COMPUTER SUPPORTED COLLABORATIVE RESEARCH

By

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A thesis submitted for the degree of Master of Philosophy

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26 August 2008

UNIVERSITY OF SOUTHAMPTON

ABSTRACT

FACULTY OF ENGINEERING

SCHOOL OF ELECTRONICS AND COMPUTER SCIENCE

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Although the areas of Human Computer Interaction (HCI), Computer Supported Collaborative Work (CSCW), and Computer Supported Collaborative Learning (CSCL) are now relatively well established, the related field of Computer Supported Collaborative Research (CSCR) is newly proposed here. An analysis of the principles and issues behind CSCR is performed leading to a full definition and specification of the CSCR domain is provided with a view to setting up an e-laboratory designed to support research students and their supervisors wherever they are located, as well as general collaborative research supporting diverse faculties and business developments. The present state of the subject with a literature review of the parent subjects have been considered to determine the models and methodologies necessary. The analysis will lead to the design of a particular computer interface and collaborative support engine to support the research community. This is to be trialled on research projects and through an iterative process of feedback and re-design to create an effective interface and collaborative e- laboratory.

The primary outcome will be the analysis and re-design of the online e-research laboratory together with a measure of its efficacy in the research process.

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Acknowledgements

I would like to thank my Supervisors David Argles and Gary Wills for their unfailing help and support and constant encouragement.

I would also like to thank my friends for their support and understanding.
They know who they are.

"A VRE is a specific instance of a software tool whereas CSCR is a conceptual domain which contains the specification for all possible collaborative research environments".

Chapter 5

Chapter 1 Introduction

The field of Computer Supported Collaborative Research (CSCR) is not yet established. There is very little in the literature concerning the significant issues which arise in the design of a support system for collaborative researchers to enable them to work together effectively from a distance.

Much has been written about the twin related fields of Computer Supported Collaborative Work (CSCW) and Computer Supported Collaborative Learning (CSCL) which have been the subject of intense interest in the HCI research community during the past years. CSCR on the other hand has arisen from within these fields recently, (Hinze-Hoare, V. 2006c) and needs to be examined more closely.

The split between CSCW and CSCL has grown wider in response to the recognition that the learning process is distinct from the working pattern and is more intensively understood through theories of pedagogy and education. Furthermore, it is recognised that the distinction between learning and research leads to its own requirements and issues for a collaborative framework.

It has become apparent that CSCL requires all of the facets of CSCW but in addition is constrained by pedagogical theories, and as such it is argued here that CSCL is a subset of CSCW. In addition, it is also apparent that CSCR is a subset of CSCL, with research understood to be a highly specialised and highly refined learning process that takes place without the presence of a teaching environment. This requires new mechanisms of learning, new theories of independent knowledge acquisition and new mechanisms to support these activities with new techniques and tools.

The purpose of this research is to focus upon the relatively unknown field of CSCR and to examine the significant issues in designing a computer supported collaborative system to assist the research community including research students and their supervisors. A survey of the recent literature will be undertaken which will highlight the central issues. A methodology for constructing, evaluating and testing a CSCR environment will be considered. Using an iterative process of feedback and re-design it is hoped to fine tune the requirements of the system and so produce a viable CSCR research environment.

What now follows is a detailed literature review. The area of HCI will be considered and this will be followed by consideration of CSCW and CSCL. Because the collaborative learning environment is based upon educational principles as well as HCI principles the pedagogical viewpoint will then be looked at. The relationships of HCI disciplines are illustrated in Figure 1 After the literature survey has been concluded the new area of Computer Supported Collaborative Research CSCR is addressed and its relationship to both CSCW and CSCL is examined. A proposal is made for the development of a CSCR environment to support the particular case of collaboration between research students and their supervisors.

At that point a hypothesis is proposed as an answer to the research question:

> ***"What are the significant issues in designing a CSCR system to support research students and their supervisors to work on collaborative research?"***

Using a methodology of iterative investigation, analysis and evaluation the method of a viable interface construction is discussed in detail. This will involve the feature analysis of a range of standard VLEs together with a set of custom e-learning environments as the closest environments to a CSCR system. The tools used are categorised and evaluated to determine the requirements for the particular CSCR environment to produce an appropriate toolset which can be taken forward for evaluation.

1.1 Background

The twin fields of Computer Supported Collaborative Work (CSCW) and Computer supported Collaborative Learning (CSCL) have been the subject of intense interest in the HCI research community during the past seven years. (see Hinze-Hoare, V. 2006c) The split between CSCW and CSCL has grown wider in response to the recognition that the learning process is distinct from the working pattern and is better understood through theories of pedagogy and education as discussed in chapter 4.

It has become apparent that CSCL requires all of the facets of CSCW but in addition is constrained by these pedagogical theories and as such it is argued here that CSCL is a subset of CSCW (see figure1)

The process of research is also a learning process but one which is more highly refined and involves learning in a particular way. "***Research** is the creation of new kn*owledge".[1] "***Research** encompasses activities that increase the sum of human knowledge [OECD Definition]*".[2] This definition of research means that the body of knowledge cannot be taught by another but must be discovered. The learning process is a subset of the normal learning and teaching process. It is argued further that research, which is supported by computer collaboration, is a subset of CSCL. (see Figure 1)

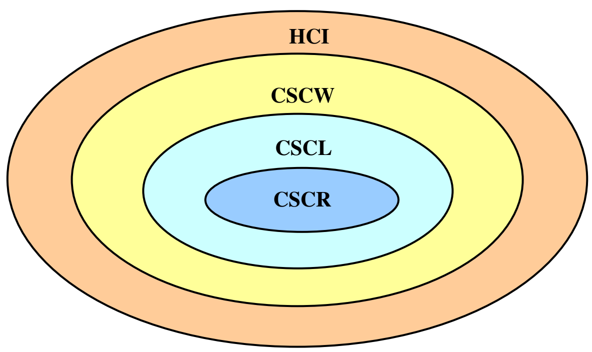

Figure 1 Relationship of HCI Disciplines

This diagram represents one particular way of viewing the relationships between these disciplines and focuses on 'areas of jurisdiction'. Other ways of ordering the disciplines could be based on scope or history etc. We see in this diagram that CSCW is subset of the discipline of HCI in so far as it is that limited part of HCI which is concerned only with collaborative working. CSCL in turn is a subset of the field of CSCW and is that part which is governed by additional constraints of educational theory. Finally, in this view, CSCR is a subset of CSCL as it is one of many types of learning – that which is concerned only with the discovery of new knowledge.

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[1] www.universities-scotland.ac.uk/Facts%20and%20Figures/Research.pdf

[2] www.jcu.edu.au/office/research_office/researchdef.html

An alternative way to view these relationships is not from the viewpoint of increasing refinement of the field, but of the supportive principles by which each field is governed. In order to deal with collaborative working the HCI principles need to be supplemented with principles which are specific to collaboration, and these can be laid on top of standard HCI principles as an additional set of rules for this specialization only. In addition CSCL will use all the rules of HCI and CSCW but will require its own set of rules determined by its particular constraints and CSCR similarly will use all the rules of HCI, CSCW and CSCL but will be further constrained by the specialist rules of its own area. This support structure can best be illustrated in Figure 2 which shows how each discipline rests on the rules of the discipline below it. More will be said about this when we come to consider the specific nature of the CSCR system.

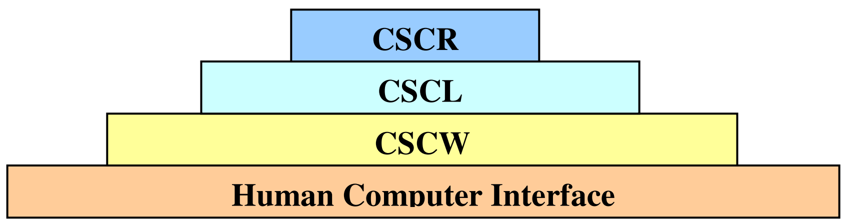

Figure 2 Collaborative Working Layer Cake

1.2 Summary

It has been shown that HCI contains a number of disciplines and these are subsets of each other determined by the layering of the accumulating constraints of collaboration, learning and research.

This thesis deals with the development of CSCR by analysing the proposed definitions of CSCW and CSCL, in showing the weaknesses of the present formulations of these fields and in offering new definitions which incorporate them into a single larger framework that brings together these fields and the new area of CSCR.

Chapter two initially involves a literature review of HCI and examines the basic theories and models presented by the leading authors in the field. HCI is shown to be fragmentary and inconsistently defined with no clear agreement as to its scope or nature.

CSCW is reviewed in Chapter three where the structure of fifteen e-laboratories is analysed. These are dedicated online areas for a variety of activities including testing, learning, exchanging information and a range of other work centred actions. These are introduced in order to determine the necessary components for a description of the CSCW domain. A review of research findings is provided.

The study of CSCL is addressed in Chapter four which also considers the pedagogical basis for the CSCL domain.

Chapter five leads to the central and most significant part of this thesis in that a new area of research is defined as CSCR. A clear definition of this domain is provided which links it into a larger framework containing CSCW and CSCL. Previous definitions of CSCW and CSCL are shown to be adequate within their own domain but incomplete without reference to CSCR.

The CSCR domain is brought into concrete realisation in Chapter six with a proof of concept design of a particular collaborative research environment for students and their supervisors (CRESS). A full categorisation and selection of appropriate tools is made and three scenarios are provided to illustrate instances of its use. This is tested with a pilot study and the feedback used to refine the interface which has the potential to re-formulate the questionnaire for further evaluation. Finally an analysis is undertaken to determine the most appropriate way to realise the interface.

Chapter seven offers conclusions and directs attention to possible future work.

The work presented here is original to the author and presents new features which have been developed as a result of personal research in the fields of CSCW and CSCL. The new field of CSCR is entirely original to this thesis and is distinct from e-Science, e-Research and related concepts such as VREs. See Chapter 5 for a full definition of CSCR and section 5.9 for a comparison with other environments and domains.

Chapter 2 Review of Human Computer Interaction (HCI)

2.1 History of HCI

According to Diaper (2005) the chronology of HCI starts in 1959 with Shakel's paper on *"The ergonomics of a computer"* which was the first time that these issues were ever addressed. This was followed by Licklider who produced what has come to be known as the seminal paper (1960) on *"Man – Computer Symbiosis"* which sees man and computer living together. There was no further significant activity for almost 10 years when in 1969 the first HCI conference and first specialist journal, *"The International Journal of Man-Machine Studies"* was launched. The 1980s saw the launch of three more HCI journals and conferences with an average attendance of 500 (Diaper 2005). It was not until the 1990s that the "I" in HCI switched from *"interface to "interaction"* reflecting the vastly expanding range of digital technologies. It was also during the 1990s that the term "*Usability*" has come to be synonymous with virtually all activities in HCI. Prior to this HCI encompassed five goals to develop or improve:

- Safety
- Utility
- Effectiveness
- Efficiency
- Usability

Originally usability was the least but has since been promoted to cover everything. *"The study of HCI became the study of Usability"* (Diaper, 2005).

