventional	According to the students, most core education units are not keeping abreast of technological advances, nor are they actively promoting current learning theory. While students perceive a need for education to incorporate cognitive tools into its culture, certain barriers make this aim difficult.	S: If you look at some of the theories they teach us ... they don't do anything like that in the classes ... My criticism of education is that they've not kept up with the times ... [computers are not integrated into the units] because they don't see a need to. The courses have been taught in such a way for so many years that there's no need to upset the apple cart (IB1/2)
Negative feelings	Cognitive issues	According to some students, collaborative group work was not conducive to effective learning. Also, the cognitive load associated with having to learn the software as well as the unit material was seen as problematic.	S: [The learning environment is] ... noisy. Someone always has something to say. They're usually the loudest and they have to be heard every week. It's group work every week ... that's fine but I think there should be a bit of your own private time too. [Collaborative group work is] fine but it's not the best way to learn ... I prefer working independently. (IP2/2)

Theme	Sub-theme	Description	Example
	Practical issues	According to some students, one or two specific functions of the software were inefficient. Also, the hardware was believed to be problematic in that the MACs were incompatible with PCs used beyond the classroom. System crashes were also described as frustrating and detrimental to general progress.	S: [The visual representation of the map is] a pain [because] you can't see it all in one go or print it out on one page ... a bit bitsy. That would be good to see it all pieced together. (IS3/2)

These findings are elaborated upon and discussed as follows:

Discussion

- Partnerships

According to Gilbert (1999), when cognitive tools are accessed as partners in learning, "the [student] and the computer work in an interactive partnership, directed by the [student's] intent" (p. 254). The cognitive tool becomes a *functional organ* which enhances the student's ability to represent problems, envision solutions and provide visual feedback. In this regard, the cognitive tool moves closer towards achieving the claims cited earlier that it can both amplify and augment cognitive activity. Therefore, based on the findings in this study that the students perceived the cognitive tool to be a collaborative, visual, metacognitive and motivational partner, it can be inferred that the cognitive tool contributed to effective cognitive functioning.

Furthermore, given that the DLE is based on the principle that learning is a partnership between the students and contextual resources, it can be inferred that the *partnership* theme was a direct by-product of the environment within which learning took place. Through careful orchestration of the tasks, curricula, teaching and assessment methods, the students were enculturated into this partnership which, in effect, enabled them to participate in the distribution of their cognition. According to the students, the precise way in which this partnership manifested itself was directly related to the cognitive tool.

For example, interactions with the cognitive tool were seen as being integral to the collaborations that occurred between the students as the visual representation of concepts stimulated intensive discussions.

> Q: You've obviously got a good grasp of this. How did you learn all of this?
> A: Talking, talking and talking some more and just looking at where it's all ended up on the map ... We just debate and present views on what we read, or didn't read but have an opinion about anyway. Tom and Nat don't mind a bit of a debate so we strip concepts down to the bare basics and won't move on until we all agree what they mean and if they're in the right spot on our map. (IB2/2)

This finding suggests that the infrastructure for distributing learning to one another had clearly been established and embraced by the students as being crucial to their learning. Collaborative pathways were not only a means of accessing social resources but, more importantly, fuelled the entire DLE framework. Also, because these collaborations were identified by the students as being crucial to making sense of the material, this partnership was clearly important. In fact, many students stated that their concept-maps and their overall understandings would have been less developed had they been constructed individually. Furthermore, it can be inferred that this partnership was enhanced by *Inspiration's®* superior visual component in light of Gilbert's (1999) assertion that cognitive tools function more like partners in learning when their representational capabilities are increased.

In fact, the visual component of the cognitive tool had several advantages which the students recognised as being particularly helpful to their learning. Because the concept-symbols and their descriptive links were quickly and easily recognised by the students, there was less of a strain on their group's collective working memory to activate previously learned concepts. Also, the spatial arrangement of the concepts allowed for development of a holistic understanding of the topic-modules that words alone could not convey:

> Q: So the concept-map is part of your discussions?
> A: Oh yeah ... it's sort of like a visual representation of what's going on in the discussion ... and that's excellent for me because I'm not good at picturing concepts ... It's allowing me to focus on understanding and it's doing the picturing for me. So it's freeing up my working memory if you like. (IB2/2)
> Q: How have you found using the software?
> A: It's good cause it's organized my thoughts and I'm quite a visual learner. If I can see a picture of it then I'll understand it better. (IS1/2)

Furthermore, the visual representation of the concept-map encouraged the students to not only uncover their thoughts, but to reflect upon them in a metacognitive way. Reflecting upon one's own experiences and cognitive development is an important element of self-directed, autonomous learning. Metacognitive learners are aware of not only their goals and objectives in completing a learning task, but the strategies necessary to do so. They monitor their progress, evaluating and proceeding accordingly. This continuous engagement in reflection ultimately enables students to become increasingly adept in their subject domain (Jones et al., 1993).

The notion of metacognition was raised frequently in the student interviews, which is not surprising given that it was an integral part of both the DLE framework and the unit material. However, while there was a general acknowledgement of the important role played by resources in the process of learning, the computer (in particular) stood out as a tool that promoted metacognitive awareness. Not only did the concept-map enable students to visualise their prior knowledge, which facilitated the process of linking it to new information, the spatial arrangement of concepts also encouraged the students to evaluate their overall understanding of concepts, diagnose potential misunderstandings and take steps to reorganize concepts in more meaningful ways:

> Q: Do you think [*Inspiration*®] has helped you learn the material?
> A: It's reinforced it ... made me more metacognitive. Basically it's made us look at what is important in our notes and where do these things fit and what should they be linked to? Where does the flow go? And it keeps on reinforcing it and each week there's a change and you look at it and you think "Gosh why didn't I put that there and how did that affect that"? (IN1/2)

This type of metacognitive self-evaluation, where students attempt to diagnose what they *don't know* as well as what they *do know*, is vital to processing information deeply. Bereiter and Scardamalia, (1989) contend that without this knowledge, "... the only kind of learning goal one can set is to learn more about a topic" (p. 375). The desire to know *more* about a topic is at odds with the basic tenets of a DLE where the objective is to *make sense* of information and to build a comprehensive picture of concepts and their relationships. If parts of this picture are missing then students must call upon appropriate resources that will enable them to determine where the deficiencies lie and how they can be resolved. From the students' perspectives, the most appropriate resource in this instance was the cognitive tool.

From both an affective and cognitive point of view, the students found the learning environment very motivating. There was a definite sense of enjoyment and interest in the class activities, and an appreciation of the relaxed, communal atmosphere. The cognitive tools were highly motivating in that they were novel, offered variety within each class and enabled groups to work at their own pace. It can be inferred from the students' statements that their positive reactions to the cognitive tools led to an increase in effort and an overall sense of satisfaction with their accomplishments. These positive attitudes also contributed to the development of a warm classroom climate which were defined in Chapter 7 as being important within a DLE:

> Q: Can you describe the learning environment as you see it in our classroom?
> A: I think it's positive because ... I think most people are genuinely happy putting the effort in and trying to understand the concepts and see how they all fit together on the map.
> Q: Why is that?
> A: ... maybe because it's different to most other education units. Maybe because it's a bit of a change for once and we're all working in it together. (IB3/2)

The immediate feedback provided by the visual component of the concept-maps challenged the students to reconsider and rearrange the links all the while adding depth to their understandings. Mayes (1992) contends that the interactive properties of cognitive tools capitalise on this type of intrinsic motivation in that they engage students in the act of thinking. Similarly, Fisher (1992) argues that cognitive tools "serve as an *inducement* to think as well as a tool for thinking with" (p. 68). She goes on to say that "The challenge and satisfaction involved in organising and polishing one's knowledge representation can be addictive" (p. 68). While the students in this study did not discuss their experiences with the cognitive tool as addictive, they were nonetheless, motivating and rewarding.

In essence, the four components of this partnership are interrelated in that their existence is dependent upon and fuelled by each other. For example, through interaction with the computer, the students were able to visualise their developing understandings of concepts, which frequently stimulated discussion and further collaboration with their group. This collaboration (in conjunction with subsequent visualisations) acted as a metacognitive prompt enabling the students to discuss both what they did and did not understand. This experience was clearly motivating for the students which influenced subsequent interactions and learning outcomes.

Clearly, the cognitive tool's visual component played a leading role in this interrelationship given that it initiated and maintained discussion. Without the visual image of the concept-map (and the ease with which this image could be manipulated and transformed), it can be assumed that collaborative, metacognitive and motivational affordances would have been less accessible. Although further research is necessary, this interrelationship may address (to some extent) Chan Lin and Reeves' (1994) concern as to *how* interaction with computer graphics enhances students' academic goals.

- Deep approach to learning

While this theme is essentially an outcome of the previous one (i.e., when used as a partner in learning, the cognitive tool promotes learning for understanding) the extent to which the students' discussed it in the data has led to the development of a separate category. Throughout the interview transcripts, students referred to learning as an endeavour to *make sense* of the unit material. There was a distinct desire to understand the relationships between concepts, rather than simply remember facts for future recall. According to the students, the concept-map was an important resource in this endeavour as it generated the type of discussion necessary for deep level processing. van Boxtel, van Der Linden and Kanselaar (2000) support this finding with their assertion that concept-mapping facilitates the type of discourse that is considered important in stimulating conceptual understanding.

Interestingly, many students said that their groups' interactions with the computer *forced* them to search for meaning within concepts, and the very act of collaboratively linking ideas together made passive involvement difficult. Learning, then, was an active pursuit where students drew on a range of resources and cognitive processes in an effort to understand the material. The intensive discussions which transpired support this view given that their momentum could only have been achieved through the involvement of mentally attuned students. While the students frequently described this intensivity as demanding, tiring, hard, challenging and tough, they appeared to accept it as an unavoidable characteristic of the learning environment:

> Q: Has *Inspiration®* affected your learning?
> A: ... it's forcing us ... to put everything into perspective. It's hard but I've sort of gotten used to it now ... it's making me make the links and I'm thinking "Oh yeah, that makes sense". At the moment we're just doing a skeleton map and working out what links to what but even in doing that it's helping us get a better understanding of the bigger picture ... (IN2/2)

However, this acceptance should not be confused with compliance where cognition has been distributed simply as a consequence of participation within a DLE. Apart from the fact that student-commitment is paramount to the distribution of cognition, cognitive tools will only be successful if "students ... agree that thinking hard is a meaningful goal unto itself" (Jonassen, 1992, p. 258). This acceptance, therefore, can be equated with the students' commitment to, and recognition of, learning as a mentally demanding, *intentional* pursuit where the construction of knowledge is a goal rather than an incidental outcome (Bereiter & Scardamalia, 1989). The DLE framework, therefore, was an invaluable catalyst for the development of this intentional mindset.

According to Wild (1996), the intentional construction of computer models (such as the concept-maps in this study) has implications for the mental models that they represent. Mental models are internalised conceptions of phenomena and because they are typically constructed incidentally, they are not generally readily available for reflection, nor are they easily manipulated. However, because the construction of computer models involves sophisticated thinking about concepts and their interrelationships, the mental models they represent are more accessible, relevant and flexible. Consequently, because the construction of the *Inspiration®* concept-maps was a conscious process - one that required the groups' active mental involvement - it can be inferred that the mental models they represented will be more meaningful and readily accessible for future recall, interpretation and communication.

