Computer-mediated communication in undergraduate mathematics courses

by

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Dedication

Mammatjie – diese Arbeit ist Dir zur Ehren!

Declaration

I declare that

Computer-mediated communication in pre-graduate mathematics courses.

is my own work and that the sources that I have used or quoted have been indicated and acknowledge by means of complete reference.

Rhena Delport 26 April 2003

Acknowledgements

Mein Vater im Himmel	Dir sei Ehre, Lob und Preis.
To my promotor – Prof Johannes Cronjé	Thank you for being inspiring and kind.
Allan, Marthinus, Michelle	Vir baie, baie ure se verdra en ook vir julle liefwees vir my.
Tuta	Danke, meine liebe Schwester, für Deine Treue und Liebe.
To my colleagues and dear friends	For your support and friendship.

Abstract

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Title: Computer-mediated communication in pre-graduate mathematics courses.

Computers afford an environment in which use of communication tools can promote deep learning. This may be ascribed to the creation of a varied learning environment, and to the induction of active, collaborative and self-directed learning.

A quantitative study was performed based on the results of a questionnaire developed to evaluate the students experience of web-supported learning. The association between presumed active use of communication tools, and perceptions concerning learning principles (varied and challenging learning environment, application of higher order thinking skills, and lecturer feedback and encouragement to interact frequently), was evaluated.

The results indicate that in general, learners associated a varied and challenging learning environment with the lecturer's feedback and encouragement to interact frequently (e.g. with discussions; e-mail contact etc.) and with perceived active communication via the bulletin board and e-mail facility. It appears that CMC using all communication tools, excluding the calendar, was dependent on encouragement by the lecturer to interact frequently. Perceived active use of e-mail and the chat facility was significantly associated with recognition of the need to apply higher-order thinking skills in order to do well in the course.

These findings support previous reports that CMC promotes deep learning. It is recommended that

- The e-mail facility is used for deeper problem analysis and where alternate solutions and strategies are to be generated.
- The bulletin board is used for application, analysis, evaluation, and synthesis.
- The chat facility is used to build attitudes, beliefs, confidence and motivation.
- The challenge of an environment should be created in which communities of learners are formed. Opportunity should be provided for socialising as well, as this promotes interdependence and collaboration.
- Feedback to individuals and groups and encouragement is provided timely and continually via e-mail and the bulletin board.

Opsomming

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Rekenaars skep ‘n omgewing waarin kommunikasiemiddele diepteleer kan bevorder. Dit kan toegeskryf word aan die daarstel van ‘n leeromgewing met verskeidenheid en ook aan die induksie van aktiewe-, groeps- en selfgerigte leer.

Hierdie kwantitatiewe studie is gebaseer op die resultate van ‘n vraelys wat ontwikkel is om die studente se ervaring van webondersteunde leer te evalueer. Daar is gepoog om die verwantskap tus sen vermeende aktiewe gebruik van die kommunikasiemiddele, persepsies betreffende leerbeginsels (‘n variërende en uitdagende leeromgewing, toepassing van hoër orde denk vaardighede, en terugvoer van die lektor, asook aanmoediging tot gereelde interaksie) te evalueer.

Die resultate dui daarop dat leerders oor die algemeen ‘n variërende en uitdagende leeromgewing assosieer met terugvoer van die lektor, asook aanmoediging tot gereelde interaksie (bv. deur gesprekvoering, e-pos kontak e.d.m.) en met vermeende aktiewe kommunikasie via die bulletinbord en die e-pos fasiliteit. Dit blyk dat rekenaar-gemedieerde-kommunikasie, met uitsluiting van die kalender, afhanklik is van aanmoediging tot gereelde interaksie Vermeende aktiewe gebruik van e-pos en die “Chat” fasiliteit was betekenisvol geassosieer met die aanname dat toepassing van hoër orde denkvaardighede nodig is om te kan presteer in die kursus.

Hierdie bevindings ondersteun vorige bevindings dat rekenaar-gemedieerde-kommunikasie diepteleer bevorder. Voorts word aanbeveel dat:

- Die e-pos fasiliteit aangewend word vir dieper probleem analise en in gevalle waar alternatiewe oplossings en strategieë gegenereer moet word.
- Die bulletinbord gebruik word vir toepassing, analise, evaluering en sintese.
- Die “chat” fasiliteit gebruik word om houdings, ingesteldheid aannames en selfvertroue te bou.
- ‘n Omgewing behoort geskep te word waarin ”leerdergemeenskappe” (communities of learners) gevorm word. Geleenthede om te sosialiseer moet voorsien word, aangesien dit interafhanklikheid en samewerking bevorder
- Terugvoer aan individue en groepe tydig en ook deurlopend gegee word via e-pos en die bulletinbord.

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CMC	Computer-mediated communication
HOTS	Higher-order thinking skills
e-mail	Electronic mail
UP	University of Pretoria
WebCT	World-wide Web Course Tools
VLE	Virtual Learning Environment
GSS	Group support system
TAM	Technology Acceptance Model
CSCL	Computer-supported collaborative learning environments
FTF	Face-to-face

CHAPTER 1

BACKGROUND INFORMATION

1.1 INTRODUCTION

This mini-dissertation examines the relationship between learning principles and computer-mediated communication in mathematics pre-graduate learning.

In this chapter, the problem statement, research objectives, basic hypothesis and research method are presented, followed by an exposition of the chapters.

1.2 PROBLEM STATEMENT

In line with continued advances in communication and information technology and with student numbers ever increasing at resident universities, more and more tertiary institutions have opted to offer on-line courses. McNeil, et al (2000), describe the key-concepts of change in tertiary education as listed below:

- Faculty migrates from being deliverers of information to facilitators and mentors.
- Students are being transformed from passive recipients to participants in an active learning environment.
- Interactions form the basis of the change as new types of interactions are emerging between faculty and students, between students and other students and between students and the educational resources they are exploring.
- New social and instructional interactions are replacing the traditional occurrences in face-to-face classrooms.

- New communication options are also evolving and a shift from a synchronous to an asynchronous communication structure is observed.
- "The use of e-mail, listservs and web-based conferencing has given teachers and learners new flexibility and has fostered a climate where learning takes place wherever and whenever it is convenient."

Different models of on-line or web-integrated learning have been proposed (Sherron and Boettcher, 1997; Mason, 1998; Bonk, et al., accessed 2000; Harasim, et al., 1999). Harasim, et al. (1999) provides a simple description of the ways in which traditional courses can be enhanced through distance learning methods. She describes on-line and Internet delivery of course material as being either an adjunct in traditional courses, or mixed with face-to-face teaching, or alternatively that the course material is delivered completely on-line.

Whatever model of web-support is used, or whatever level of web integration is present, interaction will only occur if both learner and facilitator are completely knowledgeable about, and are committed to use of CMC. Interaction may be defined as a: "…mutual or reciprocal action or influence and may occur between a student or groups of students and the instructor, the instructor and the whole class, among students themselves as a whole or in groups and between the students and the resources used in the course." (McNeil, et al. 2000). Tu (2000), states that:

Integrating CMC into classrooms requires an understanding of the relationship between CMC, the learners, and the instructors. Increasing all four types of interactions (learner–instructor, learner–content, learner–learner and learner–interface necessitates a thorough understanding of the strengths and weaknesses of each CMC system and the users (students and teachers) to integrate CMC technology into a virtual classroom.

Lee, et al. (1999) have identified the following affordances of CMC environments:

- A textual, permanent record of interactions is retained which keeps all participants up to date.

- Students for whom English is not their first language can take the time to check their understanding and they can also take their time to compose their replies without being under pressure as in a face-to-face situation.
- Deeper processing of material is possible because time for reflection is allowed, learners can refer back to things that were discussed earlier, and they can take their time to respond, perhaps researching their answers before putting them on-line.
- Opportunities for group-work and peer discussion are provided.

Lee, et al. (1999) have also identified the following limitations of CMC environments:

- Access to a computer and the internet are necessary as well as a certain level of technical competence
- Lack of expressive richness is observed since no non-verbal cues exist to enhance what is being said, and comments can often appear more critical than intended.
- Responding to questions may sometimes take extremely long.
- Decision-making may be difficult due to flexibility over time and the notion that everyone should have their say.

Advantages of asynchronous communication (e-mail) have been summarised as follows (James Cook University, Australia):

- 24 hours a day access: the e-mail can be sent at any time and will conveniently be received when the receiver switches on the computer;
- Easy access: you only need an account and a computer;
- Location / time independent;
- Open-entry and open-exit; you can enter or leave whenever you choose to;
- Independent learning;
- Distribution lists simplify distribution of information to a group;

- Private messages: you can send or receive a private message or file from anyone in the group;
- Better content of messages: you can take your time to formulate what you want to say; and
- Discussion of topics via listservs or discussion groups.