Brad Myers (1998) has reviewed the history of HCI from a technological point of view and shows that HCI started with university research in direct manipulation of graphical objects as long ago as 1960, with commercial research not starting until 1970 and commercial products available from 1980. Myers also highlights up and coming areas of modern HCI research

- **Gesture Recognition:**
  pen-based input device,
- **Multi-Media:**
  multiple windows and integrated text and graphics
- **3-D Input/Output:**
  ultrasonic 3D location sensing system
- **Virtual Reality and "Augmented Reality":**
  much of the early research on head-mounted displays and on the Data Glove was supported by NASA.
- **Computer Supported Cooperative Work.**
  the remote participation of multiple people at various sites
- **Natural language and speech:**
  fundamental research for speech and natural language understanding and generation

2.2 The Basic Characteristics and Structure of HCI

Dix *et al* (1992) states that "*Human computer interaction can be defined as the discipline concerned with the design, evaluation, and implementation of interactive computing systems for human use and with the study of major phenomena surrounding them*"

HCI has been influenced by a number of disciplines including theories of education, psychology, collaboration as well as efficiency and ergonomics as shown in Figure 3.

Recent developments in the area of HCI have shown an interest in adaptive interfaces

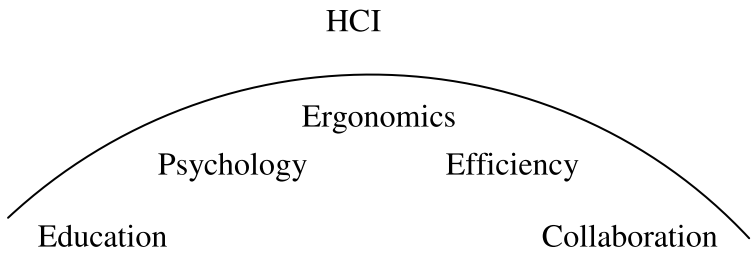

Figure 3 HCI Contributory influences (Hinze-Hoare 2006)

(Savidis and Staphanidis 2004), speech recognition (Wald 2005), gestures (Karam and Schraefel 2005) and the role of time (Wild and Johnson 2004, and Oulasvirta and Tamminen 2004).

2.3 HCI Theories and Principles

There are typically many thousands of rules which have been developed for the assessment of usability (Nielsen, J. 1993, p19), and there have been many attempts to reduce the complexity to a manageable set of rules (Nielsen, J. 1993, Baker, Greenberg and Gutwin, 2002). Jacob Nielsen has produced 10 rules which he calls usability heuristics and which are designed to explain a large proportion of problems observed in interface design, which he recommends should be followed by all user interface designers.

1. Simple and natural dialogue

Efforts should be made to avoid irrelevant information. Nielsen says that every extra unit of information competes with units of relevant information and diminishes its visibility.

2. Speak the Users' language

All information should be expressed in concepts which are familiar to the user rather than familiar to the operator or the system.

3. Minimize the Users' memory load

It is important that the user should not have to remember information from one part of a dialogue to another. Help should be available at easily retrievable points in the system.

4. Consistency

Words, situations and actions within the context of the system should always mean the same thing no matter where they occur in the system.

5. Feedback

Users should always be informed about what is going on in the system in a timely and relevant way.

6. Clearly marked Exits

Errors are often made in choosing functions which are not required and there needs to be a quick emergency exit to return to the previous state without having to engage in extended dialogue.

7. Shortcuts

Required by the expert user (and unseen by the novice user) to speed up the interaction with the system.

8. Good error messages

These need to be expressed in a plain language that the user understands which are specific enough to identify the problem and suggest a solution.

9. Prevent Errors

A careful design will prevent a problem from occurring.

10. Help and documentation

The best systems can be used without documentation. However, when such help is needed it should be easily to hand, focused on the users task and list specific steps to solutions.

Baker, Greenberg and Gutwin (2002) have taken Jakob Nielsen's heuristic evaluation a stage further and considered the problems posed by groupware usability concerns. They have adapted Nielsen's heuristic evaluation methodology to collaborative work within small scale interactions between group members. They have produced what they call 8 groupware heuristics.

- **Provide the means for intentional and appropriate verbal communication.**
  The most basic form of communication in groups is verbal conversation. Intentional communication is used to establish common understanding of the task at hand and this occurs in one of three ways.

    - People talk explicitly about what they are doing
    - People overhear others conversations
    - People listen to running commentary that people produce describing their actions.
- **Provide the means for intentional and appropriate gestured communication.** Explicit gestures are use alongside verbal communication to convey information. Intentional gestures take various forms. Illustration is acted out speech, Emblems are actions that replace words and Deixis is a combination of gestures and voice
- **Provide consequential communication of an individual's embodiment** Bodily actions unintentionally give off information about who is in the workspace, where they are and what they are doing. Unintentional body language is fundamental for sustaining teamwork.
- **Provide consequential communication of shared artefacts** A person manipulating an artefact in a workspace unintentionally gives information about how it is to be used and what is being done with it
- **Provide Protection** People should be protected from inadvertently interfering with the work of others or altering or destroying work that others have done
- **Manage the transitions between tightly and loosely coupled collaboration** Coupling is the degree to which people are working together. People continually shift back and forth between loosely and tightly coupled collaboration as they move between individual and group work
- **Support people with the coordination of their actions** Members of a group mediate their interactions by taking turns negotiating the sharing of a common workspace. Groups regularly reorganize the division of work based upon what other participants have done or are doing.
- **Facilitate finding collaborators and establishing contact** Meetings are normally facilitated by physical proximity and can be unscheduled, spontaneous or initiated. The lack of physical proximity in virtual environments requires other mechanisms to compensate.

Others have produced alternative sets of rules. However, the important issue is that there is no consensus as to which set of rules should be applied in any given case. In other words HCI is a fragmented discipline which according to Diaper (2005) shows a lack of coherent development.

2.4 HCI Models

A variety of different models have been put forward which are designed to provide an HCI theory in a particular context. This includes Norman's Model, Abowd and Beale's model and the audience participation model of Nemirovsky (2003), which presents a new theoretical basis for audience participation in HCI.

2.4.1 Norman's model of interaction

This has probably been the most influential (Dix *et al* 1992 p105) because it mirrors human intuition. In essence this model is based on the user formulating a plan of action and then carrying it out at the interface. Norman has divided this into seven stages:

1. establishing the goal
2. forming the intention
3. specifying the action sequence
4. executing the action
5. perceiving the system state
6. interpreting the system state
7. evaluating the system state with respect to the goals and intentions

2.4.2 The Interaction Model

Abowd and Beale (Dix *et al* 1992 p106) have produced an interaction framework built on Norman's model but theirs is designed to be a more realistic model.

This has four main components:

1. the system	S	2. the user	U
3. the input	I	4. the output	O

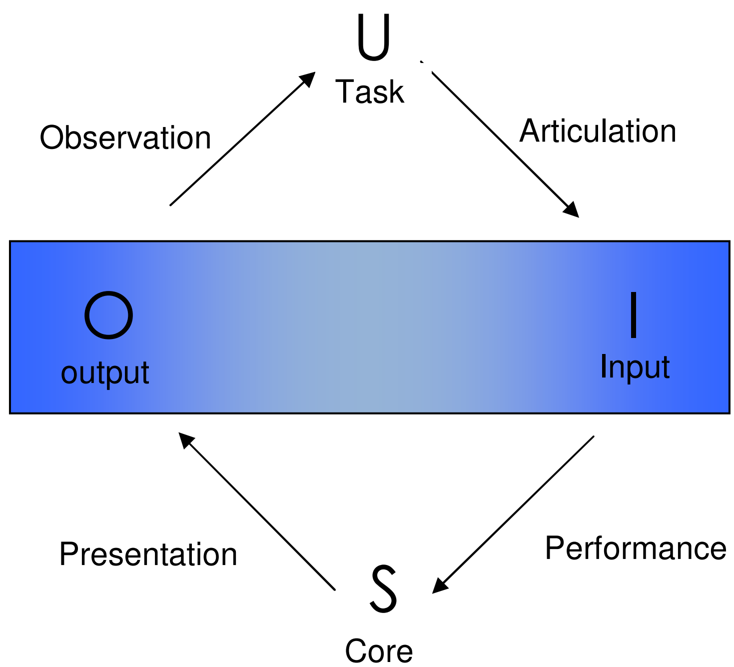

Figure 4 The General Interaction Framework (after Abowd & Beale 1991)

The interface sits between the user and the system and there is a four step interactive cycle as shown in the labelled arrows of Figure 4. The user formulates a task to achieve a goal. The user manipulates the machine through the input articulated by the input language. The input language is translated into the systems core language to perform the operation. The system is in a new state which is featured as the output. The output is communicated to the user by observation.

2.4.3 Audience Participation Model

Nemirovsky (2003) put forward the controversial view that sees computers as deterministic boxes blindly following their commands while users are incapable of changing the course of the program running on the computer. Users are considered to be an audience rather than participants. The old model included the idea that the mass of people wish to be entertained rather than to be creative. Users which treat the computer and its interface in a creative way are punished for creative thinking which is regarded as making a mistake. As a consequence computer users do not have a proper framework to express themselves. This is a strikingly radical approach. Instead, Nemirovsky is concerned with users as participants that explore the media space. He goes on to discuss the "emonic" environment, which he defines as a framework for creation, modification, exchange and performance of audio visual media. This is composed of the three layers:

- Input (interfaces for sampling)
- Structural (a neural network for providing structural control)
- Perceptual (direct media modification)

This latter and more radical model is unlikely to have any real application to the CSCL problem at hand, since its sphere of application is designed to emulate the creative inspiration of the artist battling against the mechanical controls of the machine. This does not correspond to the sphere of collaborative environment this paper is concerned with.

2.5 HCI Analysis Methodology

A number of different methodologies have been created to determine the effectiveness of HCI measurements. These have been refined resulting in the *User Needs Analysis* of Lindgaard *et al* (2006) that suggests how and where user centred design and requirements engineering approaches should be integrated. After reviewing various process models for user centred design analysis they suggest a refined approach and identified the main problems as:

- The decision where to begin and end the analysis needs to be clarified.
- Deciding how to document and present the outcome.

Lindgaard's user needs analysis method involves the following steps:

- **First**: Identify user groups and interview key players from all groups to find the different roles and tasks of the primary and secondary users.
- **Second**: Communicate this information to the rest of the team by constructing task analysis data and translating this into workflow diagrams supporting the user interface design. Create a table that shows the information about user roles and data input.
- **Third**: Upon submitting the first draft of the user needs analysis report create the first iterative design prototype of the user interface based on minimising the path of data flow. Lingaard initially produced a prototype in PowerPoint which he said was faster and more effective that prototyping in Dreamweaver.
- **Fourth**: Prototypes were handed over to developers as part of the user interface specification package.
- **Fifth**: Usability testing was used to determine the adequacy of the interface. Feedback from watching users work with the prototype and discussing with them what they were doing always resulted in more information.
- **Sixth**: Prototype usability testing meant that the requirements became clearer which resulted in more changes to the user interface design and the prototype.
- **Seventh**: The formal plan involved three iterations of design- prototype- usability tests for each user role.
- **Eighth**: Practical issues of feasibility should not be overlooked in the quest to meet users' needs. A highly experienced software developer is a necessity on the user interface design team in order to ensure that the changes proposed were feasible.

2.6 The Fragmentation of HCI

The History of HCI according to Diaper (2005) shows a lack of coherent development. There is no agreement as to:

- What HCI should be
- What HCI can do
- How HCI can do it
- How HCI can be allowed to do it

The fragmentation of HCI discipline is already so extensive according to Diaper 2005 that it is hard to even characterise the method of approach. As an example different practitioners have different priorities and different methodologies. Some approaches will start with requirements, while others start with evaluation and yet others with dialogue or user modelling or scenarios or information or design or artefacts or processes. This lack of agreement highlights the necessity for the development of a general systems model, both in the general HCI approach and in the specific collaborative approach. This view is also expressed by a number of other researchers who have directly commented on CSCL which is fully applicable to HCI because according to our model HCI is the container for CSCL:

Kligyte, **(2001)** has recorded that "*CSCL emerged as an autonomous research field out of the wider CSCW research area quite recently, and there is still lack of consensus about core concepts, methodologies and even the object of study"*.