- A requisite tool for teachers

Another clear source of students' enthusiasm about working with cognitive tools was their conviction that computer-literacy was or would soon be a requisite in their teaching careers. They perceived computers as being so pervasive in schools that familiarity with a range of software and hardware would be a professional necessity. Thus in describing the role computers would play in their positions as teachers, the students frequently used phrases like:

> It's a must. It's the way of the future (IB1/2)
> It should be a standard expectation ... to be able to access and use computers (IB1/2)
> It's the future. Computers are in the schools so ... they should be in the universities too ... (IB1/2)
> I think they have to come into everything. (IB3/2)
> I think they're the way the world is going and those who choose not to learn them will be at a disadvantage – that includes lecturers and students and kids in the classrooms too. (IJ2/2)
> I think it's really important being a teacher to be able to use the computers otherwise students run rings around you and it's another resource you can use in the classroom. (IS1/2)
> Teachers are going to be expected to use them so the people who teach the teachers should also be teaching them how to use the computer. (IS1/2)
> As a teacher, if you're not computer literate within the next five years you're going to be in trouble. (IT3/2)

Accompanying this enthusiasm, however, was an element of concern that computer-based learning was not more prevalent across *all* units within the students' respective courses. While the students were generally willing to implement *Inspiration®* into their own classrooms based on their recent experiences with it, they were less willing to adopt other applications as cognitive tools. On the whole, the students felt ill-prepared to integrate computer-based learning in schools, and generally dissatisfied with their training in this area. A similar finding was reported in Byrum and Cashman's (1993) study into pre-service teachers' perceptions of educational computing. In asking the students in this study why they thought computers were not more prevalent in other units, they responded:

> A: I think it's because of the class sizes. A lot of the classes are too big for everyone to be sitting around a computer. (IM2/2)
> A: I think the lecturers' knowledge of the computer and the software would have a lot to do with it (IM2/2)
> A: I think a lot of people have a fear. A fear of time. Some people can't seem to put in the time I guess.
> A: I think because ... it's sort of a relatively new concept and maybe the changes will come around ... Maybe they don't have the funding. Maybe they don't have the know-how (IS1/2)
> A: The teachers we've had are predominantly ... not familiar with technology and to be fair to them the classrooms just aren't set up for it. This uni was built in the times when all you needed was a blackboard so it's not easy to bring in computers unless you go to a lab. And I think also people are afraid of technology. They are intimidated by it and they don't want it to make them look dumb in front of the class (ISc1/2)
> A: It's threatening if you don't know it and it takes a lot of time too I'm sure. (IU1/2)

While these responses generally relate to practical issues, other students draw on the 'culture' of education to explain why computers have not been established as learning tools across all units:

> A: It's a cultural mind-set. I think there's a bit of a mind block to stay away from computers (IM2/2)
> A: Maybe ... they don't see a need to. The courses have been taught in such a way for so many years that there's no need to upset the apple cart. (IB1/2)
> A: A lot of lecturers are of the older generation and they're not about to learn. They've resisted learning them in the past and while they're around the culture will remain as it is. (IP3/2)

Others have argued along these lines and claimed that the integration of technology into the discipline of education has been resisted simply because it does not sit comfortably with existing university culture (Pearce, 1993). While this argument might appear dated, a recent exploration of tertiary students' access to and competency with information communication technology (ICT) suggests that little has changed. In their comparison of ICT skills between courses among university students, Oliver and Towers (2000) reported that Education, Training and Childcare returned the lowest scores whereas the more technically oriented disciplines of Science, Engineering and Computing scored the highest.

In this vein, it can be argued that because education is traditionally a non-technical discipline, the possession of computer skills has not been a prerequisite for successful completion of related courses. Consequently, exposure to technology is usually superficial and based on the objective of learning *about* computers rather than how students can learn *with* them. As such, content within this domain is generally taught using the more traditional approaches.

- Negative reactions to the cognitive tools and the DLE

In addition to the themes that revealed the students' positive perceptions of the cognitive tool in a DLE, negative perceptions also emerged. For example, for the same reason that some students in Part 2 did not distribute their learning to social resources, the preference for individualised learning made it difficult for one student in Part 3 to come to terms with collaboration. His dislike of collaborative group work not only impeded his attempts at distribution, but also appeared to affect his perception of the cognitive tool in general. Although he recognised the merits associated with the concept-mapping tool, he believed that the collaborative way in which he interacted with it was detrimental to these merits being realised. According to this student, collaborating with others around the cognitive tool was a risky and inefficient way of learning the unit material:

> Q: What about *Inspiration®*? Has that helped [you learn the concepts]?
> A: Not yet no ... For me, I have to go read, then I'll come back and use *Inspiration®* to help me put it into a more clear picture which is difficult if the others have got their own ideas that are not like mine. But anyway, if I don't read or understand the text first *Inspiration®* won't be any help to me so it's taking up time that I could be doing it properly by myself (IP2/2)

This student was a member of Group 3 whose discourse was occasionally found to be 'individually oriented' in the previous chapter. Clearly, his aversion towards collaboration surfaced in his interactions with his group to the extent that the other students' attempts to distribute cognition were also suppressed. This inference is supported by the following statement made by another member of Group 3:

> Q: ... Can you describe the actions taken by your group to create this map?
> A: As we always do it – Pablo types and pretty much takes the lead and Sally and I input our thoughts. We don't talk too much about it – we just do it.
> Q: So it's not really a collaborative effort?
> A: Yes and no. We discuss things a little but I find Pablo is very single-minded and so if he believes the map should have something in it or changed somewhere he just does it without really talking to us about it. (IB2/2)

The implications of this finding are two-fold. For example, had student resistance extended beyond this one student, would the entire fabric of the DLE framework been jeopardised, and if it had, how might the teacher have overcome this problem? In the event that a large number of students were opposed to any element of the participation infrastructure, it can be inferred that the DLE framework would be negatively affected. Given that collaboration, using resources and strategic thinking are the trademarks of DLEs, even erratic participation by a large number of students would be detrimental to the overall flow of distribution. Assuming that the only way to resolve this problem is to promote the learning benefits associated with distributing cognition, the teacher would have to persistently encourage his or her students to adopt this approach. This solution, however, presents ethical implications.

If the teaching and learning methods used to promoted distributed cognition are in opposition to the students' preferred learning styles, can it be inferred that the teacher is in fact *imposing* his or her own belief upon the students? Certainly, the frequent appearance of the term *force* in the data implies that the students had no other choice but to comply with the requirements of the learning environment and adopt its learning methods. While this outcome might be favourable in terms of guaranteeing the success of a DLE, forcing its features on students whose learning style is diametrically opposed to its principles is potentially unethical. However, because the students mostly used the term *force* to describe the way in which the framework sustained and encouraged, rather than dictated its defining principles, the ethics of this study have not been compromised. The fact that some students consciously rejected aspects of the participation framework supports this claim.

Cognitive overload was also identified by some students as being a problematic factor in using the cognitive tools. For example:

> Q: How do you feel about using *Inspiration®* as a tool in this class?
> A: Um ... concerned at this stage. I think there's still so much about it that I don't know and we're always trying to learn about the different keys and things so that sort of gets in the way of getting on with the activity. (IT1/2)

However, these sorts of comments were rare and were mainly made in the first recording session when some students were still coming to terms with the cognitive tool's functions. Most students believed *Inspiration®* to be an easy tool to learn which did not interfere with their attempts to learn the material. Nevertheless, the students did believe *Inspiration®* had its limitations which were largely related to practical issues.

For example, as the concept-maps grew in size over the course of the semester, the students were frustrated that they could only view one or two sections of it at a time. Reduction of their maps to fit one page meant text was illegible thus voiding the students' ability to view their thought processes of a topic in its entirety:

> A: What do you think about using the map as an overview of what you've learnt in the unit?
> Q: Yeah good. It's good but it's a pain that you can't see it all in one go or print it out on one page ... a bit bitsy. That would be good to see it all pieced together. (IS3/2)

Furthermore the outline view which is a text version of the links between concepts did not reflect the links between concepts as the students interpreted them. For some reason, the software arranged the relationships between the concepts according to its perception of the main concepts. Given that most of the students' concept-maps were not hierarchical, this 'ranked' representation was not accurate. The outline view therefore was not a correct summary of the interrelationships between concepts and could not be used as a point of reference for later study.

In addition to these software problems the system's hardware did not seem to like the visual demands of *Inspiration®* and each week computers crashed and screens would freeze for no apparent reason. The following extract from a journal illustrates the students' exasperation in relation to this problem:

> Macintosh computers are very frustrating, in particular the ones in room 302. They are constantly crashing, losing material, freezing, getting my disk stuck ... and other very frustrating problems (JB2)

As is indicated in this example, many students held Macintosh computers responsible for these problems. While they were not to blame for most of the crashes, the students were equally frustrated at their inability to continue their maps at home given the incompatibility between the Macs and PCs, which most of the students used beyond the classroom environment:

> Q: Are you enjoying [the concept-maps]?
> A: ... yes but it's frustrating when you can't bring it home. You kind of get pumped up and motivated in class and you want to continue a line of thought and links at home but you can't - well I cant because we've got IBMs ... (IW2/2)

Conclusion

Although some negative perceptions were evident, the students generally felt very positive towards the cognitive tool and the learning environment. In light of the three positive themes to emerge from the data, the majority of the students appeared to have perceived the cognitive tool as a partner in their learning, one that was motivational and encouraged collaboration and learning for understanding. Their experiences of using the computer as a cognitive tool led many students to question the lack of computer-based learning in other units within their courses, given their perceptions that computer technology will prevail in learning environments in the near future.

Despite the challenges posed by cognitive tools and the DLE in general, these findings suggest that students are willing to move away from the more traditional approaches to learning and adopt tools and methods that facilitate meaningful, purposeful learning. While a DLE does not offer students (nor teachers for that matter) an effortless approach to learning, the opportunity to attain an understanding of the subject matter by exploring concepts socially (and with a range of mediating resources) is, it seems, well worth the exertion.

Furthermore, this study suggests that the use of a cognitive tool within a DLE can promote intentional learning, a goal that typically eludes educators and students alike. Given that intentional learning, where students are consciously attuned to the demands of the tasks and the learning environment, is crucial to effective learning, this implication holds much promise for learning environments in general. The generic nature of the DLE means that its features can be adapted to any type of learning environment and, indeed, can accommodate any number of (*good*) cognitive tools. Consequently, this combination would appear to have the potential to induce intentional learning across a broad spectrum of learning contexts. Provided all features of the DLE are implemented appropriately, the partnership that powers this intentional learning has the ability to induce rich cognitive and affective gains in students of varying age groups and disciplines.

Nevertheless, this conjecture, along with those that have emerged from the investigations described in Chapters 8 and 9, poses implications for teachers and students alike. Following a summary of each investigation, the next chapter explores these implications and suggests opportunities for further research in this area.

-11-

Conclusions

A summary of the study and its findings

The aim of this study was to develop a framework for the implementation of cognitive tools such that effective learning was promoted. Cognitive tools were defined as computer-based devices that promoted reflection and student-regulated knowledge construction. Providing the students' learning intentions were favourable, cognitive, social, affective and (arguably) administrative affordances were described as attributes of *good* cognitive tools that had the potential to facilitate the development of deep understandings and extensive knowledge structures. However, in keeping with claims that these types of learning outcomes can be realised only when cognitive tools are implemented within learning environments that are conducive to their inherent attributes, exploration was undertaken to identify this environment and, subsequently, to develop an appropriate implementation framework.

Given that the attributes afforded by cognitive tools are closely aligned with the principles of social constructivism, this literature base was consulted and found to be particularly supportive. Based on the fundamental belief that knowledge is mindfully constructed in partnership with a range of contextually defined resources, this theory endorsed the use of cognitive tools as mediating devices that promoted active mental engagement. Social constructivism also acknowledged the shared, distributive nature of learning and postulated that cognition is not an individual pursuit but is spread over an array of resources found within the learning environment. These resources were categorised as *social, physical, symbolic* and *intellectual* and it was suggested that while it is possible to learn by drawing on only one resource (e.g., an individual's intellect), cognition is most powerful when it is distributed across a variety of resources.

In researching this belief, the literature on distributed cognition was consulted and was subsequently introduced in this thesis as an extension of social constructivism. In effect, the discussion on distributed cognition provided rationale as to the means by which learning occurs in a social constructivist learning environment. For example, when completing a task collaboratively, the cognitive effort contributed by a student influences the joint achievements of the group, which in turn, alters the student's existing cognitions. A spiral-like distribution of cognition is formed when the student's altered cognitions are once again contributed to the group, thus resulting in subsequent, altered joint performances (Salomon & Perkins, 1998; Salomon et al., 1991). Add to this the mediating effects of other resources (e.g., concept-maps, computer applications, texts, calculators, etc) and learning becomes "a recursive, bidirectional [affair within which] mediated activity simultaneously modifies [the cognitive state of] both the environment and the [student]" (Cole & Engeström, 1993, p. 9).

The research design

In an effort to define the characteristics by which this scenario is encouraged in the classroom, an extensive literature review on distributed cognition was conducted and a distributed learning environment framework was developed. This process was the first and most important part of the study, given that the success of each part thereafter was contingent on the quality of this framework. In keeping with the principles associated with *action research*, each of these parts transpired as a result of three interrelated plans of action that were devised in an effort to determine the extent to which cognitive tools contributed towards effective learning when implemented within a DLE. Figure 11.1 is a pictorial overview of the research design and illustrates how the three interrelated plans worked in unison to address the main investigation (as opposed to isolated sub-investigations).