James Cook University regard the primary educational values of using e-mail in tandem with the WWW as:

- *Integrating information resources seamlessly to a dynamic and interactive teaching and learning environment;*
- *Allowing us to point and link to valuable existing educational resources on other Web sites;*
- *Enabling educators to create highly portable and accessible presentations and demonstrations;*
- *Providing learners with up-to-date information and answers/ feedback to their questions 24 hours a day, every day;*
- *Motivating learners to experience the real world of computing and networking in an engaging and active way when learners create their own home pages and put them on-line. This expands the meaning of computer literacy; and*
- *Encouraging a true learner-centred environment for learners by giving them complete control when they learn in a non-linear fashion.*

Ingram, et al. (2000), describe the disadvantages of synchronous communication are listed as:

- It does not always lend itself to deep reflective conversations;
- It places a premium on quick thinking and fast typing over careful thought;
- Many of the comments made in chat rooms are trivial and do not contribute to the discussion, at least not directly, as they may be important to establishing the social dimension of the chat adequately;
- Participants in synchronous discussions can become overloaded with information; and
- Skilful moderation in an on-line discussion is frequently needed.

The Committee on Classroom Use, Indiana University, defines a learning environment as follows: *"A learning environment is a physical, intellectual, psychological environment which facilitates learning through connectivity and community."* The environment that appears to support a constructivist-learning approach is a Virtual Learning Environment (VLE). According to Bayne and Cook (Accessed March 2003) a VLE "provides learners with all the facilities and learning opportunities they would experience in a face-to-face teaching situation, with the added advantages of flexibility of access to discussion, support, resources and assessment."

Britain and Liber (1999), describe Virtual Learning Environments (VLEs) as "learning management software systems that synthesise the functionality of computer-mediated communications software (e-mail, bulletin boards, newsgroups etc) and on-line methods of delivering course materials (e.g. the WWW)." They add that the technology provides learners with new tools to facilitate their learning and that VLEs aim "to accommodate a wider range of learning styles and goals, to encourage collaborative and resource-based learning and to allow greater sharing and re-use of resources."

Britain and Liber (1999) conclude that "Most of the benefits of VLEs lie in their potential to support styles of learning that are especially time-intensive for university teachers using traditional methods, but which have always formed a core part of a university education," referring, in particular, to:

- Collaborative learning;
- Discussion-led learning;
- Learner-centred learning; and
- Resource-based learning.

These authors (Britain and Liber,1999) employed an evaluation framework for VLEs using the interactions in the conversational model of Laurillard, (1993) as criteria against which to identify the tools and level of structuring provided by the VLE. These interactions are described as discursive, adaptive, interactive and reflective and the actions on the part of the student are

constructed around the dialogue, guided by constructive and meaningful feedback from the teacher and by their own reflections. The primary workflow actions that take place through the interactive medium are defined as follows:

1. Teacher presents conception.
2. Student presents conception.
3. Teacher sets up micro-world.
4. Student interacts with micro-world.
5. Tutor provides feedback to the learner.
6. Student modifies actions.

Table 1 below the evaluation framework for VLEs Britain and Liber (1999) employed using the interactions in the conversational model as criteria against which to identify the tools and level of structuring provided by the VLE. For each interaction they have provided examples of what they were looking for in an integrated VLE.

This methodology was implemented for the evaluation of WebCT, and Britain and Liber (1999) showed that WebCT appears quite suitable to realise these interactions as illustrated in Table 2.

Table 1. An evaluation framework constructed by Britain and Liber (1999) for VLEs, using the interaction stages of the conversational model.

	Tools	***Structuring***
1. Teacher Presents Conception	*What tools does the teacher have to hand: Text, video, audio, images?*	*Can a teacher easily put together different multimedia formats for presentation of a conception? Can these be readily altered for re-presentation in a different way*
2. Student Presents Conception	*Can the student interact with the teacher through the system? Does the student have multimedia authoring capabilities? Even if text-only, how does the student communicate with the teacher?*	*Clearly the dialogue between student and teacher is at the centre of the conversational model and how this is visually structured for both tutor and student is very important. Conversations should be at the centre of activity in the VLE rather than pushed to one side.*
3. Teacher sets up micro-world	*Multimedia authoring tools for creating course materials, embedded or linkable simulation programs, testing software such as quiz creation programs etc.*	*In a VLE the notion of micro-world can be applied at many different levels. The important point from the perspective of the conversational model is that it should be versatile enough to be adapted for an individual student on the basis of the ongoing conversational dialogue with that student.*
4. Student interacts with micro-world	*See 3 above*	*Again we can see this notion of micro-world at various levels. We are looking for more from the student side than simply being able to view content.*
5. Tutor provides feedback to the student	*Can the tutor use the communications tools to provide feedback to the student in the context of the learners' activities?*	*It might seem obvious that this would be true but the important point is that the feedback can be easily related to the action - i.e. any discussion thread should be linked to or embedded in the domain of actions.*
6. Student modifies actions	*Can the student return to the activities and modify their actions based on feedback received from the tutor?*	

Table 2: An evaluation of WebCT from Britain and Liber (1999), using the interaction stages of the conversational model.

	Tools	***Structuring***
1. Teacher Presents Conception	*Primary presentation is through course material space (html pages). Other presentation of concepts is possible via e-mail, Bulletin Board and Whiteboard*	*Learning Goals can be set for each page of content.*
2. Student Presents Conception	*Learner Presentation Area permits uploading of learner materials. Otherwise e-mail, BBS and Whiteboard*	
3. Teacher sets up micro-world	*The micro-world essentially is the course structure and materials. These are mostly prepared in advance. More fine-grained materials can feasibly be inserted at this stage. Any Web-interactive content can be incorporated.*	*Dynamic tree representation allows hierarchical structuring of course 'path'. Each tree branch is a web page.* *Calendar Tool allows time structuring.*
4. Student interacts with micro-world	• *Browsing content* • *Auto - Quizzes* • *Annotates content* • *Interacts with simulations and other live content*	*Study guide generation*
5. Tutor provides feedback to the student	*e-mail* *BBS (full conferencing tool)* *Whiteboard*	
6. Student modifies actions	*Learner can freely modify actions*	

When the principles rather than the stages of the conversation model (discursive, adaptable, interactive, reflective) were used to construct the evaluation of WebCT, Bayne and Cook identified the following possibilities for the realization of the principles, as shown in Table 3:

Table 3: An evaluation of WebCT using the principles of the conversational model.

Principle	*Finding*
Discursive	*E-mail and bulletin board for asynchronous communication, with whiteboard and chat for synchronous. Topic-specific discussions can be built into course materials. Learning outcomes can be defined with course content or on the welcome page. Tutors can create different 'fora' to separate topic discussions, though fora all appear within the same discussion board frame. Fora can be public or restricted to specific groups of learners.*
Adaptable	*Course content is uploaded in html and then converted into a linear sequence of pages (a 'path'). The path can be automatically redirected in response to a student's quiz answers. Learners can annotate pages of content. Private groups can be set up for exchange of documents. Materials are generally set up in advance of course starting and navigation through them is very structured. Ease of inserting new material would be limited.*
Interactive	*The ability to build discussion areas and self-test quizzes into course material makes each topic area potentially interactive. Students can make personal annotations. Group presentation areas allow students to share documents, though these areas are separated from the discussion fora.*
Reflective	*Self-test quizzes can be assigned at each stage of course content. Test results and feedback can be accessed. Contextualised discussion exists for each stage of course content.*

Web-supported learning using WebCT as learning management system appears to provide a learning environment that is conducive to learning as it offers benefits that concord with the recommendations of the Dearing report (Britain and Liber, 1999), which are:

- Flexibility of time and place.
- Coping with increased learner numbers.
- Sharing and re-use of resources.
- Collaborative work.
- Learner-centered learning.
- Reducing the administration burden.

The need was expressed by the Department of Mathematics at the University of Pretoria to investigate students' in undergraduate mathematics courses

perceptions of the learning environment. The aim of this study was therefore to determine whether web-support of mathematics courses provides an information rich and socially meaningful learning environment in which CMC facilitates communication and collaboration, and enables reflective and higher-order thinking.

The following questions guided the study:

- What are the implications of perceived active use of communication tools in a course for recognition of the need to apply higher order thinking skills (HOTS) in order to do well in the course?
- How does perceived provision of varied and challenging learning opportunities (e.g. debates; group work; etc.) relate to active use of communication tools and recognition of the need to apply HOTS in order to do well in the course?
- How does lecturer encouragement to interact frequently (e.g. with discussions; e-mail contact etc.) impact on perceived active use of communication tools in a course?

1.3 RESEARCH OBJECTIVES

The objectives of the research are divided into a general and specific objective.

1.3.1 General objective

The general objective of the study was to evaluate the significance of web-support and in particular, CMC in mathematics learning.

1.3.2 Specific objectives

The specific research objectives were to:

- Conceptualise the contribution of CMC to web-supported learning from the literature.
- Evaluate the interaction between the lecturer and the learner, and amongst learners in the online learning environment.
- Assess whether CMC management can be used to promote the use of higher-order thinking skills in pre-graduate mathematics courses.
- Explore the relation between the affective domain and use of communication tools.