Lipponen (2002) concludes his review paper on CSCL with the comment "*There is still no unifying and established theoretical framework, no agreed objects of study, no methodological consensus or agreement about the concept of collaboration or unit of analysis"*.

Strijbos *et al* (2005) have pointed out that a review of CSCL conference proceedings revealed a general vagueness in the definitions of units used in the analysis of CSCL. They further comment that arguments were lacking in choosing units of analysis and reasons for developing content analysis procedures were not made explicit. They conclude that CSCL is still an emerging paradigm in educational research. This suggests that there may be a need to evaluate new definitions in order to contextualise this work.

2.7 This Project's Analysis of HCI principles

It has been shown that HCI is in a state of fragmentation. This leads to the problem of adopting a coherent and consistent set of principles by which to measure the HCI performance of an interface. To this effect many sets of principles have been put forward by many different authorities in this field. However there is no consistent single set of principles accepted by all. The purpose of this section is to normalise the range of principles which have been proposed and to determine the most significant set.

2.7.1 Methodology

It will be described here how the normalisation process is accomplished.

Stage1: Use Authors' citation frequency as a weighting factor.

A survey of the HCI literature was undertaken based upon the citation frequency of authorship. It was deemed that the most frequently cited authors would provide the most important and respected HCI principles. Furthermore the citation frequency of the authors would constitute a mechanism for weighting the authority of the principles. HCIBIB.ORG maintains a citation frequency database of all HCI authors[3]. This shows the most frequently cited authors (10 or more publications) in the HCI Bibliography starting in Dec 1998 generated from the author fields and from tables of contents. The top ten names together with their citation frequency are given as follows[4]:

Citation Number	Author	Weighting
436	Nielsen,	29.
186	Shneiderman,	13
165	Carroll,	11
133	Myers,	9
102	Salvendy,	7
96	Pemberton,	7
92	Marcus,	6
92	Grudin,	6
87	Perlman,	6
87	Greenberg,	6

Table 1 HCI Authors and their Citation Ranking

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[3] http://www.hcibib.org/authors.html

[4] As of March 2007

These are simply weighted as a percentage of the overall number of citations so that in effect Nielsen is showing 29% of the total number of citation listed in ranking. The work of each significant author was examined for HCI principles and these principles listed in a matrix and factored according to HCI categories. By this means a full set of HCI principles was drawn from the works of each significant author. The most popular of these principles were obtained from many different authors while some of the least popular principles were drawn from just one or two authors. Every principle had at least one author proposing it.

Stage 3: Determine the weighted frequency of HCI principles

The categories of principles where largely taken from Dix et al (1992). The number of times that a particular HCI principle was proposed by a significant author multiplied by a weighting factor derived from the author citation frequency allowed a ranking of HCI principles to be determined.

It is expected that this method will overcome some of the degrees of fragmentation of the HCI field by bringing together a set of principles which have been constructed in such a way as to reflect the degree of respect and authority attributable to the authors who proposed them.

This analysis provides what is thought to be the first realistic approach at consolidating HCI principles in this way. (See Table 2). It might be asked by some, why should a single set of guidelines or principles be suitable for evaluating interfaces in very different contexts.The answer to this is that the principles which have been put forward by the field experts are not context dependent. In other words none of these principles have been set forth by their originators with limited jurisdiction. These are general principles applicable across the full HCI domain.

	Schneiderman Principles – Desinging the User Interface	Jenny Preece- Principles	Jenny Preece- Interaction Design quoting from Medline Plus	Donald Norman - The Design of Everyday Things	Robert J. Kamper-Extending Usability of Heuristics (Journal of HCI)	Smith & Mosier (1986), Schneiderman P 80	Lockhead Principles (1981) Schneiderman P 80	Caroll, Hollan et al (2000) ACM Transaction,Vol 7, No.2, June 2000	Ken Maxwell, Carrol P 191, Levels of HCI maturity	Steve Pemberton http://www.cwi.nl/~steven/	Brad A. Myers	Jeff Raskin, (2000) The Human Interface	Jennifer Niederst, 1999, Web Design in a Nutshell P 23/4	Cogdill, K * 1999, Medline plus Interface evaluation, Final Report, University of Maryland	Jacob Nielsen 2001 Ten Usability heuristics	Mill & Shultz, Carroll P 537 - The next Frontier for HCI research	Andrew Dillon, Carroll P 466 Do we really know our users?	Erikson & Kellog, Caroll P 326	Raw	weighted
Weighting	13	1	1	1	1	1	1	11	1	7	9	1	1	1	29	1	1	1	Raw	**weighted**
Predictability				1	1										1			1	4	**32**
Synthesisability		1			1	1	1		1						1				6	**34**
Familiarity	1	1	1	1	1	1	1			1				1	1	1			11	**57**
Generalisability		1																	1	**1**
Consistency	1	1	1	1	1	1	1			1				1	1	1			11	**57**
Feedback			1		1									1					3	**3**
Dialogue initiative	1	1	1	1		1	1							1					7	**19**
Multithreading																			0	**0**
Task Migrateability		1			1				1	1					1	1			6	**40**
Substitutivity	1	1	1		1		1			1				1	1				8	**54**
Customizability		1			1	1				1						1			5	**11**
Observability	1			1	2														4	**16**
Recoverability	2	2	2	1	2				2			1		2	2				16	**96**
Responsiveness	1	1										1				1		1	5	**17**
Task Conformance									1			1							2	**2**
Social Ergonomics								1									1	1	3	**13**
Cultural Ergonomics								1											1	**11**
Holistic Ergonomics									1										1	**1**
Physical Ergonomics				1	1												1		3	**3**
Perceptual Ergonomics					1										1		1		3	**31**
Cognitive Ergonomics								1									1		2	**12**
Economic Accessibility													1						1	**1**
Technical Accessibility															1				1	**29**
Visual Disability							1						1						2	**2**
Auditory disability																			0	**0**
Speech disability																			0	**0**
Motor disability							1						1						2	**2**
Cognitive disability							1												1	**1**

Table 2: Frequency analysis of HCI principles

2.7.2 *Findings*

The fundamental principles of each author were examined, categorised and weighted according to the citation frequency and the top eight rules were found to be (Hinze-Hoare 2004):

1	Recoverability	96
2	Familiarity	57
3	Consistency	57
4	Substitutivity	54
5	Task Migratablility	40
6	Synthesisability	34
7	Predictability	32
8	Perceptual Ergonomics	31

Table 3: Weighted HCI rules according to frequency of use

In detail these eight principles are as follows:

1. Recoverability

This is the ability of users recovering from their errors, which they invariably make. There are two directions in which recovery can occur both forward and backward. Forward error recovery involves the prevention of errors. Backward error recovery concerns the easy reversal of erroneous actions. The latter is usually concerned with the user’s actions and is initiated by the user. The former should be engineered into the system and initiated by the system. In this sense recoverability is connected to fault tolerance, reliability and dependability. Ken Maxwell (2001) considers this basic usability a level one priority, which he calls error protection. Jeff Raskin (2000) rates this as part of his first law of interface design, which states, "*a computer shall not harm your work or through inaction allow your work to come to harm*". This gained a weighted rating of 96.

2. Familiarity

This is the degree to which the user's own real world personal experience and knowledge can be drawn upon to provide an insight into the workings of the new system. The familiarity of a user is a measure of the correlation between their existing knowledge and the knowledge required to operate the new system. To a large extent familiarity has its first impact with the users' initial impression of the system and the way it is first perceived and whether the user can therefore determine operational methods from his own prior experience. If this is possible this greatly cuts down the learning time and the amount of new knowledge that needs to be gained. The term familiarity is proposed by Dix *et al* (1992) but is referred to by other authors under different terms i.e. as guessability. Schneiderman (1998) and Preece (1994) each refer to familiarity in terms of the reduction of cognitive load. This was the most quoted principle amongst all HCI authors and as such gained a weighted rating of 57.

3. Consistency

Consistency, according to Dix *et al* (1992) relates to the likeness in behaviour arising from similar situations or similar task objectives. He also suggests that this is probably the most widely mentioned principle in the literature on user interface design. This principle comes out as joint first place with familiarity. It is considered of vital importance that the user has a consistent interface. However, there is an intrinsic difficulty in defining the nature of consistency, which can take many forms. Consistency is relative to a particular area for example one can speak of consistency of mouse movements, menu structures, response etc. Whereas familiarity can be considered as "consistency with respect to personal experience" this consistency is one with respect to "internal similarity of appearance and behaviour". This principle shared the top slot with familiarity, also with a weighted rating of 57.

4. Substitutivity

This concerns the ability of the user to enter the same value, or perform the same action in different ways according to the user's own personal preference. For example a user might wish to enter values in either inches or centimetres, or he may wish to open a program with the mouse or with the keyboard. This input substitutivity contributes towards an overall flexible HCI structure, which allows the user to choose whichever he considers most suitable. Schneiderman (1998) and Preece (1994) provide a specific example of providing shortcuts as an alternative. This is the ability of the interface to provide multiple methods for performing the same task. This achieved a weighted rating of 54.

5. Task Migratablility

This concerns the transfer of control for executing tasks between the system and the user. Checking the spelling of a document is a good example. The user can quite easily check the spelling for himself by the use of a dictionary. However the task is made considerably easier if it can be passed over to the system to perform with simple checks made by the user as to the acceptable spelling i.e. the difference between US and British Dictionaries. This is an ideal task for automation. However, it is not desirable to leave it entirely in the hands of the computer as dictionaries are limited and therefore the task needs to be handed over to the user at those complex points where the system cannot cope. Ken Maxwell (2001) talks of this as level two collaborative organisational interaction which he considers being a high level of HCI interaction.

This is the ability of the interface to hand the task over to the user so that the initiative rests with the human side of the interaction. This can be measured by the degree of performance available through the use of unfamiliar tasks. This has a weighted rating of 40.

6. Synthesisability

This is the ability of the interface to allow the user to construct a predictive mental model of how it operates. In other words: through using the interface the user gains an understanding of what to expect next (predictability). In addition the user works out a framework or scaffolding for all the actions he can perform. For example, if the user moves a file from one place to another he should be able to check after the action is completed that the file is in the new location as expected. This is what Dix *et al* (1992) call the "*honesty of the system*". Without this the user would not be able to learn the consistent procedure for interacting with the interface. This has a weighted rating of 34.

7. Predictability

This is support for the user to determine the effect of future actions based upon a past knowledge of the system. It allows the user to know beforehand what will happen when he clicks on a menu item or presses a key. This is a user centred concept where the user can take advantage of his knowledge of how the system is going to respond. Any system which does not respond as expected or responds inconsistently will be difficult if not impossible to learn. This has a weighted rating of 32.

8. Perceptual Ergonomics

Human perception involves the stimulus of sense organs. Measuring the Ergonomic properties of stimulus patterns is one method by which a more efficient interface can be created. This places the emphasis on the human side of HCI. For instance, if human hearing cannot perceive very high notes then it would be important to ensure that audible signals did not fall outside the human range. Similarly, if the user cannot perceive particular colours then those colours must be removed from the interface. Tracking the way humans perceive things is important to making an interface efficient for human use. This had the lowest weighted rating of 31.