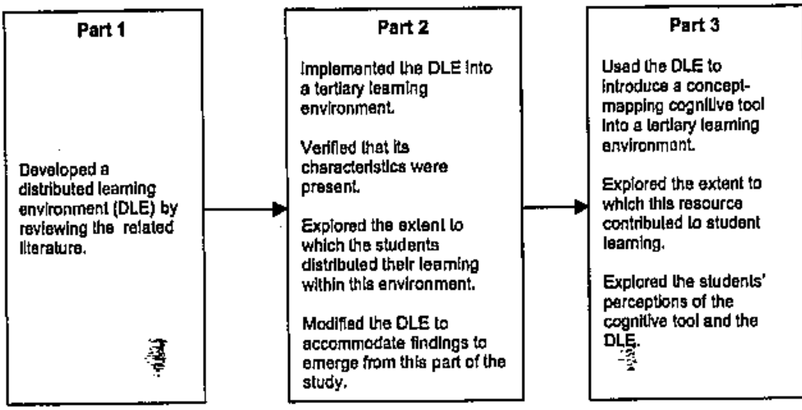


Figure 11.1 Overview of research design and its three interrelated plans of action

As is evident within this diagram, the first plan constituted Part 1 of the study where the literature was reviewed in an effort to develop a DLE framework. The second plan constituted Part 2 where this framework was implemented and the students were observed to determine the extent to which they distributed their learning within this setting. The final plan constituted Part 3 of the study within which the DLE framework was used to introduce the cognitive tool. During this part of the study, the extent to which the cognitive tool contributed to student learning was assessed, as was the students' perceptions of using the cognitive tool within a DLE. The findings of each of these parts are briefly addressed below.

Part 1 The DLE framework

The DLE framework consisted of three interrelated components (*teaching context characteristics, student characteristics* and *process characteristics*) and functioned in the same way that a system might. Although the defining features differed within these three components, their presence in the classroom was mutually dependent. For example, it was argued that the *process characteristics* would proceed accordingly only if the *student characteristics* were favourable, which in turn was contingent on effective implementation of the *teaching context characteristics*. Conversely, it was stated that the *teaching context characteristics* would have little effect if the *student characteristics* were not conducive, which would ultimately adversely effect the *process characteristics*.

The *teaching context characteristics* were described as factors within the teaching context that are influenced by the teacher. It was suggested that through careful orchestration of tasks, curricula, teaching and assessment methods, the teacher shows students how to participate in distribution through the processes of collaboration, using resources and thinking strategically. However, effective implementation of these features is dependent upon the teacher's commitment to the principles of distributed learning, which in turn, impacts upon the *student characteristics*.

The *student characteristics* were associated with the students' perceptions of the learning environment and their roles within it. These perceptions are believed to influence the students' commitments to distributed learning methods, as well as their acceptance of the responsibility they have for their own learning and the learning of others. Consequently, they affect the way students approach their learning, that is, the processes they adopt. *Process characteristics* were defined as the students' use of social, physical, symbolic and intellectual resources.

While each component was described as being essential within a DLE, the *teaching context characteristics* were identified as particularly important. It was suggested that unless these features were present, the likelihood that the other components' features would prevail was low. In particular, the teacher's commitment to the principles of distributed cognition was identified as being paramount. While it was acknowledged that some *teaching context characteristics* are fixed institutional features (e.g., curriculum content), most are teacher-controllable and a direct reflection of the teacher's commitment towards distributed learning.

This framework paved the way for exploration into the study's three research questions. Following the implementation of the framework into a fourth year Bachelor of Education unit, the first research question sought to determine the extent to which students distributed their learning within this type of environment. The findings from this part of the study and Part 3 are discussed below.

Part 2 Implementation of the DLE

RQ1: To what extent do students distribute their learning within a distributed learning environment?

Satisfied that all elements of the DLE framework had been implemented appropriately, data was analysed to explore the first research question. To gain a comprehensive insight into this concern, this question was initially looked at from the point of view of the resources which the students accessed in the learning environment and distributed their learning to. Consequently, analysis was carried out in four stages and in response to the four resource categories – social, physical, symbolic and intellectual.

While each of these resource categories was accessed frequently throughout class activities, the extent to which cognition was actually distributed to them varied. For example, in attempting to discern the extent to which students distributed their learning to social resources, five categories were identified ranging from instances where there was no distribution to instances where quality distribution was apparent. Similarly, in examining students' distribution to physical resources, three types of reflective thought were evident in their journals. The first type was characteristic of spontaneous thought about concepts and cognitive processes. The second was deeper in that reflections were more critical and analytical, and the third was deeper again in that reflections were abstracted and extended to other contexts.

Discerning the extent to which learning was distributed to symbolic resources was less straightforward compared to social and physical resources. For example, although qualitative differences were evident in the diagrams constructed by the students, even the less elaborate ones had the potential to encourage deep cognitive processing given that their deficiencies provided insight into what the students *did not know* and consequently needed to develop further. Therefore, rather than presenting a continuum of categories for this resource category, all of the symbolic resources accessed by the students were discussed in terms of the way in which cognition was distributed to them. Content-specific language, for example, enabled students to develop a common language base as well as a method of negotiating concept meanings. Inscriptions on the board, student notes and other language symbols were used by the students to index meaning.

Distribution of cognition to intellectual resources was evident in that students used a range of cognitive, metacognitive and resource management learning strategies. The extent to which each of these types of learning strategies was used was not evident in the data although cognitive strategies appeared to be more prevalent. Given that learning is enhanced when all three types are used consistently, this perceived deficiency needs to be further researched in the context of a DLE framework. Although there were instances where the students unintentionally accessed their intellectual resources, distribution was largely active and students made concerted efforts to link new information to their existing knowledge structures.

Part 3 Introduction of the cognitive tool into a DLE

RQ2: *How does a cognitive tool contribute to student learning when implemented in a distributed learning environment?*

The findings from Part 2 confirmed that the DLE framework successfully encouraged students to distribute their learning to resources within the classroom. With this in mind, the DLE framework was used as a catalyst for the introduction of a computerised concept-mapping tool known as *Inspiration®* into the same unit but in the following semester. In an effort to determine the effects of the cognitive tool, four groups were audiotaped on three separate occasions as they collaborated with each other around *Inspiration®*. The discourse to emerge from these collaborations was subsequently analysed for the sorts of socio-cognitive processes that support and are characteristic of varying levels of understanding.

Seven categories of discourse were identified, each of which represented a type of conceptual discourse that contributed in its own way to the groups' learning outcomes. For example, *social discourse* allowed group members to gauge each other's commitment to and perceptions of the learning situation while *procedural discourse* operationalised the task and computer demands. *Prestructural discourse* enabled the students to pool their knowledge resources and articulate misconceptions, and *foundational discourse* provided the basic infrastructure upon which developing knowledge structures could be based. *Relational discourse* facilitated the development of the intricate relationships between concepts and *extended abstract* discourse allowed some individuals to attain higher levels of thought. Finally, *metacognitive discourse* mediated the entire collaborative experience.

However, given that *social, procedural* and *prestructural discourse* were generally representative of lower-order socio-cognitive processes whereas *foundational, relational, extended abstract* and *metacognitive discourse* were representative of higher-order socio-cognitive processes, it was expected that these latter categories would prevail if the cognitive tool was to enhance learning. While the lower-order socio-cognitive processes were evident, group discourse was mostly representative of the high-level socio-cognitive processes that support quality learning. It was concluded from these findings that collaborative group work around the computer fostered the conditions that led to quality learning outcomes in a DLE. Interaction with the computer appeared to have mediated the groups' attempts to place structure and coherency in their dialogue, identify gaps in their understandings and take the appropriate steps towards integrating knowledge.

RQ3: What reactions typify students' responses to the use of computers as cognitive tools in a distributed learning environment?

Even though the findings from research question two suggested that the cognitive tool supported the development of deep socio-cognitive processes, the students' perspectives were subsequently sought in an effort to determine the precise way in which this support manifested itself. A range of themes emerged from this inquiry, most of which related to the students' perceptions of the cognitive tool as a collaborative, visual, metacognitive and motivational partner in their learning. For example, through interaction with the computer, the students were able to visualise their developing understandings of concepts, which frequently stimulated discussion and further collaboration with their group. This collaboration (in conjunction with subsequent visualisations) acted as a metacognitive prompt enabling the students to discuss both what they did and did not understand. This experience was clearly motivating for the students which influenced subsequent interactions and learning outcomes.

In relation to the second theme, the students identified the learning environment as one that promoted a deep approach to learning. Mindful involvement with the cognitive tool and the activities encouraged learning for understanding as opposed to the accrual of meaningless information. Many students actually said that their groups' interactions with the computer 'forced' them to search for meaning and the very act of collaboratively linking ideas together made passive involvement difficult.

The third theme was in relation to the students' perceptions of computer technology as a learning tool and its role in education in general. There were widespread references throughout the interview transcripts and student journals to the computer as a requisite tool in their teaching careers. Based on the belief that most schools expect teachers to be computer literate, the students voiced a strong desire for a heavier emphasis on computer-based learning in all education units.

Finally, the fourth theme was in relation to negative feelings the students held towards both cognitive and practical aspects of the cognitive tool. Although these perceptions were not typical of the data in general, their existence provided insight into findings which emerged in previous phases of the research project.

The findings from these investigations have implications for teaching and learning, which are discussed as follows.

What are the implications associated with using cognitive tools in a DLE?

In Chapter 2, the cognitive, social, affective and administrative affordances associated with cognitive tools were discussed and described as qualities that have the potential to significantly enhance learning. The results from this study concur with these claims in that they demonstrate the positive impact cognitive tools can have on student learning. For example, when accessed as an intellectual partner, the cognitive tool can:

- stimulate the type of discourse that leads to conceptual growth and understanding;
- encourage students to construct knowledge by creating visual representations of mental models, rather than absorb representations preconceived by others;
- facilitate collaboration and the social construction of knowledge;
- promote cognitive and metacognitive awareness;
- motivate students such that they are intrinsically encouraged to make sense of the subject matter, and
- promote deep, reflective thinking that is necessary for meaningful learning.

These affordances however, are double-edged in that the intellectual, social and affective challenges they present are representative of both their strengths and their potential downfall (Jonassen, 1996). While the learning benefits of socially constructing knowledge in partnership with the cognitive tool are immense, the demands of supporting this endeavour in the classroom are also considerable.

However, the DLE framework appears to have met this challenge, in that its features support the inherent qualities associated with cognitive tools. Findings indicate that this framework presents teachers with a practical opportunity to operationalise current learning theory in their classrooms, and at the same time, implement an environment that embraces and advances the learning benefits associated with cognitive tools.

Recommendations for implementing this environment are listed in Table 11.1. The cross-references refer to the parts of the thesis where a more detailed account of each recommendation can be found (e.g., TTC/CTF is the abbreviation for Teaching context characteristics: Curriculum and Task features, as is evident in Table 5.3).

Table 11.1 Recommendations for implementing a DLE

The teacher must	Cross Reference
• Be fully conversant with the principles of social constructivism and distributed cognition.	Chapters 3 & 4
• Design coursework accordingly. For example, tasks should: - be based on realistic and relevant problems - promote learning for understanding - encourage discussion, use of resources and learning strategies	Table 5.3 (TTC/CTF)
• Ensure teaching, learning and assessment methods are fully aligned.	Table 5.3 (TC/AF)
• Identify learning resources (including the cognitive tool) that are conducive to the unit's objectives. Ensure the cognitive tool is representative of one that is *good* and has a powerful graphical component.	Table 5.3 (PC) Table 2.2
• Secure a room that is physically conducive to the implementation of these resources (e.g., a computer laboratory).	Table 5.3 (PC)
• Discuss these methods with the students and evoke questions and concerns about the participation framework (i.e., learning through collaboration, using resources and thinking strategically).	Table 5.3 (TCC/TF & SC)
• Model effective use of resources (social, physical, symbolic and intellectual) and discuss their potential as learning tools.	Table 5.3 (TCC/TF)
• Monitor the students' collaborations with each other and the available resources, all the while ensuring that the lines of communication and distribution are kept open.	Table 5.3 (TCC/TF & SC)
• Monitor the usefulness of resources to ensure that their affordances remain challenging to the students' ZPDs.	Table 5.3 (TCC/TF & PC)

Nevertheless, the features upon which these recommendations are based are extensive and stem from principles that are in direct contrast to those that transpire in conventional classrooms (Jonassen, 1996). Given that many classrooms follow instructivist models of teaching and learning, acceptance of the social constructivist theories that inspire distributed cognition inspires fundamental restructuring of the learning environment. After all, "If nothing significant changes in the classroom save the introduction of a tool, few if any important effects can be expected. Indeed ... If the tool is to be effective, most everything in the classroom learning environment ought to change" (Salomon, 1993c, p. 189). These changes present implications for both teachers and students.

How does the cognitive tool in a DLE impact teachers?

Whereas some approaches to computer-based learning threaten to remove the teacher from active participation in the students' learning, teacher intervention and commitment in a DLE is paramount. Intervention is evident in the fundamental role the teacher plays as DLE engineer, co-learner and facilitator, and commitment is evident in his or her dedication to the framework's aims. This level of involvement will not only encourage the teacher to persevere with the demands associated with implementation and maintenance of the DLE, but will sensitise him or her to the type of learning that is occurring in the classroom.