1.4 BASIC HYPOTHESIS

A significant relationship exists between active use of communication tools in web-supported mathematics courses, and the defined learning principles:

- Provision of varied learning opportunities.
- Lecturer input.
- Facilitation of co-operative learning.
- Application of higher order thinking skills.

1.5 RESEARCH METHOD

The research method consists of the literature review, followed by an empirical study.

1.5.1 Phase 1: Literature review.

The literature review focuses on the following steps:

Step 1: Conceptualising the model of web-supported learning in WebCT, the learning platform currently used at the University of Pretoria.

Step 2: Understanding the contribution of CMC to learning from the literature.

Step 3: Indicating the underpinning constructs of on-line learning according to the literature.

1.5.2 Phase 2: Empirical study.

The following steps were followed in the empirical investigation:

1.5.2.1 Step 1: The choice of a research design.

This study was based on the results of a questionnaire routinely completed by learners upon conclusion of a web-supported module (Addendum A). The research was quantitative and the design of the study was a non-experimental survey. Data was analysed blind for course and for any information pertaining to the respondents and lecturers.

1.5.2.2 Step 2: The choice of a study sample.

Completion of the questionnaire was voluntary and the data of all pre-graduate learners registered for mathematics courses was extracted from the WebCT database. The study sample consisted 161 respondents from 1131 students who were enrolled for seven pre-graduate mathematics courses that were presented with web-support.

1.5.2.3 Step 3: The choice of measuring instruments.

A standard WebCT user evaluation questionnaire, customized by the Department of Telematic Learning and Education Innovation, was used for the study.

1.5.2.4 Step 4: Statistical analysis.

The statistical analyses were performed using STATISTIX software (STATISTIX 7 for Windows, Analytical Software, 2000). The Chi-Square Test procedure was used to analyse two-dimensional tables of discrete data. The hypothesis of independence was used to examine whether the variables acted independently from one another, or whether a significant association ($p < 0.05$) could be observed.

1.6 DIVISION OF CHAPTERS.

Chapters in this mini-dissertation address the following:

Chapter 1: Introduction
Chapter 2: Research article
Chapter 3: Conclusions, limitations and recommendations.

1.7 CHAPTER SUMMARY.

In this chapter, the research questions were formulated, based on the research problems that were identified and the objectives that were stated. A

basic hypothesis was presented as well as information on how the study was designed to test the hypothesis. Relevant literature was alluded to and an exposition of what could be expected in following chapters was provided.

The research article is presented in Chapter 2.

CHAPTER 2

RESEARCH ARTICLE

2.1 Introduction

Computer-mediated communication is meant for sharing and building of ideas, information and skills among the participants to strengthen knowledge building, integration and the application of conceptual information.
(Harasim, et al., 1995)

The purpose of this quantitative study was to examine the computer-mediated communication (CMC) experiences and perspectives concerning learning principles of undergraduate mathematics learners in web-supported courses.

2.1.1 Research questions

The following questions guided the study:

- What are the implications of perceived active use of communication tools in a course for recognition of the need to apply higher order thinking skills (HOTS) in order to do well in the course?
- How does perceived provision of varied and challenging learning opportunities (e.g. debates; group work; etc.) relate to active use of communication tools and recognition of the need to apply HOTS in order to do well in the course?
- How does lecturer encouragement to interact frequently (e.g. with discussions; e-mail contact etc.) impact on perceived active use of communication tools in a course?

2.1.2 Rationale for the study

The rationale for the study is that lecturers could increasingly encourage and manage CMC if active use of the communication tools appears to impact positively on learning in mathematics.

2.1.3 Aim of the study

The aim of the study was therefore to determine the relation between CMC and mathematics learning.

2.1.4 Basic hypothesis

Active use of communication tools is associated with application of higher order thinking skills.

2.1.5 Summary

It was found that:

- Learners associated a varied and challenging learning environment with lecturer's provision of helpful feedback on learner progress, learning from the lecturer's feedback and comments to the group and encouragement to interact frequently (e.g. with discussions; e-mail contact etc.)
- Learners associated a varied and challenging learning environment with perceived active communication via the bulletin board and e-mail facility;
- CMC using all communication tools, excluding the calendar, was dependent on encouragement by the lecturer to interact frequently; and
- Recognition of the need to apply HOTS in order to do well in the course was associated with perceived active use of e-mail and the chat facility.

2.2 Background

2.2.1 The model of on-line learning at the University of Pretoria.

The University of Pretoria (UP) endeavours to create a flexible learning environment that includes an electronic learning component to accommodate diverse learner needs. Electronic learning is "any learning situation where methods and techniques enabled by electronic devices combined with instructors and learners who are physically separated and who use methods and techniques enabled by electronic devices to transmit instructional messages over the distance between them." (Stubbs and Burnham, 1990).

The UP is currently using WebCT (World-wide Web Course Tools), which is "a tool that facilitates the creation of sophisticated Web-based educational environments" (Goldberg and Salari, 1997) as a learning management system. Currently 19 postgraduate programmes are presented on-line at UP, while a total of 1006 courses are presented with electronic support. Materials that supplement face-to-face teaching courses are made available on the web; in some courses active use is made of CMC to facilitate learning.

Mason (1998) describes three basic models of existing on-line courses, and the "Content and Support Model" would probably be most descriptive of the UP model as it has a relatively static body of content supplemented by tutorial support, and the level of on-line interaction is low (typically no more than 20% of the learners' time).

2.2.2 Computer-mediated communication

CMC is defined as the 'transmission and reception of messages using computers as input, storage, output, and routing devices' (Paulsen, 1997). In WebCT communication tools provide both asynchronous and synchronous mediums of communication.

The affordances, which refer to the "properties of objects or systems that allow certain actions to be readily performed with them, and which therefore push behaviour in certain directions (Gaver, 1992; Dede, 1991), as well as the limitations of the communication tools are briefly discussed in terms of their pedagogical application.

E-mail supports asynchronous text-based discussion and WebCT has a built-in e-mailer that distributes e-mail between lecturers and learners, as well as amongst learners registered for the course. The main difference between e-mail and a CMC system, like the one provided by WebCT, is that the user maintains the structures of discussions in a coherent manner without any action. This makes it suited to group-based interactions. With e-mail, messages arrive chronologically and are only grouped if the user takes the time to put related messages into a folder. Discussion threads may be broken if the subject line is changed. Learners can e-mail individual learners, instructors or groups. The internal e-mail system supports searching functions and attaching files. Learners can elect to forward their mail to an external address. (Clarke and Cronjé,1999; De Villiers, 2001).

The bulletin board allows participants to carry on discussions, upload and download files, and make announcements without the users being connected to the computer at the same time. Threaded discussions, forums, e-forums, and conferences can be conducted with this system. Discussion forums can be viewed by topic, by date, and by thread. Instructors can enable or disable anonymous posting and file attachments. Posts can contain a URL. Instructors may create separate discussion environments for small groups of learners and teaching assistants. Reed (2000) points out that bulletin boards are indicated when the instructor wants:

- longer responses;
- problem-solving or critical thinking; and
- analysis, synthesis, or evaluation level of interaction.

The chat facility allows real-time communication between multiple people, logged in at the same time. Comments are posted to a screen that is seen by all users at the same time, offering "the ability to trade ideas and information quickly and without necessarily being locked into a position" (Ingram et al. 2000). At times the conversation may be haphazard and difficult to follow, especially when a few topics evolve simultaneously. Reed (2000) states that chat discussions often seem to lack coherence, and with the text-based nature of chats, discussions can scroll out of view before they can be read. Reed (2000) says a chat room is indicated when the instructor wants:

- spontaneous responses;
- brainstorming;
- social interactions;
- role-play; and
- knowledge or comprehension-level questions and answers.

The on-line calendar facility provides an opportunity for the lecturer to communicate important dates and other information, while learners can use it for personal planning purposes as well.

2.3 Literature survey

2.3.1 What makes good web-supported learning?

The Committee on Classroom Use, Indiana University (Accessed April 2003), defines a learning environment as follows: "A learning environment is a physical, intellectual, psychological environment which facilitates learning through connectivity and community." The environment that appears to support a constructivist-learning approach is a Virtual Learning Environment (VLE) (Jonassen, 1993). According to Bayne and Cook (Accessed March 2003) a VLE "provides learners with all the facilities and learning opportunities they would experience in a face-to-face teaching situation, with the added advantages of flexibility of access to discussion, support, resources and assessment." According to Johnson (Johnson, 1989) the quality and quantity

of learning in a variety of areas, e.g. problem-solving, concept attainment, etc., are improved by placing the learners in a cooperative rather than a competitive or individualistic learning setting. Making use of communication tools in web-supported learning extends possibilities for cooperative learning. The learner, however, remains responsible to "co-constructs meaning by exploring an environment, solving a problem, or applying information to a new situation that he/she helps to define" (Campbell, 1999).