2.8 HCI summary

It has been shown that HCI theories are not yet fully established and that the discipline is highly fragmented, making it difficult to characterise a single method of approach or even a set of accepted principles. The lack of agreement between authorities in this field suggests that the approach must be carefully tailored to the specific needs of the environment to which they are applicable.

This section has briefly considered the history of HCI which showed how usability has become the central feature of virtually all HCI activities from the 1960's onwards. The structure of HCI has been reviewed to show how it encompasses a number of disciplines.

Three HCI models were examined which illustrated the increasing refinement of interactive description culminating in Abowd and Beale's interaction theory. The approach to HCI analysis has evolved into the methodology of Lindgaard *et al* which focuses on user's needs. This is an approach which is commonly adopted and it will be addressed in more detail when the methodology of this project is considered.

Because of the fragmentation of HCI principles it was felt necessary at this stage to perform a frequency analysis of HCI authors and their chosen principles. This was done on the basis of the key features that each author listed as being the most important. These were then weighted according to the citation frequency of the authors themselves. The purpose of this was to produce a set of principles which would be held to be the most accepted.

It was found that eight rules have been established by this analysis. This project will expect to incorporate these rules in the creation of the CSCR interface.

Chapter 3 Review of Computer Supported Collaborative Working (CSCW)

3.1 Introduction

When HCI is applied to the specific area of collaborative work it is commonly known as CSCW. This involves an analysis of collaboration in the workplace on top of HCI principles, which will be considered at a later stage. The review undertaken in this chapter is tightly focussed on those areas of CSCW that are strongly design oriented. Accordingly the work reviewed here has been chosen from this extensive field with design orientation in mind. It does not represent the full range of work done by the CSCW community. The new features of collaboration form the basis of the following two sections.

3.2 E-Laboratories under Review

In this section we will review the findings of current research using CSCW e-laboratories (These are mostly CSCL systems but since it is contended that CSCW is included in CSCL as a subsystem-see Figure 1, these will play the role of both). To this end thirteen different CSCW/CSCL e-laboratory interfaces were reviewed with a view to determining the principles that they were based upon, the range of tools used and the findings of the research groups. These thirteen systems were selected as being indicative of a wide diverse range of different CSCW/CSCL environments:

Argles *et al* (2006) have an e-learning laboratory called "*CECIL*" which is designed to enable pairs of students to collaborate in the writing of program code. The interface allows them to see the output of their work as well as a simulated LED display.

Bachler *et al* (2004) employ an instant message client called "*Buddy Space*" to facilitate multiple views of collaborative workgroups together with information about the location, attendance and recording of virtual meetings.

Baker *et al* (2002) have analysed commercial real time distributed groupware called "*Groove*". This contains a real time collaborative workspace based upon text and voice chat.

Berger *et al* (2001) have set up a CSCL environment called "*Le Scenario*" to support community health projects. Their environment simulates social interaction in a face to face web based learning space which provides access to a range of knowledge sources.

Dalziel (2003) has developed an e-learning environment called "*Learning Design*" together with a learning activity management system "*LAMS"* which facilitates student run-time activity and teacher run-time monitoring.

Harper *et al* (2004) have created a three dimensional virtual learning environment referred to as the experimental team room "*ETR*". This allows participants to move freely around a virtual room set up like a standard meeting room. It also includes an electronic meeting assistant (*EMMA*) which provides a human face to interact with and to accomplish basic tasks in the environment.

Hosoya *et al* (1997) of Japan have developed a 3D virtual reality environment called "*HyClass*" based on "*CORBA*" which allows the user to walk around, pick up objects, move them from place to place and share them with other users, all in the form of representatives or avatars within the environment.

Kligyte *et al* (2001) have designed an interface named "*Fle3*" for the "*ITCOLE"* project which looks and acts much like a standard VLE but that allows a limited degree of shared working.

Miao *et al* (2005) have been employing a CSCL tree-based script authoring tool called "I*MS-LD*" which can be used collaboratively to create learning scenarios for students.

Pekkola (2003) uses the "*VIVA*" interface to support peripheral awareness in a 3D virtual environment. This allows the use of common artefacts for framing activities in workplaces.

Walters’ *et al* (2006) “*Mgrid*” framework provides a method for learning distributed computing. Although not properly a collaborative environment it does enable the rapid prototyping of distributed systems within a basic browser framework to enable security through a sandbox approach. This is designed for many machines to do the work of one.

Liccardi *et al* (2006) has produced a wiki system to improve workspace awareness to advance effectiveness of co-authoring activities. This co-authoring wiki system “CAWS” is designed to improve the user’s response to document development and to extend the area of workspace awareness.

Sim *et al* (2005) have discussed a Web/Grid Services approach for a Virtual Research Environment (VRE). They are working on “*CORE*” which is a project to develop a VRE to enable orthopaedic surgeons to collaborate in the design, analysis and dissemination of experiments. Individual user spaces are supplemented by templates for standard documents, a database for experiments, access to e-print archives and a limited discussion facility between collaborators.

An analysis of these e-laboratories together with a categorisation of their tools and their application to CSCR systems will follow at a later stage.

3.3 CSCW Structure

3.3.1 Four CSCW Viewpoints

An examination of the Literature of CSCW has revealed four separate models which have been used to characterise different approaches to CSCW. The first model of Muller and Wu (2005) is suitable when the core features are events and roles. The second model of Hawryszkiewycz, (1994) may be more suitable in a scenario where an object oriented approach (checklist) may be needed. The third model of Carroll *et al* (2006) is more important when activities are viewed from the standpoint of the collaborators’ personal needs. Finally the fourth model of D’etienne (2006) focuses in on the relationship between work and the way it is organised between collaborators. Each model has value in and of itself and their application should be situationally determined.

Model 1

Muller and Wu (2005) have remarked that within CSCW work is structured around five landmark entities which are:

- Documents including Drafts
- Dates and Calendars particularly start and end dates
- Events including the "kick off meeting" (first event)
- Roles and persons
- Systems and databases

Model 2

Hawryszkiewycz, I. (1994) has proposed an alternative set of semantic elements as follows:

- Artefacts (files, reports, documents, policies etc)
- Actors (a person in the organisation, each person can play many parts)
- Tasks (This is some well defined business function)
- Activities (the process for interactions between artefacts)
- Environments (provide the supportive structures for activities)

These elements are combined to model the design process using diagrams which are similar to Systems Analysis diagrams.

Model 3

Carroll *et al* (2006) have approached CSCW from a more primitive standpoint. They asked the fundamental question "*What do Collaborators need to share in order to work together effectively*". Carroll *et al* consequently derived four design requirements for effective CSCW:

- o public display of shared information,
- o integration of data into community metaphors to facilitate analysis,

- aggregation of individual contributions into collective overviews to evoke trust and commitment,
- contrast of individual capabilities and roles to invite collaborators to perform beyond themselves.

Model 4

In contrast D'etienne (2006) has suggested valuable new research directions in the following areas:

- The coupling of work and its organisation,
- informal communication and informal roles,
- awareness in distributed design,
- establishment of common grounds and perspective,
- clarification and convergence mechanisms in co-design.

Following D'etienne this work will be looking in particular at the first and last but will also encompass the others.

3.4 CSCW Review and Research Findings

The review of CSCW literature has shown additional areas which may be of importance in the consideration of a CSCR environment and which will need to be considered carefully.

3.4.1 Real Time Collaboration

Juby and De Roure (2002) have argued that real time collaboration requires more than just audio, video and data sharing, and have proposed two specific enhancements to provide a richness of interaction that is required for proper collaboration which are "*speaker identification and participant tracking for the automatic generation of dynamically updated attendance lists"*.

3.4.2 Gestures

Karam and Schraefel (2005) have taken this a stage further by examining the role of gestures in HCI in order to see if this provides the necessary richness for effective collaboration. They provide a literature review of over 40 years of gesture based interactions which they then categorize into a taxonomy of gestures denoted by four key elements: Gesture styles, Enabling technologies, Application domain and system response.

3.4.3 Unanticipated Use

Pekkola (2003) has considered the area of design for unanticipated use of artefacts. Under consideration is the design of a software application and he concludes that support for common artefacts can be designed to a certain extent to make them more suitable for unanticipated uses.

This research is based on the idea that users did not always use applications as expected by their designers; instead they found alternative ways and reconstructed a use to match their work process. This has application to the design of user interfaces on software programs. They cite a particular case of an interface design which was set up to work in a particular way but its use was circumvented and improved by unanticipated shortcuts using the right mouse button instead. They conclude that "*the search for common artefacts is a better starting point for analysis and design than a search for work sequence*". This requires a revised process of design which involves "*taking a step back, having an overview of the situation and making generalisations rather than concentrating on the sequence needed to perform a task*".

3.5 Additional Research Findings

A further review of CSCW literature has shown four areas which may be of interest in the consideration of a CSCR environment and which may need to be considered. These include

- Social Network Analysis to analyse the impact of CSCW
- the role of anonymity as a tool to promote freedom of discussion,
- the mechanisms of negotiation between participants who may disagree in their conclusions,
- social sensitivity support structures to avoid misunderstanding in communication.

3.5.1 Social Network Analysis

The method devised by Daniel B. Horn *et al* (2004) to analyse the impact of CSCW research involves the consideration of social network analysis. This is performed by viewing a network of authors as nodes and shared papers as links.

By this means it is possible to compare patterns of growth from one CSCW domain to another. See Figure 5.

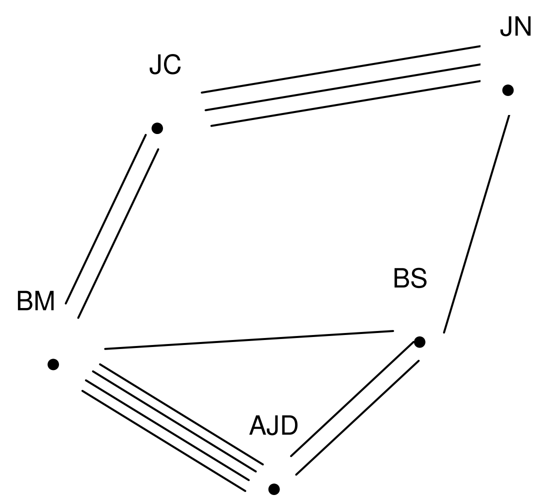


Figure 5 Social Networks

The initials refer to authors acting as nodes indicated by points and links represent the number of papers co-authored. It gives a graphical idea of the composition of the CSCW research community. This is called

> "*Social network analysis which is the primary lens to understand the patterns of collaboration*".
>
> "*An individual with high centrality is potentially influential because this person may link together many people who otherwise would not be connected*". Horn *et al* (2004).

Only recently with the advent of increased computing power has an analysis of very large communities numbering tens of thousands of members been possible enabling the depiction of ecologies of collaboration which might encompass an entire scientific discipline. A number of community based web sites automatically include dynamically shifting network analysis diagrams to illustrate community relationships.

3.5.2 Anonymity and Identity

Postmes *et al* (2001) have found that by allowing contributors to remain anonymous throughout their communications they are prepared to interact more and become more vocal participants and show a higher degree of influence within a group.

Sassenberg and Postmes (2002) have further concluded that the use of photographs of group members meant that individuality became more important even if incorrect photographs were shown.

Spears *et al* (2002) concur with Postmes that isolation and anonymity in cyberspace produce more social interactions rather than fewer. People can be more outspoken online than they would be in real life which can lead to social repercussions if the anonymity is taken away.

3.5.3 Negotiation

Swaab *et al* (2004) have concluded that negotiation support systems should stimulate a common cultural identity among the individual participants and negotiation support systems should provide information to develop shared cognition among negotiators.