In this way, the cognitive tool within a DLE becomes an effective means for the teacher to assess the pace and progress of student learning. Given that the cognitive tool externalises group cognition (both in its visual representations and the discourse it promotes), the teacher is able to closely monitor conceptual growth as well as the development of misconceptions. However, while collaborative learning outcomes are an important aspect of a DLE, teachers also have an obligation to evaluate individual achievement. In the discussion on distributed cognition, it was proposed that individuals *appropriate* socially constructed knowledge and understandings based on their current ZPDs. Teachers need to tap into these appropriations if they are to provide adequate support for individual cognitive growth as well as meet the practical requirements of classroom assessment. In consultation with the assessment features presented in Chapter 5, individual achievement can be measured successfully within

DLEs without compromising the fundamental principles of social constructivism or distributed cognition.

Furthermore, the four interrelating components of the students' partnership with the cognitive tool (visual, collaborative, metacognitive & motivational) have implications for the type of cognitive tool teachers wish to implement in their classrooms. Given the leading role played by the visual component, it is important that teachers choose one with strong graphical capabilities. Even though all cognitive tools have a visual component, some are better than others. The graphical capabilities of *Inspiration®*, for example, exceed other concept-mapping software in that its extensive symbol-library enables students to attach visual meaning to the nodes they choose to represent various concepts. These nodes are easily manipulated, thus encouraging students to re-work the spatial arrangement of the concepts and revise conceptual relationships. This flexibility is further enhanced by directional links that can be drawn straight or curved and labeled for additional meaning.

How does the cognitive tool in a DLE impact students?

While all classroom resources mediate student learning to some extent, the cognitive tool, placed within a DLE, is a particularly powerful device. When accessed within a DLE, the cognitive tool becomes an intellectual partner that places form and logic in student collaborations and cognition. Although not explored in this study, this partnership can also have resounding effects on student learning in other contexts. The skills and understandings learned in partnership with the cognitive tool can potentially enhance performance in other contexts irrespective of whether the cognitive tool is present or not (Salomon & Perkins, 1998; Salomon et al., 1991). Consequently, the cognitive tool has the potential to become an integral and invaluable presence in students' learning experiences.

For these learning benefits to transpire, however, students must be committed to the DLE and be prepared to meet its challenges. This means acceptance of, and a willingness to participate in, activities that are centred around collaboration, using resources and thinking strategically. Given that students are more familiar with teacher-centred classrooms (Hurwitz & Abegg, 1999), they may find the transition to a student-centred environment taxing and difficult. Indeed, the responsibility they have for their own learning, as well as the learning of others, may appear overwhelming at times. This is unavoidable, however, given that learning within a DLE is primarily a social pursuit, where each student's contribution adds to a communal network of knowledge.

In this way, the affordances of any one resource, whether it's social, physical, symbolic or intellectual, has implications for student learning. Given that students learn with and through these resources, their inherent qualities influence the nature of what is learned within the classroom. While this is largely a constructive experience, not all resources mediate learning in a positive way. Take for example the distribution of a misconception by one student to his peers in a collaborative group setting. Rather than extend conceptual understanding, this misrepresentation can impede conceptual growth. Similarly, the use of inappropriate resources in a particular context can thwart the efforts of students who have become increasingly reliant upon the mediating effects of tools as scaffolds. Teacher intervention is the only way to overcome these problems.

Finally, teacher-education students' desires to be more conversant with computer-based learning has implications for the culture of teacher education as a whole. By integrating cognitive tools into the mainstream of teaching and learning, its courses will not only lose their 'non-technical' label, but will also adopt a leading role in preparing these students for the roles they will inevitably play in implementing cognitive tools into their own classrooms. In this way, effective implementation is distributed across multiple learning environments thus providing students of all ages with a powerful learning tool. The usefulness of the DLE, therefore, is potentially extended beyond the confines of tertiary classrooms to learning contexts of all descriptions.

Significance of this Study

Possibly the most significant aspect of this study is the identification of the DLE framework that allows the potential of cognitive tools to be recognised. In light of the numerous claims that, given the right environment, cognitive tools can enhance learning, this framework is long overdue. Based on the principles of distributed cognition, it provides a solid infrastructure for the implementation of cognitive tools as intellectual partners. While discussions about distributed cognition are becoming more prevalent in the literature, those that actually operationalise it in the classroom are limited.

Based on the social constructivist belief that learning is a collaborative endeavour, this study also provides insight into the development of shared understandings and group constructions of knowledge. Rather than examining the effects of the cognitive tool on individual learning outcomes (as many studies do), the analysis focused on the socio-cognitive processes that student-groups engage in. Given that individual knowledge is, to a large extent, the by-product of socio-cognitive processes, a sound understanding of these processes is important and typically undervalued.

Furthermore, previous studies in distributed cognition have mostly been concerned with how knowledge representations are coordinated and distributed among resources and individuals (Flor & Hutchins, 1991; Hutchins, 1995; Rogers & Ellis, 1994). While this is a valid endeavour, there is consensus in the literature that the study of distributed cognition must also include an analysis of changes in knowledge representations and cognitive processes (Greenberg & Dickelman, 2000; Moore & Rocklin, 1998). This study addresses this need and, as such, positively contributes to knowledge in this area.

A more practical (but no less important) significance of this study is its focus on the exposure of computer-based learning to teacher-education students. Exposure such as this is of paramount importance as it prepares teachers-of-the-future for the roles they will inevitably play in implementing computer-based learning into mainstream education. It also provides them with insight into the capabilities of cognitive tools and, most importantly, into the characteristics of effective instruction and learning.

Limitations of the study

Potential limitations of the study are associated with threats to its validity and reliability. Although these concerns have been addressed in Chapter 6, other issues require recognition. For example, in keeping with Reeves (2000b) contention that action research projects can lack generalisability, the outcomes of this study are largely confined to the conditions within which it was conducted.

While the DLE has been designed to accommodate any *good* cognitive tool (see Table 2.2), the results of this study are based on students' experience with one particular type of application only. Concept-mapping software was used in this study due to its compliance with the unit's goal to encourage students to interrelate concepts and understandings. A different set of objectives, however, would potentially require the use of a different cognitive tool, which could result in different learning outcomes. Transferability of the findings is, therefore, limited to the same or similar cognitive tool applied to a unit with similarly styled objectives. Furthermore, based on the inference that the visual component of the cognitive tool influenced the partnership that ensued between the cognitive tool and the students, the use of a less graphically capable application would perhaps yield different results again.

Other methodological limitations were also evident. Although the teacher-researcher was ideally placed to monitor the overall progress and success of the study, her position was also a potential limitation in relation to her association with the students. It is possible that the students provided positive responses in the interviews due to the fact that it was their teacher who was interviewing them about their learning experiences. Had they been interviewed by another individual, their comments might have been more open.

Opportunities for further research

The identification of a DLE framework has yielded positive results in this research – results that provide educators with an opportunity to integrate contemporary theories of learning into the classroom, alongside a range of rich resources that promise to enhance thinking and learning. For this framework to be adopted as a mainstream method of teaching and learning, however, and for the affordances of cognitive tools to be more fully understood, further research is required. Table 11.2 outlines these research opportunities:

Table 11.2 Opportunities for further research

Investigation	Rationale
Conduct a study into the extent to which the DLE framework contributes to student and group learning.	To determine the extent to which the DLE framework enhances learning both individually and socially.
Conduct a study using the DLE framework in a variety of units using a variety of cognitive tools.	To determine the effectiveness of the DLE as a generic framework for the implementation of any type of cognitive tool.
Conduct a study into the effect cognitive tools have on individual cognition when implemented within a DLE.	To determine the extent to which cognitive tools support cognitive residue and individual knowledge construction.
Conduct a study into the effect cognitive tools have on a range of learning contexts when implemented within a DLE.	To determine the effectiveness of the cognitive tool and the DLE with a range of demographics and student-groups.
Conduct a study into the extent to which knowledge and skills learned in partnership with the cognitive tool are transferable to other contexts.	To determine the usefulness of knowledge constructed in a computer-based learning environment.
Conduct a study into the effect cognitive tools have on group learning using a combination of group sizes.	To determine the most suitable group size for maximising the benefits of cognitive tools (i.e., qualify Hurwitz & Abegg's recommendation of three students).

Conclusion

Clearly, cognitive tools present students with powerful learning devices that have the potential to greatly enhance their learning. Maximising this potential, however, is not a straightforward pursuit and teachers are required to cultivate an intellectual partnership between the cognitive tool and the students. The DLE framework developed in this study has demonstrated its value in providing a practical guide to the conditions that are necessary for the development of this intellectual partnership. Notwithstanding the usefulness of this framework, further research into this area is paramount if educators are to achieve the inspiring claim that cognitive tools can extend human processing capabilities and enable students to achieve increasingly higher, more sophisticated levels of learning and cognition.

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Appendices

Appendix A

Guidelines for research assistant

Dear

Below are a few pointers that you may like to consider when working the equipment over the next three recording sessions:

- Check equipment is working / batteries are sufficient prior to commencement of recording. Refer to the checklist below to confirm all equipment is on hand.
- Apart from my initial introduction, do not make contact with any of the students you are filming / recording.
- Be as unobtrusive as is physically possible, that is:

- Prior to arrival of students, arrange desks in groups of four such that 2 x 2 students facing one another.
- In relation to the 2 x 4 participating students, position cameras / audio recorders accordingly (prior to commencement of lesson).
- Once students have settled into their desks, make adjustments to the equipment to ensure both groups are in focus, and close enough to tape recorders.
- Do not make any adjustments thereafter, except to change tapes if necessary.
- Start recording after my initial address to the students. I may ask you to stop recording on certain occasions in relation to activities that are not relevant to the study. When you start recording again, do so with little disruption to the students.
- Once the lesson is underway, do not ask any students to reposition themselves to ensure they are in focus. Do your best to get as much of the group as possible on tape.
- Apart from checking the running of the equipment every now and then, quietly seat yourself away from the groups,
- If students ask you questions, direct them to me.
- Immediately after the lesson, clearly record the session date on both VCR and audio cassette tapes (e.g., Session 1: 21/4/99: Group 1)

Once again, thank you for your assistance. I appreciate your help.

Regards
Carole Steketee

☐ 2 x VCR cameras	☐ 2x 90 minute VCR cassette tapes
☐ 2 x tape recorders	☐ 2x 90 minute audio cassette tapes
☐ 2 x tripods	☐ 2x extension cords

Appendix B

Guidelines for participating students

Dear

Below, are a few pointers you may like to consider during today's lesson with regards to the collection of data for my study.

- Try to ignore the recording equipment, and the research assistant, as much as possible.
- Conduct yourselves as you normally would in class activities, that is, any comments, questions or concerns can be openly directed to your peers or myself, as per usual (not the research assistant).
- As the activities are group centred, please do not work individually, but rather collaborate with others within your group.
- Speak clearly.
- Speak freely. Do not hesitate to verbalise any thoughts or reflections that come into your head, even when you think they may not be totally relevant.
- Please leave any questions you have about the actual study to the end of the session, or the 15 minute break.
- Remember that your identification will remain anonymous in the analysis of the data.

Towards the end of the lesson, I will provide you with a list of possible times for the interview sessions. Please indicate, which time and location is most suitable for you.

Once again, thank you for agreeing to partake in the data collection for this study.