Britain and Liber (1999) propose that VLEs aim "to accommodate a wider range of learning styles and goals, to encourage collaborative and resource-based learning and to allow greater sharing and re-use of resources." They conclude that "Most of the benefits of VLEs lie in their potential to support styles of learning that are especially time-intensive for university teachers using traditional methods, but which have always formed a core part of a university education," referring, in particular, to:

- collaborative learning;
- discussion-led learning;
- learner-centred learning; and
- resource-based learning.

2.3.2 The relation between CMC and application of higher order thinking skills.

Shirani et al. (1999) conducted an experiment to examine the interaction between task structure (less structured and more structured) and technology to support synchronous (group support system: GSS) and asynchronous (e-mail) group communication. The GSS-supported groups, that gathered face-to-face in one room, generated more total and basic ideas. Groups using e-mail performed a deeper problem analysis as indicated by a higher proportion of inferential ideas generated by these groups. The number and proportion of inferential ideas was also significantly higher in the less structured task than those in the more structured one. They conclude that asynchronous

communication allows, and perhaps encourages, greater use of human information processing resulting in deeper analysis which is crucial in the late stages of a group decision, while interactive and synchronous communication may be more appropriate for initial stages of problem-solving when emphasis is more on generating a large number of new ideas than on generating alternate solutions and strategies.

As mentioned previously (Lee, et al., 1999) learning in a CMC environment can lead to deeper processing of material because time for reflection and response is allowed and the learner can refer back to the textual record that is kept. According to Grabinger and Dunlap (2000), deep learning results from validation of the learning experiences, and the necessity to articulate at a certain level in order to promote collective knowledge building. Furthermore, CMC promotes engagement and productive discussion (Harasim, 1990)

Lastly, if the communication tools are used actively, one can presume that student-to-student interaction and communication occur frequently. According to Boettcher and Cartwright (1997) interaction and communication between learners can promote active learning, encourage deeper-level mental processes and facilitate the manipulation of concepts and thought processes.

2.3.3 The relation between a varied learning environment, use of communication tools and application of higher order thinking skills.

Before we can investigate the relation between these variables, we need to find out what factors may influence the relation. Although CMC has potential benefits for learning in higher education, this does not always happen. Successful implementation of CMC appears to be effected by critical factors that provide a context and rationale for on-line communication by helping users to establish a *shared purpose*, according to Tolmie and Boyle (2000).

The Technology Acceptance Model (TAM) of Davis (1986) may possibly provide additional insight into use of the communication tools:

- In TAM both perceived usefulness and perceived ease of use could predict an individual's attitude concerning the use of an application.
- Venkatesh and Davis (1996) regarded computer self-efficacy as a determinant of perceived ease of use. This suggests that learners who are proficient users of the communication tools may use them more readily and effectively in web-supported courses. Wu and Lee (1999) regard the computer literacy of its users as a major factor in the success of any CMC program. They state: "As such, if the facilitators or the learners suffer from inadequate competency or a lack of exposure to educational technology, they would not make use of such resources well since they lack the proficiency to do so."
- If learners fully understand the added value that the communication tools (characteristics of the target technology) offer in terms of learning, they would probably make use of them. This assumption is based on the findings of Agrawal and Prasad (1997) who focused on the individual's perceptions about the characteristics of the target technology as explanatory and predictive variables for acceptance behaviour. They concluded that voluntariness and external pressures have an impact on the acceptance behaviour.

Hammond (2000) also found that perceptions of the medium were important in influencing participation. Hammond states "Learners who focused on the opportunities forums provided, and were prepared to take the risk of making a public contribution to debate, could and did become communicative learners. Learners who focused on the constraints perceived a high threshold to cross before they could join in." The author refers to a similar point made by Wegerif (1998) who describes "the challenge faced by learners in gaining the confidence to cross from outsider to insider within a group". Lee et al. (1999) propose that people need to see a real purpose for computer-based discussions (i.e. important to them and their learning) before they will use the system in meaningful ways. Gal-Ezer and Lupo (2002) report that the more

advanced the learners are in their studies, the more they tend to use the Web in its various applications.

Hammond (2000) found that interviewees frequently referred to four major aspects of on-line forums: messages were permanent; messages were public; communication was asynchronous; and messages could be edited before sending. Each of these aspects could be either an opportunity or threat to communication. He reflects on the affordances of a forum that include introduction and social exchanges, and reflective, possibly academic writing (as the permanence of text releases short term memory). Interestingly, he refers to "other types of communication (that) were not so easily afforded". Interviewees talked about "the labour of composing text (writing is slower than talking and physically more demanding) and the lack of immediate reaction".

The study of Selim (2003) revealed four major critical factors for the perceived usefulness of course websites.

1. Course work interactivity: Here the author lists the website usefulness factors of asynchronously delivered course material that:
    - Allows learners to retain control as to when and where they engage in the instruction,
    - Electronic discussion forums that enhance communications and interaction among learners;
    - Electronic availability of course materials in different formats via the course website which learners can freely download; and
    - Course websites that include links to related materials and websites and widen the learners' exposure to current information on their topics.
2. Providing them with on-line components such as animations and multimedia modules that enable learners to accomplish their course work quickly.
3. Making studying course material easier by having the course material available anytime anywhere, facilitating student–student and student–

instructor communications, and using interactive tools to explain course content.

4. Increasing the learners' productivity and effectiveness which is a result of enabling learners to finish their course work quickly and achieving their objectives efficiently using the tools available on the course website.

A paper by McNeil et al. (2000) provides some useful information concerning the relation between a varied and challenging environment, CMC and higher order thinking. The authors distinguish between learning in a computer-mediated environment and a traditional classroom.

These authors refer to a study by Harasim et al. (1995) in which they reported that in a computer-mediated environment, personal communication and discussion increased and became more detailed and deeper. Learning also became more collaborative as the traditional barriers between learners and faculty were broken down. They also noted that this type of learning environment facilitated cooperative learning: "Computer-mediated communication is meant for sharing and building of ideas, information and skills among the participants to strengthen knowledge building, integration and the application of conceptual information".

McNeil, et al. (2000), report the following differences in communications:

- In a traditional face-to-face class, communication between the faculty member and the student, dialogues among the students and dialogues between the student and the resources are synchronous. In Web-based courses this dialogue is often asynchronous.
- Communication between the faculty member and the student change from activities like note-taking, summarizing and questioning to interacting with electronic media. The role of the student changes from a receiver of information to an active participant in the learning process.
- Student-to-student interactions change from small-group work and lab activities that take place during a structured class to study groups and

collaborative projects that occur outside the classroom environment to on-line interactions.

- Lastly, student-to-resource communication that encapsulates the interaction that learners have with many of the traditional forms of resources such as textbooks, papers, research, videotapes and other instructional materials, occurs in both environments but in the electronic environment additional resources, such as Web sites, on-line databases, conference proceedings and simulations are available.

2.3.4 The relation between lecturer encouragement and computer–mediated communication.

Soong et al. (2001) reviewed the critical success factors for on-line course resources and found that the success of distance (on-line) learning relies heavily on the course facilitators (Willis, 1994), as well as their abilities (e.g. high human-emotion-interaction skills and high motivational skills) and activities (e.g. putting in the time and effort to make the resources interesting by contributing regularly to the web forum and including interesting reference materials on-line). Other studies contradict these findings in that the lecturer does not play such a direct role determining the use of resources and tools.

Gal-Ezer and Lupo (2002) studied students' attitudes towards the integration of Internet tools into traditional CS distance education and found that students do not take full advantage of the Web if use is voluntary - even those students who are advanced in their studies and have rich experience in using computers and the Internet. The use of the Web, however, increases as students advance in their studies, as the measure of distance education increases and the more it serves them as a communication channel and as a study tool.

These observations are partly explained by the theoretical constructs of transactional distance, interaction, learner control, and social context (McIsaac and Gunawardena, 1996, Tu, 2000). Moore (1990) suggests that the

transactional distance is determined by the amount of dialogue that occurs between the learner and the instructor, and the amount of structure that exists in the design of the course. An inverse relationship is observed between dialogue and structure. Dialogue increases as structure decreases and this leads to more interaction and less distance between on-line users. Chih-Hsiung Tu (2000) summarizes Saba and Shearer's (1994) findings after examining the relationship between dialogue and structure using a system model that was based on Moore's (1990) transactional distance construct as follows:

As learner control and dialogue increase, transactional distances decrease. Learner control and interaction are critical components of a learning environment. When learner controlled interactions occur in a learning environment, learners' and instructors' roles are reversed and learners initiate the dialogue. Instructors become facilitators, instead of information givers, during students' learning processes.

Ross and Morrison (1989), however, conclude: "Research findings regarding the effects of learner control as an adaptive strategy have been inconsistent, but more frequently negative than positive."