3.5.4 Social Identity

Watts and Reeves (2005) have pointed out that email lacks social sensitivity and can be detrimental to communication by fostering misunderstanding.

3.6 CSCW Summary

The basic characteristics as well as some of the theories and principles of CSCW have been briefly reviewed. The elements and requirements of design have been examined as well as the application of specialised areas including gestures, real time collaboration and unanticipated use.

From this review social network analysis has also been shown to be a useful tool and this will be worth considering when user methodology for the planned interface and the analysis of the efficacy of CSCR systems will be looked at.

In addition it is important to recall that Peccola's idea of unanticipated use may be of huge importance to establishing the methodology of this project and consideration may be given to it in more detail later.

Chapter 4 Review of Computer Supported Collaborative Learning (CSCL)

4.1 Introduction

CSCL has grown out of CSCW. Whereas CSCW is concerned with methods of communication, CSCL in contrast is concerned with the object of communication. In addition CSCW is based in the business community while CSCL is rooted in the educational community. Furthermore, CSCW focuses on group productivity; CSCL is focused on student learning.

The following table indicates the main differences between CSCW and CSCL.

CSCW	CSCL
Focuses on communication techniques	Focuses on what is being communicated
Used mainly in a business settings	Used mainly in an educational settings
Purpose is to facilitate group communication and productivity	Purpose is to support students in learning together

Table 4 Differences between CSCW and CSCL

One further fundamental difference between CSCW and CSCL is that the latter is based upon pedagogical principles of learning which influences its design and utilisation within the learning community. For this reason CSCL cannot be fully understood without an examination its pedagogical basis.

4.2 Pedagogical Basis for CSCL

According to theories of Piaget and Vigotsky the main role of the teacher is not to impart knowledge but to equip the students with strategies to become independent thinkers and lifelong learners. Any CSCL environment needs to develop systems which allow for the development and support of metacognition (A person's knowledge of what they know and how they learn) and problem solving skills development.

Daniels (2001) argues that *"unless we understand the ways in which possibilities for learning are enacted within institutions we will be frustrated in our attempts to really raise standards"*. This also follows the work of L.S. Vygotsky who considered the capacity to teach and benefit from instruction to be a fundamental attribute of human beings.

Kligyte, (2001) suggests that CSCL needs to take into account the ability to construct knowledge whereas CSCW is, in his view, mostly focused on the simple problems of efficient document management.

4.2.1 Educational Theories 1: Piaget – the individual

Kirschner and Gerjets (2006) have highlighted the importance of the individual in the learning process. "*This new age of mass individualisation has led to demand-led learning"*. Piaget's emphasis is on individual learning and providing mechanisms which allow the individual to follow their own path. On mechanism for this is "*the adaptive provision of learning materials*" which provides individual learning plans to students based upon their particular needs. This has the ability to be automated by software systems where the best approach to helping individual needs relies upon software agents that use and select appropriate materials which are optimally suited to the student's performance on previous tasks. This means that every learner can have their own individual learning plan, and be taught in a way that suits them specifically.

4.2.2 Educational Theories 2: Vygotsky – the social

The second pedagogical basis comes from Vygotsky who has proposed that individuals are purposely seeking and constructing knowledge within their social environment and that a computer system can facilitate that learning. Much of this is based upon Vygotsky's sociocultural theory of learning which teaches that individuals learn first through interaction with others in a social environment rather than working things out for themselves. Vygotsky's ideas are that an experienced person can help an inexperienced person only if there is an overlap between their knowledge areas. This equalled the Zone of Proximal Development ZPD where learning from others takes place and which is supported by CSCL. In this way the individualism of Piaget can be coupled with the socioculturalism of Vigotsky as basis for CSCL. See Figure 6

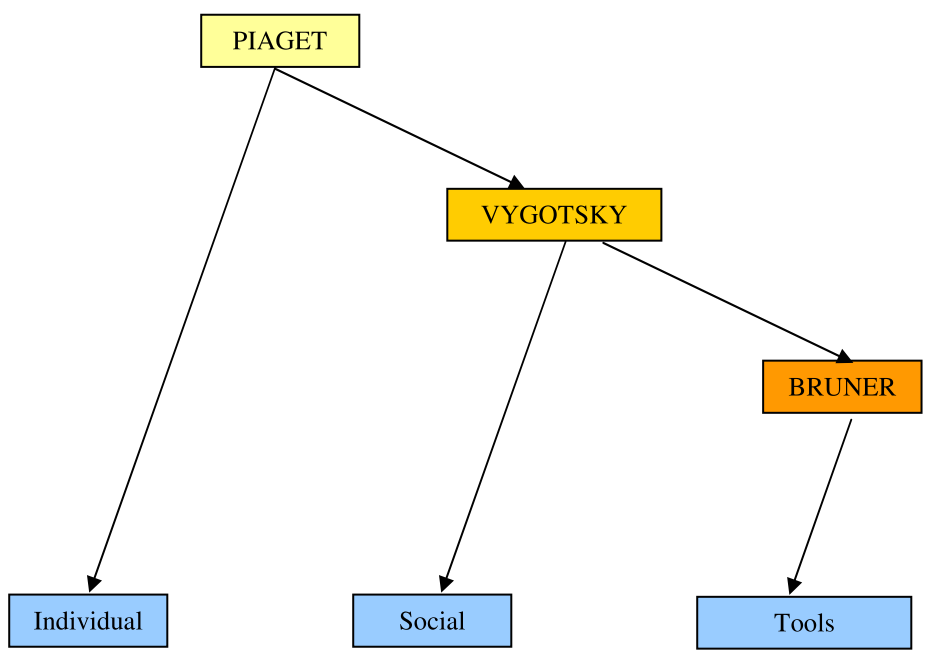


Figure 6 Influence of Educational Theories

Lipponen (2002) agrees that there are two mechanisms which promote learning in CSCL. The first comes from Piaget who said that children who socially interact with others have *"conflicts of thought"*. The second comes from Vygotsky's ideas that people who engage in collaborative activities can master something which they could not earlier do as individuals.

However to this a third view must be added that flows from the work of both Piaget and Vygotsky namely that of Bruner who has proposed a theory called constructivism which may have the greatest scope for developing collaborative learning environments.

4.2.3 Educational Theories 3: Bruner – Constructivism

The constructivist approach to learning suggests that knowledge is gained by an individual constructing it through their own experience of the real world. Bruner (1960) has argued that this model of learning emphasises knowledge construction through the active participation in social and cultural contexts. It is this view, which underpins much work within CSCL.

For Bruner, "*learning is an active process in which learners construct new ideas or concepts"*

According to Martin Dougiamas, the creator of Moodle, "*Constructivism is building on knowledge known by the student. Education is Student centred, Students have to construct knowledge themselves"* (Dougiamas, M.1998).

Bruner's constructivism is built upon Vygotsky's ideas of social interaction as the foundation for learning. Bruner's educational theory maintains that the prior knowledge of the learner is the essential element in constructing new knowledge. This idea of prior knowledge is based upon Piaget's ideas that knowledge is actively constructed and not passively received, while the construction process is a social activity in the frame of Vygotsky. The important point for Bruner is that the acquisition of knowledge by a learner is a construction process where that knowledge is constructed from interactions with the environment around them. The relationship between these three educational researchers is shown in figure 6.

In one of the seminal works on educational theory, Jerome Bruner's "Process of Education", he presents the essential components for effective learning as follows in Table 5.

1	**Collaborative learning**
2	**Active Learning**
3	**Reflective learning**
4	**Cultural learning**
5	**Reinforcement**

Table 5 Bruner's components of Education Collaborative learning

According to Shulman (1998) Students can do more in groups than they can on their own. When different kinds of students are learning different things, they can solve problems more effectively by bringing them together. In the manner of a beehive, different parts can be brought together to create a whole solution to a different problem.

Bruner has spoken at length about the value of collaborative learning where students help each other to grasp the essence of the topic. This acknowledges the value of the interplay of peer assistance and is one of Bruner's fundamental elements of learning (Bruner 1997, Bruner 1998). Participants who studied together learn more than those who studied alone. (Johnson and Johnson 1990). The importance of collaboration is also supported by Vygotsky, (1987) where the learners together can "*always do more than they can independently*".

Active learning

Students who are actively seeking information, who engage in the learning process rather than passively receiving instruction, learn more effectively. This is also supported by Lee Shulman, (1998) who regards active learning as a more effective means of learning. Vygotsky also lends his support to the importance of active learning when he says "*to learn how to swim you have to, out of necessity plunge right into the water... so the only way to learn ... is by doing so*" (Vygotsky 1997, pp. 324).

Furthermore, Bruner (1997) included learner control as one of his primary educational principles that involves the learner being able to take control of his learning process. Lee and Lee (1991) have shown that the outcomes of learner control over sequential tasks gave strong results, particularly during the initial learning phase.

Reflective learning

The opportunity for students to reflect on the processes, which they themselves engage in while learning is what Bruner calls "*going meta"*. This is the act of thinking about thinking. When students ask themselves "*How did I think that out, how did I get there, what was the evidence, what did I do this time to solve the problem?*" then they are assisting their own learning process. Any elements of a CSCR environment, which assists the students to 'go meta', would improve the learning and research process.

Cultural Environment of learning

Learning and thinking are always situated in a cultural setting. The creation of a community or cultural environment that nourishes, sustains, houses and gives meaning to interactive learning is essential to the process. Culture concerns a system of values, rights, exchanges, obligations, opportunities and power. It concerns how humans come to know each other's minds and thus support their common learning processes.

Reinforcement

This takes us to the stage after learning has occurred where the learner needs to establish and maintain his learning. This can be done by providing feedback about the correctness of the performance and by repetition of the knowledge gained. So as to ensure that learning takes hold, the learner can be asked to rehearse the knowledge gained and to show by some activity that he has achieved the goal intended. Gagne1992 pp 8 also writes about internal processes involved in learning involving such activities as gaining attention, informing learners of their objectives etc. but whereas these are suitable guidelines for lecturing they are not considered here to be educational principles.

4.3 CSCL Structure and Viewpoints

CSCL has four component parts (by definition):

- **Learning-** this is seen as an activity that takes place in a wider context than a classroom and involves the everyday social practices of people during which learning occurs and the situation it springs from (Lave and Wenger, 1990)
- **Collaborative learning –** The role of others in the learning process has been highlighted by Vygotsky (1978) and his key concept of the zone of proximal development (ZPD) as the area of overlap between inexperienced and experienced where learning occurs.
- **Supported collaborative learning**; an analysis of what tools are required to provide the environment and the mechanisms for collaboration.
- **Computer supported collaborative learning**. The computer brings a new dimension to the process of learning and can introduce a number of new features.

In short CSCL facilitates the learning process through a number of applications including email, computer conferencing, bulletin boards, local area networks, and hypermedia. It is Bannon's (1989) contention that the best way to regard computers in the CSCL process is as an enabling medium through which partners can organise and accomplish activities. The computer provides a space to work in which others can organise their activities.

Lipponen (2002) defines CSCL as being focussed on *"How collaborative learning supported by technology can enhance peer interaction and work in groups and how collaboration and technology facilitate sharing and distribution of knowledge and expertise among community members"*.

John Carroll (1990), in his book "The Nurnberg funnel", has argued that *"the learner, not the system, determines the model and methods of instruction."* By this he means that the most rapid achievement of learning does not come from drill and practice techniques, nor from standard training methods but rather from instruction via error recognition and recovery, and the study of people's learning problems and how they are solved. Stahl (2002) has examined the theoretical framework for CSCL and concludes that collaborative knowledge building comes from the intertwining of the group perspective and the personal perspective.