Regards

Carole Steketee

Appendix C

Principal Interview Schedule: Part 2

Schedule, classification and rationale

Question	DLE Characteristic				Qn Type	Rationale
	TCC	SC	PROC	GEN		
Having completed the module on (topic), how do you feel about your understanding of the concepts encountered?				√	2	Get student to focus on previous class and the concepts covered to refresh their memories about their learning experiences.
What are the main things that you've learned about (topic)?				√	4	
What sort of things did you do in class to learn these things?			√		1	Get students to focus on process of learning and types of resources accessed.
What resources did you use within the classroom to help you learn these concepts?			√		4	
Why did you use these resources in particular?			√		1	
Were there resources that you would like to have used, but for some reason didn't? Explain.			√		2	
Cast your thoughts back to the beginning of the lesson on Wednesday. You'll remember we: • revised previous concepts • looked at the day's objectives • identified personal goals						Determine if teacher has orchestrated learning context appropriately.
In your opinion, why do you think we revised last week's concepts?	√				2	
In your opinion, why do you think we had an overview of the day's objectives?	√				2	
Why do you think I asked you to identify personal goals?	√				2	
You worked a lot in groups today? How did you find this?			√		3	Determine the extent to which social resources were used in learning the concepts.
Did your group help you learn something today? If so, what was it?			√		1	
When working in groups, do you feel a sense of responsibility to the others to contribute to the discussions?		√			3	Determine if student is committed to a DLE.
Do you think you taught the others in your group anything today? If yes, what? If no, why?			√		2	Determine the extent to which social resources were used in learning the concepts.
What sorts of things did you do if you did not understand /agree with what others were saying?			√		1	

Question	DLE Characteristic				Qn Type	Rationale
	TCC	SC	PROC	GEN		
Did you feel a sense of responsibility to help your group understand and learn something?		√			3	Determine if student is committed to a DLE.
Do you think that everyone in your group shared the same learning goals for the tasks you were doing? Explain.		√			2	
What are your feelings about group learning within the class, as opposed to just learning for yourself?		√			3	
Does it matter if not everyone within the group is committed to group learning? Explain.		√			2	
What kinds of assistance did I provide you as you worked on the activities?			√		1	Determine the extent to which teacher was used as a social resource.
How important was my presence and contributions to your group discussions?			√		2	
Describe the learning environment in this class to me.				√	2	Determine classroom climate.
Today you participated in a jigsaw activity and other collaborative group activities. How did you know how to conduct yourself, and what was expected of you?	√				2	Determine if teacher has orchestrated participation f/w accordingly
Describe one of the activities that we did in class today. What did you think about this activity?	√				3	Determine whether tasks have purpose and are authentic.
If possible, how could you apply this activity to you as a learner and/or teacher?	√				2	
You've been learning about learning strategies in this unit. What sorts of strategies did you use today?			√		4	Determine if students have accessed their individual mental resources.
Why did you use these learning strategies in particular?			√		1	
What are the main phrases and terms that you used to converse with others about this topic?			√		4	Determine if students have used the symbolic resource of the unit's language to learn.
In what way did using this specific language help/hinder your understanding of the topic?			√		2	
If a colleague or friend asked you what was so important about (topic), what would you tell him/her?				√	2	Their answer will be indicative of facts or understandings learned.
How would you suggest they go about learning these things?			√		2	Their answer will/will not reflect an appreciation of a distributed orient-ation to learning.

Appendix D

Example of a lesson plan

Week 8 - Learning Strategies 2

Introduction

- Housekeeping issues.

Revision

- Students use *Inspiration®* maps to recall concepts encountered in last class (i.e., learning strategies).
- Evoke a definition of learning strategies and why they are important. Use overhead to consolidate these points.
- Pose question "What are the three types of learning strategies"? Write on board and elicit examples of these learning strategies that students use themselves.
- Ask "Why have McKeachie et al. (1986) and others found it necessary to define the different types of strategies we use"?
- Call for those who can remember the analogy we used to explain this classification scheme better (i.e., in the same way we need to draw from variety of food groups to stay healthy, we also need to use a range of learning strategy types to learn effectively). Elicit other analogies.

Review today's objectives and call for personal goals

- Explain that although activities will be different, main areas covered in last class will be revisited to consolidate understandings of learning strategies.
- Remind students to, wherever possible, relate concepts covered to themselves as learners, and to their own students.
- Show overhead of activities and explain briefly. Ask students to think about and write one or two objectives they would like to achieve in lesson.

Revise McKeachie et al's. (1986) classification scheme using jigsaw method

- Show overhead reminding students of jigsaw stages completed last week (individual and expert group study).
- Return to computer groups to discuss understandings developed with expert group. Do this with *Inspiration®* maps to enrich in light of any new information learned.
- Towards end of discussions, pose question, "Just how important are the different types of learning strategies"? Get students to think about this in relation to Norman's (1980) quote.

Norman's (1980) quote

- Show quote on overhead. Ask students to paraphrase (e.g., we expect students to *think about, remember* and *understand* subject matter, some of which is quite abstract, without actually teaching them *how* to do this).
- Whole group discussion, understandings from which are basis of group collaborations about experiences at university where learning strategies have/have not been explicitly taught.
- Discussions centred around *Inspiration®*. Notecards on specific strategies elaborated upon and links consolidated.
- As a whole class, elicit thoughts and comments to emerge from collaborations. Use these as a lead in to next activity.

Analysis of lesson plans (or videos if available)

- Students critique personal lesson plans – one at a time to discern if they explicitly teach their own students learning strategies.
- Use *Inspiration®* to guide collaborations (i.e., are concepts evident in concept-map also evident in lesson plans?).
- As a whole class, encourage groups to share their findings. What types of strategies in particular were deficient?
- Return to Norman's (1980) quote and ask students if it is true of them as teachers.
- Briefly summarise reading by Gaskins and Elliott (1991). (Whole school focus on teaching learning strategies yet strong deficiency in metacognitive strategies).
- Pose question, "Do we as teachers rob students of opportunities to be metacognitive"? If so, how? (i.e., tell students how to complete tasks, what resources they'll need, what the outcomes should be etc).
- Was this evident in their lesson plans / in their learning experiences at university?

15 minute break

Learning strategies questionnaire

- Inform students that a good way of becoming more familiar with different types of learning strategies is to try to identify those *they use as a learner.*
- In relation to this unit, student complete 'learning strategies' questionnaire. Explain scoring process and help students interpret scores.
- Based on results, ask students if they adopt a healthy combination of learning strategies or is there a deficiency? Discuss.

Evaluation of Learning Goals

- Students deicide if set goals have been achieved. Clarify areas of concern.

Alternative Articles on Learning Strategies

- Refer students to Gaskins & Elliott (1991) and Weinstein & Mayer (1986) as complementary resources to McKeachie et al. (1986).

Homework

- Distribute handout.

Appendix E

Principal Interview Schedule: Part 3

Schedule, classification and rationale

Questions	Question type	Rationale
Today we explored further, (topic-module). How do you feel about your understanding of the concepts encountered?	3	Encourage student to focus on previous class and to determine the sort of learning to emerge.
What stands out in your mind as something significant you learned in this lesson?	4	
What things did you do in class to learn these things?	1	Determine the extent to which the student has participated in DLE processes to learn.
What resources did you use in the classroom to help you come to these understandings?	1	
Why did you use these resources in particular?	1	
Were there resources you would like to have used but for some reason didn't?	2	
What are your thoughts on using *Inspiration*® as a resource to help you learn the unit material?	3	Determine the student's feelings about using the computer as a learning tool.
Looking at your concept-map, can you give me an overview of its meaning?	4	Determine the type of learning that has emerged from using the cognitive tool.
If a friend asked you to explain to him/her what this map was about, what would you say?	4	
If you had to highlight a particular component or aspect of this map in terms of its importance to learning, what would it be? Why?	2	
Can you describe the actions taken by your group to create this map?	1	Determine the extent to which the student has participated in DLE processes to learn.
What were your initial thoughts when you discovered you would be using a computer in this unit?	3	Determine the student's attitude towards computers as cognitive tools and their expectations of success when using it.
What are your expectations of *Inspiration*® as a learning tool? Do you expect it will enhance or hinder your learning of the unit material?	2	
Do you typically use computers as learning tools in your course? Why/Why not?	2	Determine the student's perception of computers as cognitive tools in their learning culture.

Questions	Question type	Rationale
How have you found working in groups for this unit?	3	Determine student's commitment towards DLE approaches to learning.
Describe what your group helped you learn in the last class (if they did)?	4	
Describe what you helped your group learn in the last class (if you did)?	4	
Describe the learning environment in our classroom as you experienced it in our last class.	1	
What would you say to a colleague or friend who was thinking of doing this unit but was concerned about the computer component?	2	Determine student's perception of using computer to learn with in education unit.
The class is always arranged in a particular way for this unit. Is it accommodating for your learning, or has it been a hindrance? Explain.	2	Determine student's commitment towards DLE approaches to learning.
How do you feel about using a computer in this normally computer-free learning environment?	3	Determine the student's perception of computers as cognitive tools in their learning culture.

Appendix F

Statement of Disclosure and Informed Consent: Part 2

Dear Student,

This letter is to inform you of the nature and purpose of the research I am completing as part of my PhD degree at Edith Cowan University. The study is an interpretive one entitled *Exploring conditions for the effective implementation and use of computerised cognitive tools.* The purpose of the study is to use the relatively new learning theory of distributed cognition as a framework for the implementation of cognitive tools into tertiary learning environments. Cognitive tools are computer applications, such as concept-maps, word processors and databases that can potentially enhance the way you think about the material you are studying.

If you agree to participate in the study, you will be videotaped on three separate occasions as you carry out learning tasks within normal class times. I will also interview you on three occasions, the times of which will be arranged to suit you. As your student journal will reflect your learning experiences, I would also like to access these at certain times. The information gathered by video, interview and student journal will be analysed by myself using qualitative research methods. There will be no discomfort to you, nor any risks, and steps will be taken to ensure that video sessions will be as unobtrusive as possible to your learning. Your journal will be returned to you once I have accessed the relevant material.

Confidentiality is assured, and you will not be identified in any part of the research. Furthermore, you are free to withdraw from the study at any time and non-participation will in no way prejudice your completion of the unit.

The advantages of participating in a study such as this are evident in the process of talking about your learning, and making self-reflective notes. These strategies encourage independence in learning and promote deep, quality learning outcomes. You will also be contributing to a much-needed body of knowledge on computer-based learning, which will ultimately enhance teaching and learning at university.

If you have any concerns about the project, you can contact me as follows:
Telephone: 9385 7720, **Facsimile:** 9385 7595 **Email:** cnsteket@echidna.stu.cowan.edu.au
Alternatively, you may like to contact my principal supervisor Dr Jan Herrington on 9273 8794. If you agree to take part in the research, please sign the consent form below.

Carole Steketee

Consent Form

I ____(Name of participant)
have read the information above and any questions I have asked have been answered to my satisfaction. I agree to participate in this research, *Exploring conditions for the effective implementation and use of computerised cognitive tools* realising I may withdraw at any time.

Signed______________________________ Date__________________

Appendix G

Statement of Disclosure and Informed Consent: Part 3

Dear Student,

This letter is to inform you of the nature and purpose of the research I am completing as part of my PhD degree at Edith Cowan University. The study is an interpretive one entitled *Exploring conditions for the effective implementation and use of computerised cognitive tools*. The purpose of the study is to use the relatively new learning theory of distributed cognition as a framework for the implementation of cognitive tools into tertiary learning environments. Cognitive tools are computer applications, such as concept-maps, word processors and databases that can potentially enhance the way you think about the material you are studying.

If you agree to participate in the study, you will be audiotaped on three separate occasions as you carry out learning tasks with your group and within normal class times. I will also interview you on three occasions, the times of which will be arranged to suit you. As your student journal will reflect your learning experiences, I would also like to access these at certain times. The information gathered by audiotape, interview and student journal will be analysed by myself using qualitative research methods. There will be no discomfort to you, nor any risks, and steps will be taken to ensure that taped sessions will be as unobtrusive as possible to your learning. Your journal will be returned to you once I have accessed the relevant material.

Confidentiality is assured, and you will not be identified in any part of the research. Furthermore, you are free to withdraw from the study at any time and non-participation will in no way prejudice your completion of the unit.

The advantages of participating in a study such as this are evident in the process of talking about your learning, and making self-reflective notes. These strategies encourage independence in learning and promote deep, quality learning outcomes. You will also be contributing to a much-needed body of knowledge on computer-based learning, which will ultimately enhance teaching and learning at university.

If you have any concerns about the project, you can contact me as follows:
Telephone: 9385 7720, **Facsimile:** 9385 7595 **Email:** cnsteket@echidna.stu.cowan.edu.au
Alternatively, you may like to contact my principal supervisor Dr Jan Herrington on 9273 8794. If you agree to take part in the research, please sign the consent form below.

Carole Steketee

Consent Form

I ____(Name of participant)
have read the information above and any questions I have asked have been answered to my satisfaction. I agree to participate in this research, *Exploring conditions for the effective implementation and use of computerised cognitive tools* realising I may withdraw at any time.

Signed______________________________ Date__________________

Appendix H

Checklist:
Verification of distributed cognition in lesson plans

Teaching context features
In this lesson, the teacher models distribution of cognition in the following ways (TCC/TF): • • • group collaboration is promoted in the following ways (TCC/TF): • • • the opportunity to use the following resources is evident (TCC/TF): • • • strategic thinking is encouraged in the following ways (TCC/TF): • • • the development of skills associated with collaboration, resource-use, and learning strategies is promoted in the following ways (TCC/TF): • • • there is an obvious emphasis on student understanding rather than the accumulation of facts. This is evident in the following ways (TCC/CTF): • • • the tasks are authentic in that they are representative of real world problems and situations (TCC/CTF). For example, Activity one: Activity two: Activity three: students have opportunities to self-assess their individual and group findings and understandings by (TCC/AF): • • •

Appendix I

Explanation of coding references and coding styles

Coding references

Coding that begins with 'I' is data from an interview transcript (e.g., I1/1D).
Coding that begins with 'CA' is data from a class activity transcript (e.g., CA2/1GA).
Coding that begins with 'J' is data from a journal transcript (e.g., J1V).