2.4 Theoretical underpinning

The theoretical underpinning for computer-integrated education lies within the cognitive psychology where learning is seen to consist of individual constructions of knowledge. Learning is regarded as a personal event that results from sustained and meaningful engagement with one's environment (Bruner, 1961, 1985, 1986). Learning occurs in a social and cultural context (Prawat and Floden, 1994). Piaget, using concepts like assimilation and accommodation, (Piaget, 1952) and Vygotsky, who developed the construct of the zone of proximal development, (Vygotsky, 1978) provide a framework for educational practices in technologically enhanced learning environments (Jonassen, 1988). Generative learning implies that meaningful learning occurs when the learner actively and consciously relates prior knowledge to new material and creates understandings based on these relationships (Wittrock,1974, Wetzel, 1993).

Gagnon and Collay (2003) have provided a simple exposition of constructivist-learning design. They refer to epistemological assumptions that form the basis of constructivist learning. The assumptions are that knowledge is constructed as follows:

- Physically, by learners who are involved in active learning.
- Symbolically, by learners who are making their own representations of action;
- Socially, by learners who convey their meaning making to others.
- Theoretically, by learners who try to explain things they do not completely understand.

According to these authors, learning design now entails the following:

Teachers develop the situation for students to explain, select a process for groupings of materials and students, build a bridge between what students already know and what they want them to learn, anticipate questions to ask and answer without giving away an explanation, encourage students to exhibit a record of their thinking by sharing it with others, and solicit students' reflections about their learning.

Current theoretical models introduce concepts like “knowledge building”, (Scardamalia and Bereiter, 1994), and “community of learners” and “community of practices”. Ligorio (2001), referring to the publication of Jonassen and McAleese, (1993) explains these terms as follows: Community of learners refers to the cognitive process of creating a new cultural product, while community of practices refers to the construction of "physical" objects. “Both concepts assume that learners construct knowledge by interpreting their perceptual experiences in terms of prior knowledge, current mental structures and existing beliefs.”

Collaborative learning fosters knowledge construction and understanding from multiple viewpoints, and Wilson (1995) defines a constructivist-learning environment as a place where different tools and sources of information are used by a group of learners who work together and support each other in problem-solving activities. Computers are defined as cognitive "artifacts" that

enable and promote active and collaborative knowledge building (Lehtinen et al., 1999).

In this study learners are expected to construct their own learning of Mathematics, using the communication tools to become part of a community of learners. The expectation is that higher order thinking and deeper learning will occur as a result of learning within the Web environment.

2.5. Research Method

2.5.1 Instrument used for the evaluation

2.5.1.1 The questionnaire

This study was based on the results of a questionnaire completed by learners upon conclusion of a web-supported module. The questionnaire was developed by a member of the E-Education Unit of the Department of Telematic Learning and Education Innovation and was based on the literature on student feedback.

The items included in the questionnaire were selected and grouped according to learning principles defined by the evaluator as:

- The provision of varied learning opportunities;
- lecturer feedback and support;
- facilitation of co-operative learning with communication tools;
- application of higher order thinking skills.

The items pertaining to these learning principles were the following:

Provision of varied learning opportunities

- The learning opportunities in the course (e.g. debates, group work, etc.) were varied and challenging.

Lecturer feedback and support

- The lecturer normally gave me helpful feedback on my progress.
- I learnt from the lecturer's feedback and comments to the group.
- The lecturer encouraged frequent interaction (e.g. discussions, e-mail contact, etc.)

Facilitation of co-operative learning with communication tools

- The discussions tool (= bulletin board) was actively used in my course.
- The WebCT e-mail facility was actively used in my course.
- The chat facility was actively used in my course.
- The on-line calendar facility was actively used in my course.

Application of higher order thinking skills

- To do well in this course, all you really needed was a good memory.

To express their perceptions of the web-supported leaning experience the learners could select one of the following options:

· Yes
· Sometimes
· No

Completion of the questionnaire was voluntary and the data of all pre-graduate learners registered for mathematics courses were extracted from the WebCT database. The total number of respondents of the 1135 subjects enrolled for the six mathematics courses was 161.

2.3.4.1 Statistical analysis

Analysis of the data was performed blind in terms of course and learner information. Statistical analyses (chi-square test) were performed with

STATISTIX software (STATISTIX 7 for Windows, Analytical Software, 2000), to test for association between variables.

2.5.2 Delimitations and limitations of the study

The sole source of information for the study was the data from the questionnaire. Actual use of the communication tools was not checked. Learner marks were not used as an outcome variable to quantify learning efficacy. Information from the lecturers responsible for the courses regarding their role in the management of communication with and between learners was not factored in. Therefore, this study reflects, solely, the perceptions and experiences of the learners enrolled for the web-supported mathematics courses.

The inclusion of an ambiguous response item: ”Sometimes” could possibly weaken the association between variables and alternative measures to express agreement should preferably have been used.

The approach of the study is interpretive and projected results may not be inferred.

2.5.3 Perspective

The research is quantitative and the design of the study is a non-experimental survey.

2.5.4 Validity and reliability

Requesting 2 colleagues to perform the grouping established reliability of the grouping of the items by the researcher according to learning principles. No differences were observed in the groupings.

The validity of the questionnaire is beyond the scope of this study since it was designed by the E-Education Unit and not by this researcher.

2.5.5 Research matrix

Table 1. The association between the defined variables in the research questions and the learning principles that were investigated

Question \ Learning principle	Provision of varied learning opportunities.	Interaction with the lecturer.	Active use of the communication tools.	Application of higher order thinking skills.
What are the implications of CMC on learner learning?				
How does the provision of varied learning opportunities relate to CMC and learning?				
To what extent does interaction with the lecturer enhance learner learning?				
How does lecturer encouragement impact on computer-mediated communication?				

The association between the defined variables in the research question and the learning principles that are highlighted is tested.

2.6. Results

The findings to the research questions are described as follows:

2.6.1 Question 1

Question 1 was defined as: What are the implications of perceived active use of communication tools in a course for recognition of the need to apply higher order thinking skills (HOTS) in order to do well in the course? The Chi square test was used to see whether the perceived use of all the communication tools differed in the mathematics courses. The perceived active use of the communication tools differed significantly between courses for all tools excluding use of the chat facility (Table 2).

Table 2. Association between active use of communication tools and mathematics courses.

Variable	Chi square	p-value
Use of the bulletin board	25.4	0.005
Use of the e-mail facility	36.5	0.001
Use of the chat facility	13.1	NS
Use of the calendar	66.3	0.001

Evaluation of the relation between the perceived use of the communication tools and the perceived application of higher order thinking skills showed that the application of higher order thinking skills is associated with the perceived active use of e-mail and the chat facility (Table 3). No significant association was observed between the active use of the bulletin board, or the use of the calendar facility and higher order thinking skills in mathematics courses.

Table 3. Association between active use of communication tools and higher order thinking skills in mathematics courses.

Variable	Chi square	p-value
Use of the bulletin board	2.1	NS
Use of the e-mail facility	11.5	0.021
Use of the chat facility	17.7	0.001
Use of the calendar	0.9	NS

When the association between active use of e-mail and higher order thinking skills in mathematics courses was evaluated 27.5% (n=42) of the respondents appeared to agree and 45% (n=78) did not agree that active use had been made of e-mail in the course. Fifty eight percent of respondents (n=91) did not agree that to do well in this course, all you really needed was a good memory. Of the 42 respondents who agreed that active use had been made of e-mail in the course 25 (59%) did not agree that to do well in this course, all you really needed was a good memory, while 10 (24%) of these subjects agreed.

When the association between active use of the chat facility and higher order thinking skills in mathematics courses was evaluated the following was observed: Of the respondents 11% (n=17) agreed that active use had been made and 69% (n=109) did not agree that active use had been made of the chat facility in the course. Fifty-eight percent of subjects (n=91) did not agree that to do well in this course, all you really needed was a good memory. Of the 17 subjects who thought that active use had been made of chat facility in the course 9 (53%) did not agree that to do well in this course, all you really needed was a good memory, while 7 (42%) of these subjects agreed.

2.6.2 Question 2

Question 2 was defined as: How does the perceived provision of varied and challenging learning opportunities (e.g. debates, group work, etc.) relate to the active use of communication tools and recognition of the need to apply HOTS in order to do well in the course?

The percentage of respondents that agreed that the learning opportunities in the courses (e.g. debates, group work, etc.) were varied and challenging, ranged between 23 and 58%. No significant association was observed between courses and perceived provision of varied learning opportunities (Overall chi square= 10.15; $p > 0.05$). The learners thus appeared to perceive the courses as being similar, concerning the provision of varied learning opportunities.

When the association between the provision of varied learning opportunities and lecturer interaction was evaluated, it appeared that learners associate a varied and challenging learning environment with lecturer feedback to individuals and to the group (Table 4). Lecturer encouragement also appears to contribute to experiencing varied learning opportunities (Table 4).

Table 4. Association between provision of varied learning opportunities and lecturer interaction.