Dillenbourg (1999) has demonstrated that a theory of collaborative learning must concern the following four items, Situation, Interaction, Processes and Effects. The four aspects of learning are highlighted in Table 6:

Four Aspects of Learning	Collaborative Learning
1 Situation	Peers must be - at the same level - must be able to perform the same actions - must have a common goal - must work together
2 Interactions between group members	Symmetry of action Symmetry of knowledge Symmetry of status
3 Processes	Interactive Synchronous Negotiable
4 Effects	Measurement of groups not individuals

Table 6 Aspects of learning

Dillenbourg (1999) further characterizes CSCL by degrees of symmetry

- **Symmetry of action** (the extent to which each collaborator has the same range of actions)
- **Symmetry of knowledge** (the extent to which collaborators possess the same level of skills)
- **Symmetry of status** (the extent to which collaborators have the same status with respect to their community)

Dillenbourg (1999) goes on to specify the defining criteria for collaborative interaction. These involve three areas:

- Collaborative situations should be interactive
- Collaborative situations should be synchronous

- Collaborative situations need to be negotiable

These systems may be categorised according to a time and location matrix as in Table 7:

	Same Time	**Different Times**
Same location	Back Channel communication E-learning laboratories	Bulletin Boards Forums
Different location	Video Conferencing Chat Whiteboards Instant Messaging E-learning laboratories	Email Forums Web logs and Journals

Table 7 Time location matrix

4.4 CSCL Research Findings

This section contains a review of findings of current research using ten CSCL systems. These are complementary to the systems discussed in 3.2 and were chosen to illustrate the pedagogical use of CSCL..

Rahikainen *et al* (2001) have shown that whereas student levels of advancement was good with the more able students, there were difficulties with the less able students and some had still not learned anything by the end of the process. They concluded that teachers need better instructions in order to guide different levels of students. The implications for their study are that the less able students need careful monitoring.

Tapola *et al* (2001) have concluded that students that have a problem being motivated may not do well with CSCL and may require greater tutor input.

Varey (1999) discusses her experience in remote teaching and evaluation of course work using Net Meeting. She claims her experience of collaboration as positive showing student enjoyment of involvement with other students.

McCarthy and Boyd (2005) have commented upon the use of digital backchannels in the context of an academic conference where during a speaker's presentation chat channels are opened up and all participants can communicate using laptops thereby adding information to what is being presented. They also point out some disadvantages of that facility leading to distraction from the presentation itself.

Joiner *et al* (2006) have concluded that students overwhelmingly prefer the goal driven scenarios to non-goal scenarios. The design of any interface must therefore include consideration of goal setting, target achievement, and personal reward.

Kester *et al* (2006) have investigated the role of written supportive help together with a script explaining the process of solving the problem. They found that when the help information and the script come together there is a lower learning efficiency. According to the findings of Kester *et al.* (2006), this is probably due to "*temporal split attention*". However there was no such temporal split if the support information or the schema were presented before the problem was tackled. This suggested that any interface that is constructed to assist collaborative learning needs to ensure that supportive information and schematic information are presented at separate times.

Dillenbourg (2006) has found that learning by pairs was less effective than learning by individuals. He interpreted this as a "*split interaction effect*" which suggested that pairs of learners would suffer from interference between the two interaction processes as well as the social interactions between the learners and the interactions with the material. This suggests that cognitive load can in some circumstances be greater in pairs than with individuals, leading to a loss of focus and learning. However, when using online animation as a delivery mechanism he found the opposite results. The animated pictures had a positive learning effect with pairs and not with individuals. Dillenbourg suggests that this finding is due to a lower cognitive load recorded by the pairs. The weakness of these two divergent results is clear and rests on the fact that there is no objective measure of cognitive load which might lead to different results. More work needs to be done in this area and this might be a suitable topic for further investigation in this research.

Graves and Klawe (1997) have found that males responded well to having a specific goal while females responded more to being able to speak to and see an image of their collaborator. It is suggested that one interesting approach would be to create an entirely user configurable learning environment so that they can choose what type of communication channels they want to use. This would help to define which elements of CSCL were valuable to different types of learners. This Meta design would lead to a whole new area of research beyond the scope of this thesis.

Klawe, M. (1999) has shown that for the design of a collaborative interface for paired working of students in teaching mathematics the implementation of specific numeric goals in the form of winning points in game based learning scenrios is very effective.

Lawless and Allan (2004) have considered the unwanted outcome of stress generated in collaborative e-learning environments. They contend that stress can be "designed out" of on-line collaborative exercises by a careful analysis of the working processes.

4.5 Summary

Drawing all of this together it can be said that collaborative learning has been demonstrated to enhance knowledge acquisition and the learning process. However some researchers, notably Dillenbourg (2006), have shown that some collaborative learning, particularly in the case of paired learning can be detrimental to the learning process which has been put down to an increased cognitive load in some circumstances which leads to a loss of focus in learning.

The Educational principles underpinning CSCL have been reviewed and it has been shown that present day CSCL environments have been based upon the theories of Piaget, Vygotsky and Bruner. In particular, collaborative learning, originally highlighted for its importance by Vygotsky and refined by Bruner, has formed the basis for virtual learning environments such us Moodle and Blackboard where tools for collaborative learning have been built into the infrastructure.

This pedagogical approach combines with HCI to provide a theoretical perspective which informs the methodology that will be adopted in this thesis. See Appendix D

Chapter 5 Defining CSCR

5.1 Introduction

In this project the issues surrounding the construction of a Computer Supported Collaborative environment have been looked at. This research began with a consideration of the history of HCI and its sub-disciplines CSCW and CSCL. Through the consideration of CSCW together with further investigation of pedagogical theories underpinning CSCL a suitable positioning for the new area of Computer Supported Collaborative Research CSCR has been determined. Differences between CSCR and both CSCW and CSCL were highlighted and this led to the posing of a particular research question and hypothesis which concerned the specific use of a CSCR environment for the support of research students and their supervisors.

In this chapter consideration will be given to the role of collaboration within a CSCR framework. It will be shown that CSCR is a new domain encompassing all types research and defined by a group of 14 "research spaces" containing within it the domains of CSCL and CSCW as set out in table 9. Since there are no CSCR environments to examine at present, this will be done by looking at CSCL environments and a consideration of the methodologies which have been applied to their analysis. These will then be applied to the area of CSCR and their applicability determined.

5.2 The Research Question and the Hypothesis

The particular problems of research collaboration especially over a distance and between research students and supervisors are an example of the need for a CSCR environment. The main issue to be considered is summed up in the research question:

"What are the significant issues in designing a CSCR system to support research students and their supervisors to work on collaborative research?"

The solution to this research question will form the hypothesis presented in this thesis and involves the finding of an appropriate vehicle to properly support the activities of research students and their supervisors. This will require the clear definition of the differences between CSCW and CSCL, and in addition the determination and definition of a new domain which is here called CSCR that contains all possible collaborative research systems, one of which (CRESS: Collaborative Research Environment for Students and Supervisors) will be suitable for the solution to the research question.

CRESS will be defined as an environment consisting of a number of specific tools that meet the particular needs of the support of students and supervisors engaged in collaborative research wherever they may be situated.

The issues range from being able to carry out research associated tasks online as well as collaborative activities with co-researchers and supervisors. To avoid jumping through multiple authorisation procedures one log-in across a range of platforms to link to a range of tools should be engineered. Research requirements should also include access to file repositories for uploading of finished projects and work in hand, as well as academic databases to access articles, conference proceedings etc, and search tools to enable access to online academic materials and published works. It is envisaged that the interface should also incorporate an academic search engine such as Google Scholar and access to the library catalogues and external academic databases.

Researchers would benefit from access to Schemas and Template facilities to assist publication of papers to journals. Additionally a method to enlist peer review assistance prior to publication would be beneficial. Researchers and their supervisors would also need public and private spaces in which to work and provide information on the current state of various research projects.

With particular respect to the needs of research students there would be a requirement for a journal to chart progress and reflect on learning taken place. Students would benefit from the ability to make social links through the creation of individual project communities and private as well as public blogs. The aggregation of information by RSS feeds to centralise data, and the facility to share content with tag markers would be of use. Students will require reliable feedback tools.

It is expected that the administration of the interface would require standard security tools for login and verification of legitimate users. Synchronous and Asynchronous Communication tools will enable collaborators to link together through the portal using a range of media such as Text, Audio and Video as well as a method of recording and replaying dialogue and online meetings. The need for scheduling tools, shared working spaces such as a whiteboard are also envisaged. Participant data should be available to collaborators with expertise tagging to enable rapid access to field experts.

This range of tools and facilities will be brought together into a portal to provide seamless access through a single login facility available only to participant research students and their supervisors. It is envisaged that each tool will be in the form of a portlet to be built in a modular fashion.

To provide individual flexibility this modular approach could eventually enable each research participant to customise the portal according to their needs by selecting their own personal choice of tools.

A number of groups have set up e-learning labs and some pertinent ones will be reviewed in the next section. These will be considered from the viewpoint of their relevance to a CSCR environment.

Systems and Models

Fifteen research groups from a range of countries are briefly introduced and some of their pertinent conclusions are summarised.

Bardeen *et al* (2005) from Fermilab have set up grid computing technologies to support the collaborative learning of students investigating cosmic rays. Their students use web browsers and a custom interface which enables them to perform a range of tasks.

Harper *et al* (2004) have created interfaces which are contextually aware and adaptive to the way that humans naturally communicate and interact. These new "*dynamic meeting environments*" are suitable for collaborative research and contain perceptive assistive agents (essentially human ergonomes) which function as "*friends and advisers*" to the user in the real world collaborative setting. Whether it is necessary to reproduce exactly the full real time learning environment in its entirety or whether a subset of those elements would be sufficient to maintain full collaboration needs further investigation.

Miettinen *et al* (2005) have introduced a system called *OurWeb* and they use it to demonstrate intelligent tutoring in a structured setting. This is claimed to be an intelligent e-learning system which is designed to provide highly structured lessons under mostly automated control.

Hosoya *et al* (1997) have developed a collaborative educational system in which students at distant locations share a virtual 3D space. Students can move around within the space observing different objects from different viewpoints. In this environment users can respond to the actions of their collaborators and manipulate objects cooperatively.

Sendova *et al* (2004) have set up a virtual laboratory "*Toon-Talk*" for collaborative e-learning for young learners. The programs in "*Toon-Talk*" take the form of animated robots which can be named, picked up and trained to form a sequence of steps.

Silva and Liesenberg (2000) have studied a synchronous user interface where all the objects being shared can be viewed from many different locations and where users interact with each other in real time.

Walters *et al* (2006) have considered the challenges involved in teaching the subject of distributed computing. They have set up an *M-Grid* framework which mimics the core features of a distributed computer system. In practice the grid network is a collection of computers that can be used in parallel to process computing tasks. The danger of accepting executable software from other computers on the system is a problem that requires a high degree of security to be in place. However, the *M-Grid* system makes use of Java applets running in a web browser which implements a **sandbox** constraining the action of the applets and preventing damage to the host machine.

Wang *et al* (2002) have created a groupware application for teaching that enables the teacher to guide students step by step through an application and allowing them to annotate directly on the student's application. In addition other tools such as messaging and chat were available. Their system implemented a tracking mechanism which stored user name, IP address, time stamp, chat messages in a database for future analysis. At this point no analysis had been attempted.