Interviews

All interview letters (I) are followed by numbers that refer to the recording session and the semester within which the investigation took place. For example I3/1L refers to data that has come from an interview transcript in the third recording session of semester one.

The letter that follows these numbers is the first initial of the pseudonym given to each participating student. The pseudonyms given to the participating students in semesters one and two were as follows:

Semester One: Andy, Viv, Gill, Dick, Fran, Rea, Kay and Linda
Semester Two: Wanda, Deb, Sally, Tom, Nat, Bronte, Una, Sean, Mary, Jess, Pablo, Susie and Bree

Therefore, the coding reference I3/1L refers to data from Linda's interview transcript during the third recording session in semester one.

Class Activities

All class activity letters (CA) are followed by numbers that refer to the recording session and the semester within which the investigation took place. For example CA3/1GA refers to data that has come from a class activity transcript in the third recording session of semester one.

The letters that follow these numbers refer to the group to which the transcript belongs. In semester one the groups were named Group A and Group B whereas the groups in semester two were named Group 1, Group 2, Group 3 and Group 4.

Therefore, the coding reference CA3/2G3 refers to data from Group 3's class activity transcript during the third recording session in semester two.

Codes that do not have a group reference at the end but rather have a WC reference relate to whole class discussions. Only whole class discussions involving participating students have been transcribed and referenced in the thesis.

Journals

Because journals were transcribed as one whole document, rather than in relation to different recording sessions, the number that follows the J simply refers to the semester it was related to. For example, J2 refers to data from a journal transcript in semester two. The letter that follows this number is the first letter of the pseudonym given to the participating students. For example J2N refers to data that has come from a Nat's journal transcript in semester two.

Quoting styles

When students are quoted from the class activity transcripts, they are referred to as Student 1 (S1), Student 2 (S2), Student 3 (S3) etc consecutively. The teacher's comments are delineated by 'Tr'. For example:

> S1: Do you think metacognitive tasks are different from cognitive ones...?
> S2: Cognition is goal setting. See this might be our problem.
> S1: But you can't set goals without thinking about it.
> S3: See most [metacognitive strategies] are tools to think with ... So it's what to control ... how you're going to save time ... Saying to yourself "Do I understand this"?
> Tr: Yes there are... two aspects of metacognition ... one aspect is the regulation of your learning, like self-testing. The other is knowledge ... about cognitive [learning] strategies. (CA1/1GB)

Quotes from the interview transcripts are delineated by 'Q' which is the question asked by the teacher and 'A' which is the response provided by the student. For example:

> Q: Do you do that in these classes? Do you always think about the new concepts in relation to what you already know about them?
> A: Yes. I can definitely answer yes because you make us do that.
> Q: How's that?
> A: Um, I'm trying to think of an example ... well just when we start a new lesson, we always begin it by looking at what we think it means before we find out what it really means. (I2/1G)

Quotes from the journal transcripts do not have a preceding introductory letter. For example:

> I am a shallow achiever. Need recognition. Poor time management and low motivation for intellectual effort requires shallow approach. Can only focus on one deep thing at a time. Everything else must be shallow. Intellectually interested but lazy. (J1A)

Individual quotes from either the class activity transcripts or the interview transcripts do not have a preceding introductory letter either. For example:

> ... so like for the qualitative conception for reading you'd look for personal interpretations wouldn't you? So like the person plus the text would give you the interpretation ... [it's] what I do with my students. Like I'll give them this little diagram of a stick person, a book and a light globe and this means that the person plus the text gives you your own meaning of the story. So meaning is the focus of the ... the objective. (CA1/2G3)

Appendix J

Preliminary coding: Part 2

Data representative of instances where learning *has* been distributed to social resources

The following data constitutes the first six pages of instances where cognition was distributed to social resources. The data was taken from class activity transcripts, interview transcripts and journal transcripts. However, because the class activity transcripts were coded first, they are the only data to show in these samp'e pages. Some coding has been cut to make room for examples from other transcripts.

Q.S.R. NUD.IST Power version, revision 4.0.
Licensee: Carole Steketee.
PROJECT: PhD Analysis Part 2, User Carole, 8:26 pm, Mar 4, 2002.

****

(1 3 1 1) Characteristics of a DLE/Process Characteristics/Social Resources/Yes
*** Definition:
Examples of incidents where knowledge has been distributed socially
++
+++ ON-LINE DOCUMENT: Class Act 1/1 - GA
*Semester One - Part 2: Distributing cognition
*First Session - 21/4/99
*Group A - Rea, Linda, Andy, Kay

++ Text units 14-67:
K: Yeah, basically the long-term. Basic's more working memory - short-term memory. Now it involves three learning strategies within those basic and complex tasks. First one is rehearsal strategies. An example of basic task is to say, read your list. 14
R: Read it? 16
K: Yeah, like to memorise it if you like. Rehearsal is like more short-term, working memory. It says here, "Rehearsal strategies are there mainly to stimulate the attention and encoding process" not necessarily to build on prior knowledge. It's kind of the first step in the learning process. When you learn something brand new, you've got to start somewhere when you don't have any existing knowledge about it. 18
L: Just to get into your ... which memory? 20
K: Into your working memory really. It's like we're just reading the text to just get it in there [points to head] but we're not actually connecting it to anything at this stage. So for basic tasks they've got 'reading a list', for complex tasks they've got 'note-taking'. When I read this article I just took notes, underlined, read it out aloud. I didn't necessarily connect it or internalise it with other examples but I think we have to use those rehearsal strategies in conjunction with elaboration strategies. 22
R: Which is the next step up, is it? 24
K: There's both basic and complex in each, right, but elaboration strategies are those strategies you use in addition to your rehearsal strategies and I'll give you some basic and complex strategies for elaboration as well. 26
R: Sorry. I'm a bit confused. Do you use rehearsal strategies for

basic...? 28
K: You've got complex, but... 30
R: Do you use them in both? 32
K: Yeah, you use them in both, and organisational you use both. So elaboration you just have to build links to stimulate the long-term memory. Your basic tasks involve doing things like imagery, reading a list and the complex tasks involve things like paraphrasing, putting things into your own words, summarising, building analogies and maybe answering questions like those generic questions we got in class a few weeks ago. You also have organisational strategies that also help to build connections between different types of information you've learned. The basic strategies for those are clustering (like grouping information into categories like mnemonics) and complex tasks are things like analysing text, maybe trying to pick your theme for a novel, main ideas, diagramming or a concept-map I suppose. They use the word networking for concept-maps in this [article]. 34
[Teacher joins in discussion with group] 36
Tr: The basic strategies you were talking about like mnemonics, method of loci and the others are they important? Do we need to know about these sorts of strategies? 37
K: Yeah. 39
T: Why? Rehearsal strategies. Do we need to know about them? 41
R: Do you mean outside institutions? 43
T: Well within formal learning situations? 45
R: I think you do. There's always a time, especially at uni where you've got to memorise something, or when you need to start somewhere for learning something. 47
Tr: What you're saying then Rea is that, depending on the task ... well we draw on strategies that are suitable for the task we're doing at any particular moment. So there's no need to elaborate - to process something deeply, in a meaningful way if we're just trying to learn someone's phone number. 49
R: Well yeah. There's no need to elaborate or whatever if we're just trying to remember a phone number or whatever. Yeah. 51
A: It's amazing with phone numbers for me. I don't process them anyway I've come to realise because I find that each time I want to call a particular person, I go to remember their number and I'm like looking in the phone book each time. I can't work out why I haven't remembered it by now. It's so damn frustrating. 53
T: Why do you think you haven't been able to remember it. How have you been trying to remember it? 55
A: I haven't been doing any thing really, apart from repeating it a couple of times in my head as I dial it. It's not a number that I thought I would be phoning more than once, but since they keep on stuffing up, I've had to keep calling - It's a tiling company. 57
R: That's probably why isn't it? The fact that you haven't ... you didn't think you would need the number again so you didn't process it into your long-term memory. You just kept it in your working memory each time you phoned thinking that that would be the last time. 59
K: So can you remember the number now? 61
A: No. Not at all. 63
Tr: I think Rea is right. You pretty much maintained the number in your working memory using maintenance rehearsal strategies then discarded it once you dialed it. 65
A: I should have just written it down. 67

++ Text units 110-116:
A: Yeah, like one of the examples it gave is like if you're reading something you'd say "Right. Do I understand what I'm reading? No. Well I better slow it down" Try to take less in. So actually change what you're

doing to try to improve the learning. 110
K: I think it's like when you're reading something that you pretty much have a good knowledge about you skim over it or at least it's not hard to quickly go over it. But if you're reading something you don't know anything about then you read every single word. So like you adjust your reading habit for the stuff you're reading about. I thought that was an interesting point they made and so true to life with the journal articles we read at uni. Like half of these journal articles you're not even aware of being metacognitive. You just do it out of habit or just because you have to and you hope that you'll learn something. 112
A: It also depends a lot on what you read. You see a phrase or a word and if you know it, like if you've seen it before, it just sort of slips straight into your mind nice and easy. But if it's new then you've got to go through this tedious linking of processing and encoding and it takes a bit longer before you can move on to the next phrase. 114
R: It's easy when it's something you know. It's almost exciting. 116

++ Text units 272-320:
Tr: Okay, just looking at this lesson plan [Kay's] it's clear to see you've spent a lot of time planning and preparing for it. You know what you want the students to learn and you know what activities to do to achieve them. Within this lesson, though does it say how students are going to grasp that knowledge? 272
K: I use a lot of chalk as an instructional strategy. Like with playoffs a lot of students get confused which feet to use and I say "right, left" and then you show them, but most kids go left, right and they're not sure. So where they're supposed to do the ??? I draw a little foot with the chalk and I put an 'r' in it for right and they put their foot in the 'r' and I do the same for the left. So they go right, left. That's a tool isn't it? 274
Tr: That's a tool for sure. It's a symbolic tool if you like. It's facilitating the learning process. 276
R: But that's just the activity isn't it. 278
K: Yes and no. I thought to myself "I want the students to be able to do a playoff properly. They're still confused and getting it wrong. What can I do - what skill can I teach them to help them get it right". So I was actually providing them with a way of getting around the problem. 280
Tr: Kay's described one kind of tool. The symbolic tool of a diagram on the pavement that enables the students to follow the skill of a playoff. I want you also to give thought to the tools that you can't see. The unobservable ones that are in the students' heads. The cognitive, metacognitive and resource management strategies that they know about and use whenever the need arises. 282
K: With the little kids where the lesson is hands-on, and I'm trying to teach them about malleable substances and how temperature affects those, how would I approach their learning. I don't really understand how I could bring cognitive and metacognitive strategies into it for the little ones. 284
Tr: Just think about the information you're trying to get them to learn. Return to your objectives and based on that you anticipate the problems they might have understanding it. So you ask yourself "What is it that is going to help my students understand this material"? You cannot just assume that by carrying out the activities, they are going to have an understanding of whatever your objectives were. They are activities that will facilitate the understanding - sure, but by simply carrying out that activity, you cannot assume that understanding will eventuate. 286
R: I still don't understand how I could do that with this. I'm getting them to use their hands and I'm not telling them the information, I'm getting them to discover it for themselves. 288
Tr: Okay it's good that they are physically involved - they are 'doing',

but you want them to be mentally involved as well - you want them to be
'thinking'. What things tell you that they are thinking? 290
R: That's it. I don't know. 292
Tr: Well, you want them to question themselves. So the students have their
hands in a tub of ... what was it? 294
R: Plasticine and butter. 296
Tr: So you say "What is this all about"? "Why is one different to the
other"? Get them to talk to one another about what they're thinking. Why
does one child have a different idea to another? Talking ... 298
R: And asking questions ... 300
Tr: All the time. 302
R: Of each other and me ... 304
L: And themselves I would suspect. 306
R: But how do you do that. How can you be sure that Year Ones are asking
themselves questions? 308
Tr: They learn to over a period of time. It's the style of teaching you
adopt. It's part of the routine of your classroom. It's part of the
learning environment. At first they find it hard to do but eventually, it
becomes common practice. 310
A: That would be the same with all sorts of strategies wouldn't it, for
any age group? They wouldn't be able to use them properly or consistently
straight away, but after a lot of practice it becomes second nature. 312
Tr: Yes, that's right. 314
L: Also with your little ones Rea, you could them to predict ... to work
out for themselves the sorts of things they could do for themselves if
they had problems. Like as my five year old does all the time saying "I
can't do this and I can't do that", rather than doing it for him, I ask
him what things he thinks he can do, what steps he can take to overcome
that particular problem. 316
Tr: Right. Putting the onus to learn back on the individual. 318
R: It's a lot easier to get someone else to do it - to be
non-metacognitive. I think it's easier said than done - what you're
saying. It sounds well and good but ... I don't know. I'm a bit skeptical
still I think. 320