Variable	Chi square	p-value
The lecturer normally gave me helpful feedback on my progress	23.5	< 0.001
The lecturer encouraged frequent interaction (e.g. discussions; e-mail contact etc.)	37.03	< 0.001
I learnt from the lecturer's feedback and comments to the group.	24.53	< 0.001

Further analyses of these results showed that of the 81 learners that agreed that they had regarded the learning opportunities in the course as varied and challenging

- 56 (69%) said the lecturer normally gave them helpful feedback on their progress
- 54 (66%) said the lecturer had encouraged frequent interaction (e.g. discussions, e-mail contact, etc.)
- 55 (68%) said they had learnt from the lecturer's feedback

It was found that learners associated a varied and challenging learning environment with active communication via the bulletin board and e-mail facility. Active use of the communication tools thus appeared to contribute to the provision of varied learning opportunities (Table 5)

Table 5. Association between provision of varied learning opportunities and active use of the communication tools.

Variable	Chi square	p-value
Use of the bulletin board	13.12	0.011
Use of the e-mail facility	9.62	0.047
Use of the chat facility	8.07	NS
Use of the calendar	0.75	NS

Of the learners that agreed that active use had been made of the bulletin board (n=59) and e-mail (n=42), approximately 62% regarded the learning opportunities in the course as varied and challenging. No significant association was observed between the provision of varied learning opportunities and higher order thinking skills.

2.6.3 Question 3

Question 2 was defined as: How does lecturer encouragement to interact frequently (e.g. with discussions, e-mail contact, etc.) impact on the perceived active use of communication tools in a course?

Evaluation of these associations showed that encouragement by the lecturer to interact was significantly related to CMC using all communication tools (Table 6).
Of the 82 learners that agreed that the lecturer encouraged frequent interaction

- 52 (63%) felt that active made of the bulletin board had been made
- 59 (72%) felt that active of the e-mail facility had been made
- 52 (63%) felt that active of the chat facility had been made
- 42 (51%) felt that active of the calendar had been made

Table 6. Association between encouragement of lecturer to interact and active use of communication tools.

Variable	Chi square	p-value
Use of the bulletin board	24.73	<0.001
Use of the e-mail facility	27.22	<0.001
Use of the chat facility	13.23	<0.05
Use of the calendar	19.7	<0.001

Table 7 summarizes the findings of associations between variables in the study. Interaction with the lecturer appeared to contribute to experiencing varied learning opportunities and resulted in the perceived active use of all communication tools. The perceived active use of the bulletin board and e-mail facility were related to experiencing varied learning opportunities, while the perceived active use of the e-mail and chat facility related to higher order thinking.

Table 7. Summary of the associations observed between the learning principles studied.

	Interaction with the lecturer	Active use of the communication tools	Introduction of higher order thinking skills
Provision of varied learning opportunities	+	Use of the bulletin board and e-mail facility	-
Interaction with the lecturer		+	-
Active use of the communication tools	Use of all communication tools		Use of the e-mail and the chat facility

2.7. Conclusions

2.7.1 Finding 1

The application of higher order thinking skills is associated with the perceived active use of e-mail and the chat facility and is not related to the perception that varied and challenging learning opportunities are provided in the courses.

Conclusion:

Higher order thinking is related to CMC (via e-mail and the chat facility).

We have so far observed that these findings are corroborated by the findings of other studies when we look at the following publications (Table 8):

Table 8. Publications referring to the cognitive affordances of communication tools

Reference	Tool	Affordance
Shirani et al., 1999.	e-mail	Deeper problem analysis. Generating alternate solutions and strategies.
Shirani et al., 1999.	Synchronous group support systems used in a face-to-face setting	Generation of more total and basic ideas. Generating a large number of new ideas.
Lee et al., 1999.	Non-specified CMC	Deeper processing of material.
Grabinger and Dunlap, 2000.	Non-specified CMC	Deep learning.
Hammond, 2000.	Discussion Forums	Reflective, possibly academic writing. Structured writing.
Harasim, 1990. Hartman et al., 1995. Hunt, 1995. Mason and Kaye, 1990. Reed, 1998.	Bulletin board	Useful for fostering higher types of learning such as application, analysis, evaluation and synthesis.

It can thus be concluded from these studies that CMC promotes higher order thinking, referring to Bloom's (Bloom et al., 1964) level where problem-solving (transferring existing knowledge and skills to new situations) occurs. One could infer that the use of the bulletin board should also be associated with

processes at the lowest cognitive level relating to knowledge (recall or recognition of specific information) as all discussions and postings are stored for retrieval that would activate recall. Use of the chat facility, given the urgency associated with the immediacy of the communications, could probably also be associated with higher order thinking. What this boils down to is that the affordances of a tool do not determine the cognitive level at which the user operates, but that a knowledgeable learner could use it optimally. Reed (1998) concludes from his own studies that:

- CMC can be a valuable tool when the type of CMC is matched to both the type of interaction and the level of complexity;
- chat and instant messaging is best utilized for the lower levels of Bloom's taxonomy, knowledge and comprehension;
- bulletin boards allow for thoughtful and reflective responses, and novice users find it easier to follow conversational patterns and topics when bulletin boards are being used;
- compared with chats, responses are longer in bulletin board posts and are more thorough;
- more peer-to-peer interaction about content is seen in a bulletin board forum than in a chat room.

He suggests that bulletin boards be used to "discuss content, ask questions that require detailed answers, and provide a place for students to help each other with their learning."

What is fascinating about the results of the reported study is the strong association between the use of the chat facility and appreciation of the application of higher order thinking skills in order to do well in the mathematics course. As the group of learners who had the impression that active use had been made of the chat facility was small, it is possible that they chose to do so of their own accord, because they were aware of the usefulness of the tool for collaborative learning, exchange of information and instant messenging.

2.7.2 Finding 2

While the majority of learners did not agree, some learners reported that active use was made of the chat facility. Learners who presumably made active use of the chat facility on their own accord were learners who had a high regard for the necessity of higher order thinking skills in order to do well in the course.

Conclusion:

The learner takes control with active use of the chat and e-mail facility.

Hannafin (1984) reported that learner control is likely to be most successful when:

- learners are older and more able;
- the educational objective is to impart a higher order of skills rather than factual information;
- the content is familiar;
- advice is provided to assist learners in making decisions.

Learner control may as well be evident when the learner chooses to make full use of the affordances of communication tools. It seems logical to expect that the more intelligent, mature learner will use any tools he/she deems useful to advance his/her learning. Wilson (2000) actually found that CMC systems will be adopted and used successfully by the same types of student who do well in courses conducted via face-to-face communication, e.g., students with high-achievement or high-aptitude characteristics (Wilson, 2000). This author observed that high-achievers are willing to work harder and longer in their CMC systems usage, just as they do in other activities. High-aptitude (and female) students appear to use CMC systems more frequently than other students, and they explain this finding as follows: “One interpretation is that both groups are using the system for give-and-take conversation, suggesting a higher level of comfort with the technology.”

Based on the empirical evidence that the cognitive processes necessary for deep learning and information retention occur in dialogues (Van der Linden and Renshaw, 2001, as referred to by Kreijns et al., 2003) it appears vital that CMC be managed to promote collaborative learning.

So far we have only looked at the cognitive domain of learning and not at the affective domain. Affective outcomes such as interest, attitude and appreciation appear to be equally important issues in problem solving (Tularam, 1997). Ingram et al. (2000) remark that many of the comments made in chat rooms are trivial and do not contribute to the discussion, at least not directly, as they may be important to establishing the social dimension of the chat adequately. Whether the learners in this study used the chat facility for collaborative critical mental processing or for idle chats is not known, but is probably not so important as Zhang and Fulford (1994) point out that student perceptions of the efficacy of social interaction in a course can have significant effects on learning outcomes. Kreijns et al. (2003), have made this thought-provoking statement:

The propensity to focus singularly on the cognitive aspects of learning has led to the design of purely functional CSCL (computer-supported collaborative learning) environments, i.e. environments that solely support and guide social interaction towards critical thinking, argumentation, or socially constructing meaning.

Tularam (1997) describes the relation between the cognitive and affective domain as quoted below:

Critical thinking, for example, comprises habits of mind such as an interest in the sources of one's attitudes, beliefs, and values; a positive attitude toward novelty; and a healthy attitude toward argumentation, as well as intellectual skills. We can teach students how to think well, but in the end they must have an interest in thinking well and choose to do so independently throughout their lives.

In fact, Johnson (1973) previously contended:

When the beauty and the importance as well as the substance of a subject are taught, when pupils appreciate the importance and usefulness of what they are learning, education is an exciting, growth producing experience. Affective reactions to school curriculum may, thus, be in the long run far more important than the mastery of content.