Bouras and Tsiatsos (2002) have sought to construct a collaborative e-learning environment by basing it upon well established collaborative learning techniques. These include "*Brainstorming*", *"Think pair share*", "*Jigsaw*", "*Quickwrites*" and "*Structured academic controversy*". They conclude that in order for full collaborative working that mimics classroom work, an online environment may need to have some extensions including audio and visual capability as well as virtual classrooms and a private whispering mode.

Boyle *et al* (2003) have developed the *QCDOC* supercomputer which is designed for the highly specialised task of calculating results for lattice quantum chromo dynamic systems. This is an example of collaboration software between University laboratories to enable joint work to be done in a multi user environment. Increasingly collaboration is taking place online for a variety of work based tasks (CSCW) and for learning based instruction (CSCL).

Brocks *et al* (2003) have developed a multi-agent based approach called the *MACIS* framework which introduces collaborative elements in a natural way. Brocks *et al* have concluded that the multi-agent approach is ideally suited to support virtual teams particularly in the realm of discussing documents.

Nick Jennings (2006) of Southampton University has written about a similar agent based virtual laboratory called *Trilogy* the purpose of which is primarily for the training of research students and also for the management of information and tools as well as to demonstrate the development of agents and virtual laboratories across three collaborating sites.

Valcke and Martens (2006) raise quality issues concerning CSCL environments and conclude that more accurate research methods are required to obtain details about CSCL processes, and a higher degree of validity and reliability of research methods is required.

Lipponen (2002) considers the results of empirical studies in CSCL research but concludes that "*It is difficult to make any solid conclusions"* due to the great variety of techniques and technologies used, purposes sought and applications applied.

Dillenbourg (1999) expresses a similar view to Baker, Greenberg and Gutwin (2002) in the field of collaborative learning, and following his research program entitled *"Learning in Humans and Machines"* which gathered together twenty scholars from the disciplines of Psychology, Education and Computer Science, they discovered that their group did not agree on any definition of collaborative learning. Collaboration is difficult to measure in and of itself and so instead some effects of collaboration such as how well a task is performed, or how accurately a result is obtained will be measured. Most research attempts to measure effects through an individual pre-test followed by an individual post-test, and the difference is measured with respect to task performance, but these results have been criticised as being too qualitative leading to limited conclusions.

Dillenbourg's second issue concerns the method of evaluation. Collaborative learning is often assessed by measuring individual task performance but objection has been raised that a valid assessment would be required for group performance. Unless some way of measuring group performance becomes available then the existence of a hypothetical ability to collaborate remains to be established.

The last two authors have highlighted some of the difficulties of CSCL research. Lipponen (2002) has shown that there are too many variables to underpin any concrete results. Dillenbourg has further illustrated the problems by pointing out that there is no agreed definition of collaborative learning and that the measurement of such is consequently difficult to obtain.

Because of these problems there are issues that will need to be considered when an approach is made to the analysis and testing of the CRESS environment. In particular care will be needed to establish the nature of collaboration and the effectiveness of the support of collaborative research. In particular a clear definition of CSCW, CSCL and CSCR is required. Moreover, responding to Lipponen (2002), a tighter focussing and justification of the techniques and technologies that will be used is needed as well.

5.3 Collaborative Toolkits

There is some discussion in the literature concerning the tools which are necessary for collaborative work. Ørngreen *et al.* (2004) have concluded that a set of seven tools is required while Bachler *et al.* (2004) have identified four significant tools.

Kligyte (2001) has laid out a scheme for another toolkit required for using CSCL. He splits these functionalities into two areas; asynchronous (4 tools) and synchronous (5 tools).

Leinonen *et al* (2002) have developed a collaborative discovery tool (*CoDi tool*) that enhances knowledge building in their "*Fle2*" learning system. The *CoDi tool* is an additional facility, which helps to collect and manage knowledge and enquiry.

The questions this raises concern the marking of students' work and how that should be organised. Further work needs to be done on how marking facilitates knowledge advancement and whether the results should be shared not only by tutors but also by students. Leinonen *et al* do not yet have an answer to these questions.

Studies of collaborative learning are often based on the analysis of transcripts generated by student interaction. De Wever *et al* (2006) have presented an overview of different methodologies and discuss fifteen instruments. Their analysis focuses on text based CSCL tools.

AUTHOR	Cognitive & Meta cognitive	Critical thinking	Vygotsky-Cognitive and constructive learning	Social Constructivism	Constructivist	Social network theory	Community of Enquiry
Henri (1992)	**X**						
Newman *et al* (1995)		**X**					
Zhu (1996)			**X**				
Gunawardena (1997)				**X**			
Bullen (1997)		**X**					
Fahy *et al* (2000)						**X**	
Veerman (2001)					**X**		
Rourke *et al* (1999)							**X**
Garrison *et al* ((2001)							**X**
Anderson *et al* (2001)							**X**
Jaervaela (2002)				**X**			
Veldhuis (2002)				**X**			
Lockhorst (2003)				**X**			
Pena-Shaff (2004)				**X**			
Weinberger and Fisher (2005)				**X**			

Table 8 Normalised data from de Wever

The analysis in Table 8 shows that the most widely adopted pedagogical theory is social constructivism.

De Wever *et al* conclude that empirically validated content analysis instruments are still lacking. They call for replication studies that focus on the validation of existing instruments.

The implications of this are that any analysis of a CSCR environment will be problematic. There are no clear categories that can be used for content analysis. Fifteen different authors have demonstrated fifteen different categories of analysis based upon seven different pedagogical approaches. It is not clear which approach is the best or the most accurate to be applied to the CSCR environment at this stage. The majority of researchers have based their approach upon social constructivism theories of Bruner and this will be a guide in setting out the CSCR analysis later.

5.4 Process towards CSCR definition

An extensive literature review has brought us to the point where we can begin to formulate the requirements of a CSCR domain. It was shown in figure 1 that CSCR was a specialised part of CSCL which is, in turn, a specialised part of CSCW which is in the domain of HCI. In this perspective CSCR sits within all of these other domains because its definition is more tightly constraint by its increased specialism. Therefore the definition of CSCR has more constraints than that of CSCL and CSCL has more constraints than that of CSCW. This means the CSCR domain will fully contain CSCL , and CSCL fully contains CSCW . Hence the definition must be determined in three stages.

Stage 1: requires the formulation and definition of the CSCW domain.

Stage 2: requires the formulation and definition of the CSCL domain.

Stage 3: requires the formulation and definition of the CSCR domain following a gap analysis of CSCW and CSCL.

5.5 Formulating the requirements of a CSCW domain

This review has shown that there is no fully defined environment, which meets all the needs of a online collaborative research community. A series of gaps have been identified from the review in section 3.4 and the requirements will be examined now.

5.5.1 Communication Space

A set of interactive tools common to the CSCW domain would be required to maintain communication and the interchange of ideas in real time.

The CSCW domain definition will be expected to included real time collaboration as well as asynchronous communication. The use of a whiteboard and video/audio channels are primarily all real time communication devices and Juby and De Roure's (2002) points about speaker identification and participant tracking will be considered in the design of the CSCW domain.

It still needs to be assessed how important gestures are for effective communication in collaborative work, and it needs to be carefully considered whether gestures need to be included in the collaborative interface. It is thought that it will take some time before gestures are incorporated as a standard feature into Microsoft Windows in the same way that say speech has been incorporated. Karam and Schraefel (2005) have demonstrated that there is a vast range of research in this area but very little application as yet.

The use of digital backchannels in the context of an academic conference where, during a speaker's presentation, chat channels are opened up and all participants can communicate using laptops thereby adding information to what is being presented, has been commented upon by McCarthy and Boyd (2005) .

5.5.2 Identification Space

Participants need identification as shown by Juby and de Roure (2002). It is agreed that speaker identification and participant tracking will form an essential element of CSCW which takes place in identification space.

In addition careful consideration needs to be given to the role of anonymity in a collaborative research environment. Although anonymity promotes greater social interaction Postmes *et al* (2001) this may not be the most important requirement. Even more important may be the need for reliability of information and being able to trace the source of information. On the other hand anonymity may be required in the area of peer review to obtain unfettered criticism. A decision about the inclusion of anonymity in a CSCR environment will be reached at a later stage.

5.5.3 Scheduling Space

Collaboration requires both synchronous and asynchronous communication and scheduling of meetings, the setting of deadlines, setting up of conferences (online or otherwise). A common scheduling facility is required to maintain collaborative structure.

The implications of Rahikainen *et al* (2001) study are that the less able research students need careful and closer monitoring. This will require clear scheduling and task setting interface tools. Joiner *et al* (2006) have concluded that students overwhelmingly prefer the goal driven scenarios to non-goal scenarios. The design of any interface must therefore include consideration of goal setting, target achievement, and personal reward. Graves and

Klawe (1997) and Klawe, M. (1999) also support the view that specific goals and target setting are important features to take account of when defining the CSCR interface.

5.5.4 Shared Working Space

Collaborative research necessitates the exchange of information which may be in multimedia formats such as sound, video, image text etc.

5.5.5 Product Space

Artefacts are the expected outcome of the working process and a tally needs to be kept and maintained as a record of work done and an indication of progress and the recording of re-iterative work on products.

5.5.6 Administration Space

The day to day management of course data and the administration of learning tasks as well as student information will require its own area.

Facilities to record and replay communications together with instant messaging and assistive agents which provide sophisticated help functions should be part of a necessary administration space for the CSCR environment. Bartholome *et al* (2005) conclude that help functions by themselves are not effective. Further work is needed in this area to see if this is borne out within the proposed CSCR environment or not and an inclusion and monitoring of a help system will allow us to validate these claims.

Consequently these six spaces (communication, identification, scheduling, shared working, product and administration) define the CSCW domain which forms the core of the CSCL and CSCR domains.

5.6 Formulating the requirements of a CSCL domain

It is further contended that CSCL is that domain in which all the aspects of the CSCW domain are available and in addition the following will be required to construct a CSCL domain.

5.6.1 Reflective Space

An important part of learning which has been recognised by recent pedagogists (Bruner 1990) is the need for internal reflection. This can be both individual and collaborative and could be assisted with the help of an on-line journal (Private and/or Group)

It has been concluded by Dillenbourg (2006) that there is no objective measure of cognitive load. This leads to the suggestion that reflective space will be an important feature of the CSCL domain where personal assessment of progress can be made. More work needs to be done in this area and this might be a suitable topic for further investigation in this research.

5.6.2 Social Space

Much learning has been shown to arise from interaction with peers and other learners as well as from a didactic discourse with mentors. (Daniels H. 2001)

Taking account of Watts and Reeves (2005) social links will be incorporated into the CSCL system. They have commented that computer mediated communication systems lack social sensitivity which can be detrimental to communication and foster ambiguity serving to amplify misinterpretation. It is expected that the CSCL system will require additional compensating tools to avoid misunderstanding.

The importance of motivation is pointed out by Tapola *et al* (2001). This is a complex subject to analyse as motivations may come from various sources. However, social spaces have been shown to contribute to the motivation of some students and therefore it will be important to consider the inclusion of social space in the CSCL definition. The experience in remote teaching and evaluation of course work using Net Meeting is discussed by Varey (1999). She describes her experience of collaboration as a positive experience which showed student enjoyment of involvement with other students.

Dillenbourg’s (2006) conclusion is that it cannot be predicted how social interactions of pairs will affect individual cognitive processes. One therefore cannot generalise from individual learning to group learning. Consequently further research in both settings is needed.

5.6.3 Assessment/Feedback Space

The learning process needs ratification through a testing regime. This may involve the provision of online questions and assessment.