++
+++ ON-LINE DOCUMENT: Class Act 1/1 - GB
*Semester One – Part 2: Distributing cognition
*First Session - 21/4/99
*Group B - Dick, Gill, Fran, Viv

++ Text units 35-51:
V: And then monitoring strategies - an example is self-testing. Now I was
saying to the group back there that funnily enough when I got to reading
that down here, I found myself self-testing. Did you hear the lecturer
next door talking about 'x' and 'y'. 35
F: Yes, the algebra. 37
V: Well, I got sidetracked and I was listening to him. So I was thinking
"Hang on. Get back on this". So I did what they say here - monitoring
strategies called 'tracking your attention when you read'. And that was
what I was doing and it was only then when I realised that I was reading
what I was doing. 39
D: And I had to re-read sections ... 41
V: Exactly. And then I had to do the other things like testing by
re-reading, especially what I highlighted to see why I did highlight it
in the first place. 43
F: So you're using cognitive strategies with the added angle of knowing
when, and knowing why you're using them. 45
V: Yeah, I guess so. But the metacognitive is the thinking - more the
awareness and being in control of your thinking. So I guess metacognitive

strategies are the engines that drive the cognitive ones. They control them, and which ones you use and why you're using one over another. Would you agree with that Dick? 47
D: Yes. 49
G: It's like a cognitive person wanting to get to A and asking a metacognitive person how to get there. [teacher appears to enquire how group progressing]. 51

++ Text units 53-95:
Tr: How are you going in this group? Anything you're not quite sure of? 53
V: Do you think metacognitive tasks are different to cognitive ones - the planning, the monitoring and the regulating? In the planning you set goals ... 55
F: Cognition is goal setting. See this could be our problem. 57
V: But you can't set goals without thinking about it. 59
D: See most of them are tools to think with; that you use to make the most of with the tools that you already have. So it's what to control, when and how, how you're going to save time etc, etc. Saying to yourself "Do I understand this? Am I on the right track". 61
Tr: Yes. There are in fact two aspects of metacognition, which you probably realise. One aspect is the regulation of your learning, like self-testing. The other is knowledge about knowledge which includes knowledge about cognitive strategies. Does that answer your question Viv? 63
V: So the metacognitive strategies are like the ones that help you think and learn and the cognitive strategies are the ones that get you thinking about what you're learning. 65
Tr: Yes. Right. 67
F: Really, then, metacognition should accompany all of the different types of learning strategies, or at least guide them. 69
G: They're not as effective otherwise. Should we get on to resource management? The taxonomy in the reader I suppose is a very useful guide. But I think I saw them being as sandwiched into two, that is, external resources and internal resources. Now to me, it was 'effort' that made the biggest impact on me. When we got together to nut this out C came around and showed us how management of effort is related to the way ... what you attribute learning to. Um, for example you may think that you failed at something due to one of four things. You may think you failed because of the tasks - it was too hard. Or you may think you failed because you have bad luck. Or you may think you failed because you are not as bright as most kids or you may think you've failed because you haven't put the effort in. Um so out of those which would you like your kids to attribute their learning to? 71
F: What do you mean my 'attribute' their learning to? 73
G: It's like when you learn something you may fail at it or you may do well at it. If someone asked you why you failed or why you did well, you may say "Oh because it was an easy task, or it was your lucky day or you are really smart at Maths" or whatever. 75
F: I see. 77
G: So if you could choose one of those four that you would like your kids to attribute their learning successes and failures to, what would it be? 79
V: Not luck. 81
D: Or the task. 83
F: What were they again? 85
G: Task, luck, ability and effort. 87
F: Ability or effort. 89
G: Well effort is the only one you can actually control, and teach your kids to control. All the others are not controllable so you'd want your students to see that they did well or not so well at something because they either did or didn't put the effort in. 91

F: That's well and good but what about a little five year old who has
put his heart and soul into trying to read something but he just can't
understand the words. 93
V: The book is probably too hard in that case and the teacher needs to
realise that quickly before he starts thinking that he's the one with the
problem and ... [teacher speaking to whole class] 95

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+++ ON-LINE DOCUMENT: Class Act 2/1 - GA
*Semester One - Distributing cognition
*Second Session - 5/5/99
*Group A - Rea, Fran, Andy, Dick

++ Text units 1-97:
D: I'm thinking about the main stuff we went over last week - the three
main approaches. And in fact if you combine the deep-achieving together
you get the best results. And then the strategies that you use - the different
approaches you use to learn. If you use the surface approach; if you have
that kind of approach, you use the surface type of strategies that goes with it. 4
G: Like rote learning. 6
D: Yep. And then what makes someone choose these approaches depends on
the motivation and the 'why' you learn, for what reason. Ok. 8
G: Yeah. Perfect. So is that what you discussed last week? 10
R: Yeah and we analysed a questionnaire we filled out because like Dick
says there's the three approaches - deep, surface and achieving, but you
can combine them so there's six. So we found out that there are really
six approaches you can use. So you can be a deep-achiever - and the
motivation behind each one. And she gave us the equation - the motivation
you have for doing something, plus the strategies you use equals the type
of approach you adopt. And she talked a lot about extrinsic and intrinsic
motivation and ... I'm sure you know all this [to Fran]. And that's connected to,
um ... 12
D: The intrinsic is related to metacognitive strategies. 14
G: And the intrinsic would be representative of deep learning - when it's
coming from within. Is that right? 16
R: Yeah intrinsic would be deep learning. And the achieving one is
interesting. 18
G: It's a little bit superficial too isn't it? 20
R: Yeah cause the achiever learns for themselves as well as having the
objective of being the best in the class. They're pretty smart. I think
she was saying the achiever utilises the resources really well; the time
management really well. What they need to do is just enough, but they do
it well enough to get the top results. 22
G: They are also the ones who look for what will be questioned in the
exams so they will need to know that and would they study anything that
wouldn't be examined in the test? 24
D: Probably not but they would optimise everything to get higher grades. 26
R: They probably would understand it though. 28
D: They can ... 30
G: But some people make choices like that when they're studying for exams. 32
R: Yeah. 34
G: They think that because it's such a broad subject they will only study
one area and go with their luck. 36
D: Not the achievers though. 38
G: Not achieving? 40

Coding out here

Appendix K

Preliminary coding: Part 2

Data representative of instances where learning *has not* been distributed to social resources

The following data constitutes the first six pages of instances where cognition was not distributed to social resources. The data was taken from class activity transcripts, interview transcripts and journal transcripts. However, because the class activity transcripts were coded first, they are the only data to show in these sample pages. Some coding has been cut to make room for examples from other transcripts.

Q.S.R. NUD.IST Power version, revision 4.0.
Licensee: Carole Steketee.
PROJECT: PhD Analysis Part 2, User Carole, 11:07 am, Mar 4, 2002.

****
(1 3 1 2) Characteristics of a DLE/Process Characteristics/Social Resources/No
*** Definition:
Examples where knowledge has not been distributed socially
++
+++ ON-LINE DOCUMENT: Class Act 1/1 - GA
*Semester One - Part 2: Distributing cognition
*First Session - 21/4/99
*Group A - Rea, Linda, Andy, Kay

++ Text units 134-152:
R: Shall we do half and half [to Linda who's studied the same section in the article]. 134
L: No. Lets do it together. 136
R: All right. You go first. 138
L: Well, Resource Management strategies, they're talking about the environment and the resources so that the learner is aware of and uses resources and is able to change or adapt to the environment in their learning. And there are a lot of different aspects to it - would you agree with that Rea? 140
R: Yeah, I see there are ... one, two, three, four things. Is that what you mean? 142
L: Yep. You go ahead [to Rea]. 144
R: Well the first one's time, the second one's place, the third one is others and the fourth is effort. The article is saying that physically and mentally how we approach our learning is very important. So everything has to be right with these things. Then I looked at place [to Linda]. 146
L: Do you mean 'environment'? 148
R: Yeah, you can do that. 150
L: Some people have a very defined place where they study. Some people need to have a very organised area where they study, or one certain place, and they need to be aware of that and be able to efficiently use it as a resource ... [teacher interrupts group discussions] 152

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+++ ON-LINE DOCUMENT: Class Act 1/1 - GB

+++ Document Header:
*Semester One - Distributing cognition
*First Session - 21/4/99
*Group B - Dick, Gill, Fran, Viv

++ Text units 15-17:
F: So anyway that's pretty much the cognitive strategies and how it links in with the information-processing model. But we also looked at specific examples. With maths, when you're learning your tables, you just recite them and learn them off by heart. Then you elaborate on them and look at the meaning behind multiplication as a mathematical phenomenon. Then you come to a more organisational process where you look at division as being the reverse of multiplication. So like when you're learning your six times tables, you rote learn them; you rehearse them. Then you elaborate by looking at them as a multiplication concept, like six times four is just four lots of six and then you organise this information further by saying how many times will six go into twenty-four? So that's the cognitive strategies. What's the metacognitive ones about? 15
V: Well basically theorists say there's two parts to metacognitive strategies. One is the awareness of and the knowledge of learning. Ok. 17

++ Text units 132-138:
F God that is so true. It's true for me when I was learning. When I was a young girl learning, you just had to remember as much as you could and repeat it in the correct fashion. That's what learning was. But even knowing that, I don't know who taught me how to rote learn. Maybe it was a subconscious thing, a skill you picked up because you had to. 132
V: So what Norman is saying is that we don't teach students strategies to learn with, is that right? 134
G: Let's move on.. 136
V: I'd like to know when this was quoted cause I believe things have changed from the days when you were at school Fran [laughs]. So seriously, it's not as bad as all that. I know in my class much of our learning is problem based. 138

++ Text units 148-177:
G: When I was in the army reserve and they spoke about 'man-management', and the adage was that one man can't manage more than five men effectively and that was reflected right throughout the structure of the army. You always find that generally one person can't really manage more than five people. So then you look at the learning environment and you see one person managing 25 students ... 148
V: 32 in my case. 150
G: It's a totally unrealistic environment. On average in that situation you've got two minutes per child and so how can you be expected to make sure that each of those kids has the tools to learn with? 152
V: This issue came up last year at school where a parent was petitioning about something and I said to her "Look, if you're going to petition about anything, do it about the fact that your son is in a class of 31 other students. 154
G: Shall we go back to the lesson plans? I was sort of experimenting with times here, in other words we were dealing with ... 156
V: What was the subject? 158
G: Bank reconciliations. Business studies. One of my lesson plans says to give them 25 to 30 minutes to tackle the questions. And my supervisor says, "Ok, you've got 28 year 10 kids, and you're expecting them to sit quietly and work individually on these problems"? He said "25 minutes is a whole quarter of AFL football. You're actually expecting them sit quietly and do your work for that time"? So what he then said was to break it up, like give them a few minutes to do that bit then check it,

then do the next bit, then check it. 160
V: So step by step. 162
F: Sorry. What are we doing again? 167
G: Not bank reconciliation as such but I was expecting year 10s to be able
to control themselves for that amount of time. 168
V: Did you actually do this lesson. 170
G: Yep. 172
V: How did the students go sitting 30 minutes of work on their own? 174
G: Not all that good. I found that I was picking them up on certain
things therefore interrupting them "OK you stop doing this, you stop
playing with that" so I might as well have split the time up
anyway. So when I did it later, I did slice it up more. 176
F: I like to give my kids a bit of a break in the day ... for them to
just think about nothing or think about what we've done during the day. 177

++ Text units 189-227:
D: I've got my lesson plan here. It's Science - states of matter [gives a
copy the others in his group who skim read it]. 189
F: This bit is like recalling prior knowledge to me. 191
V: Yes. [reads a part] "students have knowledge that chemists are
interested in studies of matter" 193
F: Have they already got that knowledge? 195
D: Yes. 197
F: How do you know? 199
D: Because they were taught it in the previous lesson. 201
F: Oh ok, so they understood it? 203
D: Yes, it was evaluated here [points to program]. 205
F: So how did you evaluate? 207
D: Questioning and discussing and whatever and the way I was teaching
allowed for a lot of self-evaluation also - letting them do what they
thought was necessary to increase their understanding. 209
F: So you did what Gill did - a lot of their own work? 211
D: No. Not really. There was more group work. When you teach science
where I come from, you have to teach in groups because the classes are
big and there's not much resources. It's how I learned. 213
G: Where are you from again? 215
D: Seychelles. 217
V: This looks great. It's very much like the lesson we viewed on TV - the
constructivist one on energy. 219
G: Look. It ran for 80 minutes. 221
V: What! 80 minutes. Was it with a break? 223
D: No. It was a double period. No breaks. 225
G: If they offered me a job like that I'd say "Forget it. Give me another
school. I mean even asking a Year 11 or 12 to sit in one room for 80 minutes is
ridiculous. 227