Wolfgang Schlöglmann (2003) defines the categories of affective representation used in mathematics education research as:

- Emotions, which are rapidly changing states of feeling, which may be mild to very intense, and are usually local or embedded in a context;
- Attitudes, which are moderately stable predispositions toward ways of feeling in classes of situations, involving a balance of affect and cognition;
- Beliefs, which are internal representations to which the believer attributes truth, validity, or applicability, that are usually stable and highly cognitive, and which may be highly structured;
- Values, ethics, and morals, that are deeply held preferences, sometimes characterized as "personal truth", stable, highly affective as well as cognitive, and may also be highly structured (Goldin, 2001).

Cognizance of these affective representations is of cardinal importance in mathematics learning, as is evident from the following: DeBellis and Goldin (1997) speculate that beliefs, attitudes, emotions, and values interplay with cognition and as such can either facilitate or hinder monitoring during problem-solving. They suggest that affective pathways are either positive or negative and that they have an impact on problem-solving behaviour. They state: “If a positive pathway is experienced initially during problem-solving experiences, curiosity may serve as a motivating factor leading the individual to a deeper understanding of the problem and the enactment of exploratory heuristics. Frustration may lead to an impasse resulting in an ineffective revision of strategies. Experiencing a negative pathway may lead to bafflement and the individual resolve to use ‘safe' procedures rather than exploration.”

These affective categories may possibly impact on the use of either synchronous or asynchronous CMC. I would expect emotions to impact on the ability to use synchronous CMC because of the tension created by

exposure while exploring, while asynchronous communication provides a safer environment to work in.

2.7.3 Finding 3

Experiencing the web-supported environment as varied and challenging is best explained by encouragement from the lecturer to interact frequently by means of e.g. discussions, e-mail contact etc., followed by helpful feedback from the lecturer on progress and learning from the lecturer's feedback and comments to the group. Active communication via the bulletin board and e-mail facility also contributed significantly to the experience, but to a much lesser extent.

Conclusion:

A varied learning environment is related to lecturer involvement and computer-mediated communication (via the bulletin board and e-mail).

The definition of context by Tessmer and Ritchie, (1997) that “Context is a multilevel body of factors in which learning and performances are embedded...not discrete factors but the simultaneous interaction of a number of mutually interactive factors: physical, social and instructional” embraces my concepts concerning the learner, the environment and communication, especially as it takes into account the learner’s emotions, needs, values and beliefs. From our research it is obvious that the lecturer plays a very important role in creating the “varied and challenging” environment.

Graham, et al. (2003) cite "lessons learned" for on-line instruction that correspond to the original seven principles of Chickering and Gamson's (1987) guidelines, and they provide valuable information on how to best to maintain a successful on-line environment:

Concerning the 1st principle: *Good Practice Encourages Student-Faculty Contact* Graham et al. (2003) suggest the following: “Instructors should provide clear guidelines for interaction with students.” Policies describing the types of communication that should take place over different channels, e.g. " The public discussion forum is to be used for all communications except grade-related questions" should be established. Clear standards for instructors' timelines for responding to messages should be set, e.g. " I will respond to e-mails on Tuesdays and Fridays between three and five o' clock."

Concerning the 2nd principle: *Good Practice Encourages Cooperation Among Students* Graham et al. (2003) suggest the following: “Well-designed discussion assignments facilitate meaningful cooperation among students.” These authors recommend the following to create effective asynchronous discussions:

- Learners should be required to participate (and their grade should depend on participation).
- Discussion groups should remain small.
- Discussions should be focused on a task.
- Tasks should always result in a product.
- Tasks should engage learners in the content.
- Learners should receive feedback on their discussions.
- Evaluation should be based on the quality of postings (and not the length or number).
- Instructors should post expectations for discussions.

Feedback from the lecturer appears to contribute greatly to learner participation and to the use of communication tools. Prompt feedback is an essential teaching principle (Rossman,1999; Chickering and Ehrmann, 1996) and this is especially true for on-line learning. Concerning the 4th Principle: *Good Practice Encourages Cooperation Among Students* Graham et al. (2003) suggest that the instructors provide two types of feedback: information feedback and acknowledgment feedback. “Information feedback provides information or evaluation, such as an answer to a question, or an assignment

grade and comments. Acknowledgement feedback confirms that some event has occurred. For example, the instructor may send an e-mail acknowledging that he or she has received a question or assignment and will respond soon."

Instant feedback is vital for e-mail to be effective as an alternative option for further two-way communication between teachers and learners. Yu and Yu (2002) reported that the willingness of many learners to have out-of-classroom contacts with the instructor via e-mail was encouraged by the instructor's instant response. They emphasize that to cultivate on-line two-way communication, instant feedback provided by recipients will be an important task all participants should adhere to.

2.7.4 Finding 4

CMC using all communication tools appears to be dependent on lecturer encouragement to interact frequent (e.g. using discussions, e-mail contact, etc.)

Conclusion:

CMC is dependent on lecturer encouragement.

Once again the involvement of the lecturer appears to be of the utmost importance. In a recent study Oliver and Omari (1999) reported that the students frequently indicated that they value the input of the teacher in web-based teaching and regard this component as a valuable part of teaching and learning. They expressed the need for remembering the important role of the teacher in any learning process and the need for ensuring that students have adequate access to, and lines of, communication with their teachers.

The contribution of the learners to their learning should, however, not be underestimated. Soong et al. (2001) defined the critical success factors for on-line course resources and hypothesize that if the course encourages collaboration, such that the learners become active participants in the learning

process, learners will have higher learning and deeper discourse (i.e. the provided resource is successful). They propose that usage of on-line course resources as well as enjoyment levels will be high if the learners' and educators' epistemology is that of a constructivist approach (Resnick, 1989) and conclude “Since learning takes place in a participatory framework, not in an individual mind (Lave and Wenger, 1991), when learners are passive participants in the learning process, they do not learn with understanding.”

2.8. Recommendations

The most important recommendations derived from this study and from the literature appear to relate to managing CMC. CMC should be managed in such a way that active, collaborative, deep and independent learning can occur within the electronic environment. The lecturer plays a very important role in motivating students to make use of CMC, and should encourage learner control and independent learning.

Table 9 shows the recommendations that follow from the conclusions of this study.

Table 9. Recommendation arising from the conclusions drawn from the study

Conclusion	Recommendation
Higher order thinking is related to CMC (via e-mail and the chat facility).	E-mail should be used for deeper problem analysis and where alternate solutions and strategies are to be generated. The bulletin board could be used for application, analysis, evaluation, and synthesis. The chat facility could be used to build attitudes, beliefs, confidence and motivation.
The learner takes control with active use of the chat facility.	The challenge of creating an environment in which communities of learners are formed should receive priority. Opportunity should be provided for socializing as well, as this promotes interdependence and collaboration.
A varied learning environment is related to lecturer involvement and CMC (via the bulletin board and e-mail).	Feedback to individuals and groups remains essential and should be provided timeously and continually. Feedback and encouragement can be communicated via e-mail and the bulletin board.
CMC is dependent on lecturer encouragement.	CMC should be integrated within all WebCT courses and it is imperative that the lecturer provides the necessary encouragement for further use of the communication tools.

To summarise, the following recommendations are made:

- E-mail facility should be used for deeper problem analysis and where alternate solutions and strategies are to be generated.
- The bulletin board should be used for application, analysis, evaluation, and synthesis.
- The chat facility should be used to build attitudes, beliefs, confidence, and motivation.
- The challenge of an environment should be created in which communities of learners are formed. Opportunity should be provided for socialising as well as this promotes interdependence and collaboration.
- Feedback to individuals and groups and encouragement should be provided timeously and continually via e-mail and the bulletin board.

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CHAPTER 3

CONCLUSIONS, LIMITATIONS AND RECOMMENDATIONS

The conclusions derives from the results of this study have been tested against the findings of other researchers and subject-matter experts. Possible limitations of the current study are touched upon and prospective research topics are listed, after defining recommendations for the institution concerning on-line learning.

3.1 CONCLUSIONS

Conclusions are drawn with regard to the specific theoretical objectives and the results obtained from the empirical investigation.

3.1.1 Conclusions in terms of the specific literature review objectives

Table 14 provides a summary of what was reported in the literature concerning the conclusions derived from this study relating to CMC, higher-order thinking, a varied and challenging learning environment and lecturer contribution.

Table 10. Findings in the literature concerning the results of this study on computer-mediated communication and mathematics learning.

Conclusion	Findings in the literature
Higher order thinking is related to computer-mediated communication (via e-mail and the chat facility).	E-mail does contribute to deep learning and also to creative thinking. Asynchronous discussion forums were related to reflective, possibly academic or structured writing. The chat facility is best used for spontaneous responses, brainstorming, social interactions, role-play, knowledge or comprehension-level; and Q&A. Chats could provide the affective scaffold that promotes cognitive learning.
The learner takes control with active use of the chat facility.	No direct relation was reported thus far.
A varied learning environment is related to lecturer involvement and computer-mediated communication (via the bulletin board and e-mail).	Useful for fostering higher types of learning such as application, analysis, evaluation, and synthesis.
Computer-mediated communication is dependent on lecturer encouragement.	The lecturer plays a pivotal role in CMC, except if the learner chooses to take control of his/her learning.