Coding cut here to provide examples from other transcripts

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+++ ON-LINE DOCUMENT: Class Act 2/1 - GA
*Semester One – Part 2: Distributing cognition
*Second Session - 5/5/99
*Group A - Rea, Fran, Andy, Dick

++ Text units 194-208:
G: Well, do you agree with it [comment on study guide saying that implicit in
the chapter that quality learning is associated with use of a deep
approach to learning.]? 194
D: Yes, yes. 196
R: Yes. Maybe. I dunno. 198
G: Why? 200

A: If you're only learning ... if you're taking the shallow approach then
you're only achieving points being made in the curriculum, which may not
be everything in that subject. By definition you're only learning that
which will be assessed and anything not assessed you don't learn. 202
G: The hidden curriculum. 204
A: Yes exactly. 206
G: ... it says "explore the relationship between what happens in the
classroom and the approaches to learning that students adopt". So...a
teacher sees her object to work to the curriculum very closely so that all
the checklists are met. 208
R: ...They're not talking about teachers' teaching habits. 210
G: No [reads sheet again]
A: It's more about student willingness to go outside the guidelines rather
than teacher willingness to go outside the guidelines. 212
D: And um... 214
A: Well they are both the same thing. 216
R: But they're not saying the teaching will change the approaches to learning. 218

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+++ ON-LINE DOCUMENT: Class Act 2/1 - GB
*Semester One - Part 2: Distributing cognition
*Second Session - 5/5/99
*Group B - Viv, Gill, Kay, Linda

++ Text units 42-56:
K: Are they your notes from last week? 42
G: Yeah - the ones I took in class. 44
K: Can I have a look at them? 46
G: Yeah, yeah, you can copy them. I guess that leaves you and me on the
poster then [to Linda and Kay and Viv were away last week]. 48
K: I really haven't got any background information to contribute. 50
L: Do you want to photocopy my notes [to Kay]? I've got about ten pages. 52
K: Did you take ten pages of notes last week in class? 54
G: Actually there weren't class notes as such. It was just things she
said. 56

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+++ ON-LINE DOCUMENT: Class Act 3/1 - GA
*Semester One - Part 2: Distributing cognition
*Third Session - 26/5/99
*Group A - Gill, Dick, Fran

++ Text units 163-235:
G: This is rotten. I'm not a terribly good artist. Seeing as I'm the
volunteer artist and I'm not an artist you'll have to put up with it. But
that's - the tool of the mind right. The subject matter and the teaching
of the strategies is integral. 163
F: Integral 165
G: Integrated. Oh my God have I just drawn a male symbol there? 167
D: Very biological. 169
G: We need a label don't we? I'll put it up here. 171
G: I think I might hand this over. It's just not happening for me. Do
they call it programmes? 173
F: So you've got that, now put features of it. 175
G: Yep, so features comes next? 177
F: You've got a circle, an oval and now a rectangle. This is very
mathematical. Are you maths-minded? 179
G: If I was to do this diagram again, I'd do it very differently, but
anyhow. So ... 181

D: We should be doing something else while you're doing that. 183
G: I was just going to suggest that Dick. Let's get learning resource
management ... I'll just write down the main points. You two discuss what
that means as if you were presenting it to the whole class. By the time
we're all finished, two jobs done for the price of one. 185
F: All right, so we need to get into the features because the others
will need to know that. So what about the subject matter? 187
D: Well it's subject matter and teaching strategies. 189
F: Like ingredients for cooking. 191
G: There's a good one. 193
F: We could make our presentation like a demonstration on how to make a
cake. 195
D: Or something else. 197
F: Yeah. What dish would you like Dick? 199
D: I don't mind really. 201
F: Do you have a favourite Seychelles dish? 203
D: No. It's the same food as we have here. 205
F: Any special rice dishes? We don't have to do cooking. 207
G: I'm not sure what you're trying to achieve but it could be related to
bio-mechanics or motor mechanics, or woodwork ... you do this followed
by that. Army instructions are very much a step by step thing - weapons
handling and that sort of thing. 209
F: I don't know much about that. 211
D: Okay so we need the right ingredients. 213
F: Yeah but that's the recipe, we want to do the menu - planning what
you're going to have. So this here would become like the planning
session, so like an entree, main cc .rse and a sweet. Then you'd plan the
guest list. Step three would be finances, how much it's all going to
cost, and you'd also plan decorations for the table and when you would
have it [teacher comes over]. 215
Tr: What number are you? 217
D: Two. Integrated Leaning Strategies. 219
F: We're looking at cooking. 221
D: How are we going to integrate the strategies here? 223
F: Well, looking at the in-context bit ... I don't know. 225
Tr: What are you trying to do? 227
F: Explain this in the context of a dinner party. 229
Tr: Great. How are you going to do that? 231
F: That's the hard part. We're not sure really. 233
G: It's not working at all. 235

++ Text units 277-339:
D: Ok come on cook [to Fran]. 277
F: But I'm the world's worst cook. 279
G: What are you guys actually doing here? Are you getting stuck with
this cooking thing? 281
F: We were looking at actual strategies. 283
D: [pointing to his work] These are the steps and these are the actual
content. And we can put the strategies in.. 285
G: Yes but what's the foundation? 287
D: I'm ... we're looking at cognitive strategies, where they come in and
why. 289
F: You'd probably take those two out now and see where they balance. 291
G: I don't get it. 293
F: We're putting this into the subject matter of cooking and the
teaching learning strategies we're looking at step by step, the menu us
actually covering the occasion. 295
G: So you're carrying cooking through these five points? 297
F: Yeah. Asking questions. 299
G: What sort of questions are you asking? 301

F: If ... well using cognitive strategies "Who's going to come and who won't"? 303
D: How are we going to present this? 305
G: That's what I mean. I think you've dug a hole for yourselves here. What I would be doing would be to look for a very simple way of getting this across. 307
F: Well the recipe is how you go about the cooking. 309
G: So? Is that going to help this class understand this section? 311
D: The subject matter is the planning of the birthday party. That's your topic. How to plan it. 313
G: I would tend to carry one thing through and use a variety of examples. The obvious one for me is pulling a piece of machinery apart. or maths. As a kid is doing long-division he is saying "What I've got to do here is say 'is six going to go into 13 and how much will I have left over'". So that's sort of thinking a loud the strategy. Or on a grander scale ... 315
*[Teacher talks to whole class asking them to now teach the whole class about the section they as a group studied. Calls on group A first. 317
G: [to Fran and the rest of the class] I'll bring up the model and you can explain it as you were discussing it before. 319
F: Oh [to the class] Dick and I were on another plane. 321
G: We picked the strategy that while I picked the bones out of the material, they would discuss how to explain it to you. We agreed on it but alas here I am and there they are. We're saying here that we have the Integrated Learning Strategies Program [pointing to overhead made by Gill] so in other words in the classroom you not only teach the subject matter but the learning strategies at the same time. That approach has a number of features, the first one being the step-by-step approach. 323
F: [from her chair] Yes the step-by-step is very procedural and that's why Dick and I immediately looked at cooking and the process of ... we had headings like planning ... 325
G: And it's also saying that it's related to the subject in a way, like the strategy is suited to a particular problem in a subject. The next one is ... actually Fran you can do this one. 327
F: Oh. Okay. 329
G: Why don't you come up? 331
F: No. I don't want to [class laughs, and Gill looking annoyed]. 333
G: What the next one meant to me was when someone is teaching maths rather than doing the calculation on the board the teacher is thinking aloud as he is doing it, like "I'm thinking of solving this problem by doing this. Then I think I will do that. What do you think? Is there a better way of doing this?" Thinking aloud their own thoughts and strategies. Also targeting or directing thinking, so the teacher asks certain questions about the subject to get the students thinking. The next one, props and clues, I'll just read that one straight out of the book for you, "As you're teaching you remind students about particular strategies, like 'remember this strategy, remember that strategy', I'll start you off on this then you can finish on your own'". And the last one, information on the various features of strategies directed towards the usefulness of them. So that's just explaining to the class the advantages of certain features, what they can do and what they can't do. 335
F: Well done Gill. 337
G: Yeah, no thanks to you [class laughs]. 339

Appendix L

Unit of analysis: Part 3

Example of sub-themes within a main theme

The following 30 text units constitute one theme and relate to a discussion on 'levels of processing'. Various sub-themes are evident within this main theme. These sub-themes are delimited by the coding references (4 4, 1 1, 2 2 etc).

Q.S.R. NUD.IST Power version, revision 4.0.
Licensee: Carole Steketee.
PROJECT: Part 3, User Carole, 10:32 am, Feb 22, 2002.

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+++ ON-LINE DOCUMENT: Class Act 1/2 - G1
*Semester Two - Part 3: *Inspiration®* as a cognitive tool
*First Session - 25/8/99
*Group 1 - Susie, Wanda & Deb

++ Text units 32-61:

S: Guys I'd really like to know a bit more about levels of processing. 32
(4 4)
D: Oh that's what I was looking for. 33
(4 4)
S: [reading the text] "developing your own knowledge, constructivism, situated learning metacognition". You know I don't know enough about that either. I'm so glad we don't have an exam in this unit because I hate memorising. 34
(4 4)
D: Me too. It's usually trivial stuff too - like NAFTA - North American Free Trade Agreement. Don't know anything about the agreement but I know what NAFTA stands for. Whoopee. I'd be good at a quiz night [laughs]. 35
(1 1)
W: Here it is. Page 262 levels of processing theories. Craik and Lockhart. 36
(4 4)
D: There's the definition in the margin [reads] "theory that recall of information is based on how deeply it is processed". So what does that mean? 37
(4 4)
W: The way you go about memorising it - whether it's in the permanent long term memory for storage - here we are [reads book] "Material that is elaborated when it is first learned will be easier to recall ..." 38
(4 4)
S: Wait a minute. I can't keep up typing or understanding. Say that again. 39
(4 4)
W: It's a form of rehearsal. It keeps the information activated in the working memory long enough to have a chance for permanent storage in the long-term memory. So you've got to keep rehashing it and that's where discussion reinforces it. So you're constantly reinforcing it. And see it says here "Second, elaboration builds extra links to existing knowledge. The more one bit of information is associated with other bits, the more

routes there are to follow to get to the original bit". So really, elaboration is different to rehearsal because you're not just rehashing over and over again but your linking it to experiences you've had to try and make it stick. 40

(4 1)

S: Yeah but how would that work for children? 41

(4 1)

D: Well the same way. 42

(4 1)

S: So is that elaboration? 43

(4 1)

W: I think that's a good definition of it. 44

(4 1)

S: Is that the same as extrapolation? 45

(4 1)

D: I think that elaboration is like reinforcing where you're talking about things and relating it to experiences and extrapolation is where you dissect things and look at bits then put it all back together again. Woolfolk doesn't say it that way but that's how I see that word. 46

(4 1)

W: Do we want to put that in [the concept map] - levels of processing? 47

(4 4)

S: Yes. Ooh what happened there [referring to *Inspiration®*]? 48

(2 2)

D: Click on this and it will never happen again. See. 49

(2 2)

S: Why have we got this lightening bolt [referring to symbol in map]? 50

(2 2)

D: [laughing] cause I thought it was a bolt out of the blue. 51

(2 2)

W: So we want to add elaboration and rehearsal. 52

(3 1)

D: But aren't they the metacognitive skill? What were they? 53

(3 1)

S: Yes I think so. Because metacognitive skills were the processes that control how you learn something. So is elaboration and extrapolation and rehearsal a metacognitive skill - it would be wouldn't it? 54

(3 1)

D: I'm so confused. 55

(3 1)

W: Well yes because they [metacognitive skills] intentionally regulate cognition. 56

(3 1)

D: But you don't intentionally - you don't say "I'm gong to intentionally rehearse these tables or I'm going to intentionally elaborate this idea" do you. 57

(3 1)

W: Not to that extent no. I don't think it has - well yes. You don't say it like that but you will intentionally keep going back over something until you're satisfied you've learned it. 58

(3 1)

S: This is actually starting to all fall into place for me. Shall we add that one to our map. 59

(4 4)

W: Oh look [reading Woolfolk] "Extrapolate is when you take the idea further". Add that in as a um, as a bit of, as a tidbit. 60

(3 2)

D: Thank you. To it's nth degree. 61

(3 2)