3.1.2 Conclusions in terms of the specific empirical objectives

The research questions, findings, conclusions, and recommendation of this study are tabled in Table 15. From this table it can be seen that the most important recommendations relate to the management of CMC in such a way that active, collaborative, deep and independent learning can occur within the electronic environment. This specifically relates to the teaching of mathematics.

Table 11. Summary of research questions, findings, conclusions, and recommendation.

Research question	Findings	Conclusion	Recommendation
What are the implications of perceived active use of communication tools in a course for recognition of the need to apply higher order thinking skills (HOTS) in order to do well in the course?	Application of higher order thinking skills was associated with perceived active use of e-mail and the chat facility and was not related to the perception that varied and challenging learning opportunities were provided in the courses.	Higher order thinking is related to computer-mediated communication (via e-mail and the chat facility).	E-mail should be used for deeper problem analysis and where alternate solutions and strategies are to be generated. The bulletin board could be used for application, analysis, evaluation, and synthesis. The chat facility could be used to build attitudes, beliefs, confidence and motivation.
	While the majority of learners did not agree, some learners reported that active use was made of the chat facility. Learners who presumably made active use of the chat facility on their own accord were learners who had a high regard for the necessity of higher order thinking skills in order to do well in the course.	The learner takes control with active use of the chat facility.	The challenge of creating an environment in which communities of learners are formed should receive priority. Opportunity should be provided for socialising as well as this promotes interdependence and collaboration.
How does perceived provision of varied and challenging learning opportunities (e.g. debates; group work; etc.) relate to active use of communication tools and recognition of the need to	Experiencing the web-supported environment as varied and challenging is best explained by encouragement from the lecturer to interact frequently by means of e.g. discussions, e-mail contact etc., followed by helpful feedback from the lecturer on progress and	A varied learning environment is related to lecturer involvement and computer-mediated communication (via the bulletin board and e-mail).	Feedback to individuals and groups remains essential and should be provided timely and continually. Feedback and encouragement can be communicated via e-mail and the bulletin board.

apply HOTS in order to do well in the course?	learning from the lecturer's feedback and comments to the group. Active communication via the bulletin board and e-mail facility also contributed significantly to the experience, but to a much lesser extent.		
How does lecturer encouragement to interact frequently (e.g. with discussions; e-mail contact etc.) impact on perceived active use of communication tools in a course?	CMC using all communication tools appears to be dependent on lecturer encouragement to frequent interact (e.g. using discussions; e-mail contact etc.)	Computer-mediated communication is dependent on lecturer encouragement.	CMC should be integrated within all WebCT courses and it is imperative that the lecturer provides the necessary encouragement to further use of the communication tools.

3.2 LIMITATIONS

The following limitations were identified for this study:

- The researcher used data that was collected with a different objective, namely to evaluate the students' experience of the on-line learning environment. Ideally a questionnaire should have been developed to test the assumption that CMC contributes to deep learning, or problem solving or conceptualisation in mathematics.

- The sole source of information for the study was the data from the questionnaire that evaluated perceived active use of communication tools. Actual use of the communication tools was not tested; neither was the nature and content of the messages or postings checked to see whether they related to social or subject matters.

- From a negative response to the question: "To do well in this course, all you really needed was a good memory", was inferred that the respondent agreed that application of higher order thinking skills was needed to do well in this course. Application of higher-order thinking could possibly have been evaluated more directly and not as circumspect as was the case.

- Test or exam marks were not used as an outcome variable to verify that learning in mathematics was enhances within the web-environment. The study design did not permit comparisons to be performed between different categories of perceived or actual use of communication tool concerning outcome of learning.

- Information from the lecturers responsible for the courses regarding their role in the management of communication with and between learners was not factored in.

- The inclusion of an ambiguous response item: ”Sometimes” could possibly weaken the association between variables, especially concerning perceived active use of communication tools. Alternative measures to express agreement should preferably have been used.

- The approach of the study is interpretive and projected results may not be inferred.

3.3 RECOMMENDATIONS

Recommendations concerning on-line mathematics learning are made in this section, and possible topics for future research are listed.

3.3.1 Recommendations for the organisation

Recommendations concerning the choice to use communication tools:
The following need to be considered for successful web-supported learning:

Learner variables:

- Educational levels;
- CMC expertise;
- Computer aptitude;
- Motivation; and
- Financial status of students

Program variables to be considered:

- The objectives of the course and the appropriateness of the course for web-supported delivery;
- The specific nature of the discipline; and
- Group sizes within the courses.

Institutional variables:

- Strategic plans should be formulated which address the changing roles of the university as provider of innovative teaching and supplier of appropriate resources and support.
- Technological infrastructure should be in place.
- Policy should be development concerning e.g.
    - Reward systems, time release for the development of web-supported courses;
    - Initial training through workshops and seminars to raise awareness of new technology;
    - Availability of continuous assistance with technical problems; and
    - Learner support in terms of registration, library access, and other services.

The following recommendations can be made, in line with a cognitive constructivist approach, concerning web-supported learning:

- Emphasis should be placed on authenticity of tasks;
- Opportunities should be provided for thoughtful reflection on experience; and
- Learner-control or self-regulation should be encourage by minimising teacher-dominated structure in the content which is being studied; and

Recommendations on how the lecturer can encourage feedback from learners (Scott, et al. 2000):

- Send weekly notes on class business via a group e-mail list for the class and encourage learners to send private e-mail messages or to phone the instructor as appropriate. Make use of personal notes throughout the on-line course to simulate the informal chat that often occurs at the beginning of a traditional class.
- Opportunities for providing feedback on individual learning activities should be provided as the course progresses. This information can be used for improving the design of the learning activities.

- Keep track of how learners are progressing, and send a gentle reminder (an e-nudge) to those learners with missing assignments noting that they are behind and asking if there is a problem or what can be done to help.
- Encourage learners to complete course evaluations. This provides learners with a forum to express concerns, raise course-related issues and to provide other feedback.
- Encourage learners to engage each other in debate and to post useful citations or URLs to the discussion forum for all to see.
- In many classes, size prevents the instructor from responding individually to each learner response. Identify similar or related comments around a common theme, the provide a summary statement that could be addressed to the group of individuals.

Recommendations concerning an approach that favours affective representations:

- Lecturers should ensure that learners approach the learning environments with a creative spirit and a motivated mind.
- Beliefs, attitudes, emotions, and values of learners should be tested to filter out negative affective representations.

3.3.2 Recommendations for future research

Future research could focus on:

- Evaluating lecturers' perceptions in a qualitative study concerning the value of CMC in mathematics learning to determine lecturer constraints in on-line learning.
- Performing action learning action research concerning the implementation of the different communication tools in different mathematics courses to promote conceptual understanding.

- Exploring all possibilities of collaborative learning in pre-graduate mathematics learning within the web environment and measure the outcomes in terms of achievement and user satisfaction.
- Investigating determinants of learner control in mathematics learning.
- Testing the association between the affective characteristics: attitudes, belief and emotions and use of CMC in mathematics and investigating whether the categories of Krathwol et al.'s Taxonomy of the Affective Domain could apply.

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Addendum A

Course Survey to be loaded per Module

Select one of the following options:

Question 1 (Lecturer: Feedback)
The lecturer normally gave me helpful feedback on my progress.
· Yes
· Sometimes
· No

Question 2 (Lecturer: Slow response)
I became frustrated because the lecturer was slow to respond to my e-mail and/or discussion messages.
· Yes
· Sometimes
· No

Question 3 (Lecturer: Interaction)
The lecturer encouraged frequent interaction (e.g. discussions; e-mail contact etc.)
· Yes
· Sometimes
· No

Question 4 (Lecturer: Learning opportunities)
The learning opportunities in the course (e.g. debates; group work; etc.) were varied and challenging.
· Yes
· Sometimes
· No

Question 5 (Lecturer: Physical contact)
The lecturer still required me to physically visit his/her office/department to obtain some of the course materials and information.
· Yes
· Sometimes
· No

Question 6 (Instruction: Feedback)
I learnt from the lecturer's feedback and comments to the group.
· Yes
· Sometimes
· No

Question 7 (Instruction: memory)
To do well in this course, all you really needed was a good memory.
· Yes

- Sometimes
- No

Question 8 (Interactivity: Discussions)
The Discussions Tool (= bulletin board) was actively used in my course.
- Yes
- Sometimes
- No

Question 9 (Interactivity: E-mail)
The WebCT E-mail facility was actively used in my course.
- Yes
- Sometimes
- No

Question 10 (Interactivity: Chat)
The Chat facility was actively used in my course.
- Yes
- Sometimes
- No

Question 11 (Interactivity: Calendar)
The online Calendar facility was actively used in my course.
- Yes
- Sometimes
- No

Question 12 (Optional)
I would like to mention the following lecturers as excellent course leaders:
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Questionnaire developed by the E-Education Unit, Department of Telematic Learning and Education Innovation, University of Pretoria.