5.6.4 Supervisor Space

The dual roles of teacher and learner need to be reflected in the construction of a CSCL domain. Tutors would require their own private area for their specific tasks.

It is suggested, following Kester *et al* (2006) that any interface that is constructed to assist collaborative research needs to ensure that supportive information and schematic information are presented at separate times.

Although it could be argued that these spaces might be required for good working and not just learning, it is contended that these spaces are more essential to the process of learning than they are to just working. Working can take place without the need for these additional spaces though it is accepted that their inclusion may enhance the working process. Since work can take place without reflection, socialisation, assessment, tutorials and course administration these additional spaces distinguish the CSCL domain.

5.7 Determining the Gaps – where CSCW and CSCL fall short of CSCR

So far we have looked at the established domains of CSCW and CSCL. This approach has brought a more rigorous definition and distinction to each of these domains in that they are shown to be related to each other, where CSCL is a subset of CSCW and all of the features of CSCW are contained in CSCL.

However, the literature review has shown that these domains are insufficient to provide a rich enough environment for computer supported collaborative research. A number of additional areas are required in order to fill in the gaps left by the CSCW and CSCL domains. The next section will examine the additional requirements needed by collaborative researchers.

5.8 Formulating the requirements of a CSCR domain

There are a number of differences between CSCR and CSCL which will be examined. One important difference is that a complete record of all interactions between participants is an important and necessary tool to evaluate the contributions of each member in a collaboration group which can later on determine “a fair capital share” if the undergoing research project is successful. This is more relevant to collaboration between partners in different institutions where the division of funding maybe dependant upon contributed weighting.

The following additional spaces will be required to construct a CSCR environment in addition to all of the spaces defining the CSCW and CSCL domains

5.8.1 Knowledge Space

Research collaboration will generate its own knowledge base and a database system will be required which can store and retrieve this information as well as allocating ownership to individual contributions to ensure an appropriate apportionment of credit. It would be expected that this system would incorporate hypertext and links as a form of cross referencing to bring cohesion to individual contributions.

5.8.2 Private Space

The research group will need a private area in which to work that is closed to non-group members. It is important to maintain a secure area where work is developed before it is published.

5.8.3 Public Space

The collaborative research group may wish to provide information upon the nature of the research which is being done, to encourage contributions, questions, raise issues etc. which can be place online in the public domain. (e.g. online questionnaires, public bulletin board etc).

5.8.4 Negotiation Space

Group research may often introduce conflicts of opinion which need to be worked through. This is more difficult online and may involve intensive and protracted discussions. This could be done by chat, forum or recorded video conferencing.

It is envisaged that a CSCR domain may require a negotiation support system as discussed by Swaab *et al* (2004) in order to foster the resolution of possible conflicts arising between research collaborators.

Conflicts between collaborators can cause unwanted stress (Lawless and Allan 2004). The provision of negotiation space is included in the CSCR environment to provide a mechanism for relieving stress in an on-line collaborative scenario and by a careful management of the research processes.

5.8.5 Publication Space

The publication of pre-prints, e-prints and draft papers to on-line sites such as arxiv.org could be assisted by an automated process incorporated into the system.

5.8.6 Additional Features

Following D'etienne (2006) this work will also be looking at: the coupling of work and its organisation, informal communication and informal roles, awareness in distributed design, establishment of common grounds and perspective, clarification and convergence mechanisms in co-design. It is felt that all of these should be realised within the aforementioned spaces.

It is the intention to make allowance for Pekkola's (2003) idea of unanticipated use of artefacts in this project in terms of the methodology and the approach that is taken although it should be acknowledged that this is a complex area because it is almost impossible to predict.

5.8.7 Summary of the differences between CSCW, CSCL and CSCR

It is contended that the primary difference between CSCW and CSCL is that CSCW can be characterised by the need for "WorkingSpace", while CSCL needs both "WorkingSpace" and "LearningSpace". Furthermore CSCR requires "WorkingSpace", "LearningSpace" and "ResearchSpace" as shown in table 9.

All three domains, CSCW, CSCL and CSCR have commonality and dependency, and borrow from one another. However, CSCR has individual aspects which are not part of the other two, and consequently is distinct and should be treated as such.

The Spaces required by each of the collaborative areas		
CSCW WorkingSpace	CSCL LearningSpace	CSCR ResearchSpace
Administration	Administration	Administration
Communication	Communication	Communication
Scheduling	Scheduling	Scheduling
Sharing	Sharing	Sharing
Product	Product	Product
	Reflection	Reflection
	Social	Social
	Assessment/Feedback	Assessment/Feedback
	Supervisor	Supervisor
		New Knowledge
		Privacy
		Public
		Negotiation
		Publication

Table 9 Degrees of Collaborative Space

It has been argued that there is a case to be made for regarding CSCR as a separate and distinct area of investigation. Each one of these domains CSCW, CSCL and CSCR has their own specification and requirements. The first two according to Stahl, G. (2003).have their own “conferences, journals and adherence”. The latter is yet to develop and is a potential fruitful area for future research. The concept of CSCR is introduced here for the first time.

Handoko (2005) describes a newly developed on-line scientific web log, which enables scientists around the world to perform an on-line collaboration over the internet. This can now be identified as one of the first examples of what is defined here as CSCR (Computer Supported Collaborative Research).

5.9 Comparison with other Collaboration Environments

The CSCR domain being proposed here is distinct from all other environments in a number of key ways. For instance CSCR focuses on people, CAWS focuses on documents, while VRE focuses on tools.

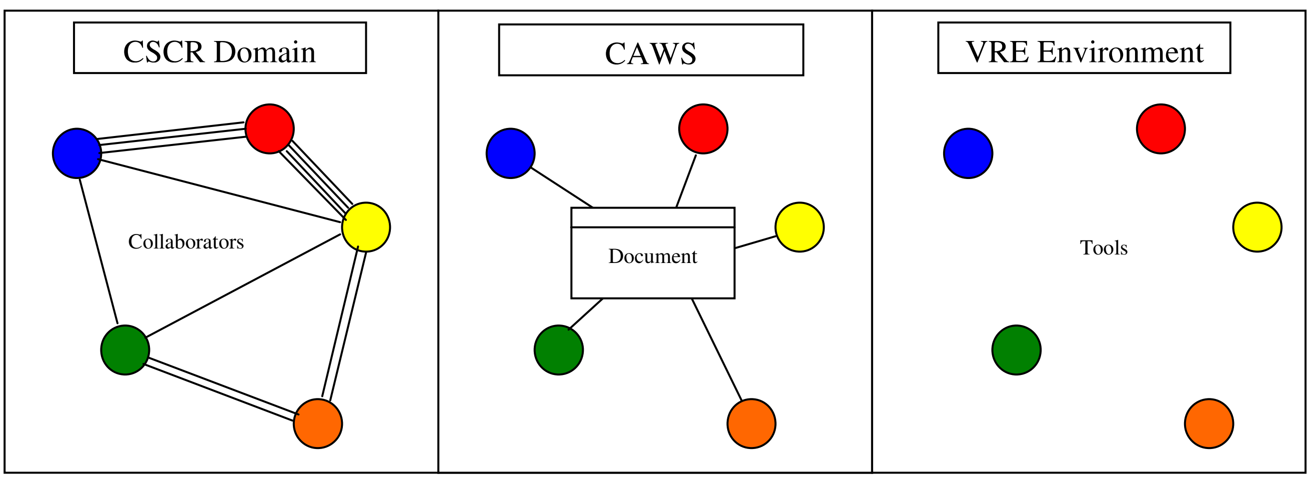


Figure 7 Comparison of Research Environments

The CSCR environment is not a Virtual Research Environment (VRE)

The VRE has a range of tools necessary for researchers to be supported in their activities which may or may not include collaborative tools. It is true to say that most VREs (eg.

myExperiment,VERA, JISC VRE) do include some collaborative tools but collaboration is not "of the essence" of a VRE nor included in the definition of a VRE as indicated by its nomenclature. There is no "Collaboration" in VRE as there is in CSCR. A VRE which neglects collaboration may well be termed 'a bad VRE' but is still a VRE nonetheless. Some VREs have no collaborative tools. VREs such as that discussed in Wills (2005) concentrate on the structures needed to support data processing and analysis, rather than collaborative roles. Furthermore a VRE is a specific instance of a software tool whereas CSCR is a conceptual domain which contains the specification for all possible collaborative research environments. VREs without collaborative elements would sit outside the CSCR domain.

The CSCR environment is not a Co-authoring Wiki Environment (CAWS)

Whereas environments such as CAWS, Liccardi, I. Davis, H., White, S. (2007) are document centred, the CSCR environment is people centred.

The CSCR domain may act as a container for both, the VRE and CAWS as well as a range of other tools. As such it is a domain defining the full range of collaborative environments which might be constructed from portals or other vehicles (Web 2.0) to bring the focus upon collaborative research.

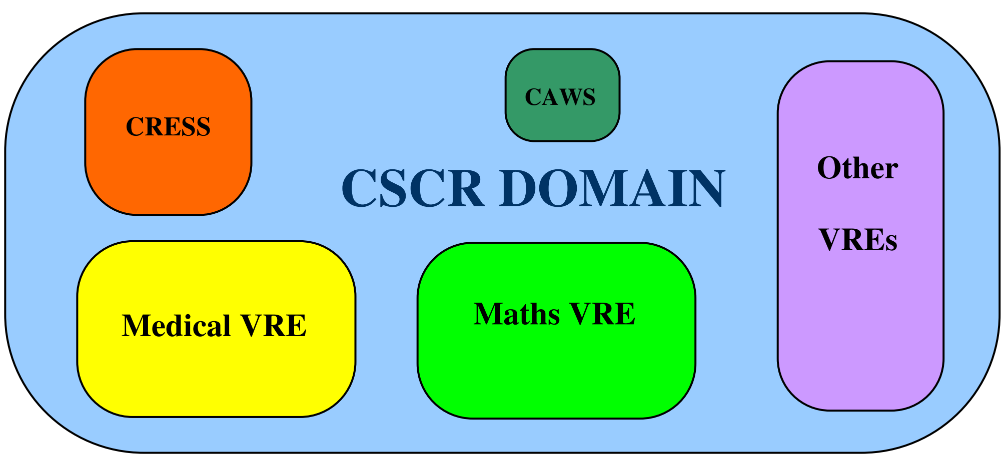


Figure 8 The CSCR Domain as a container for research environments and tools

5.10 Summary

The History of HCI shows a lack of coherent development (Diaper 2005). There is no agreement as to what HCI is, should be, or do. The discipline is becoming increasingly fragmented to the point where it is difficult to establish consensus in the field. This fragmentation of HCI is already so extensive according to Diaper that it is hard to even characterise the method of approach.

Much the same is true of CSCW and CSCL. Although these have been the subject of extensive research for a number of years there is still no accepted definition of either. *"This lack of agreement highlights the necessity for the development of a general systems model, both in the general HCI approach and in the specific collaborative approach"* (Diaper 2005). It has been the purpose of this chapter to propose a general systems model to determine the complete relationship between CSCW and CSCL and defining for the first time CSCR.

To recap, an analysis of the discipline of HCI has ultimately led to the definition of the domain of CSCR. This in turn will lead to the design of a particular environment for research students and their supervisors CRESS within the CSCR domain. In Chapter 6 there will be a review of collaborative learning theories, an examination of the role of scripts and scenarios in collaborative learning, a review of CSCL e-learning laboratories and help systems together with a summary of some important CSCL research findings. A particular instance of the CRESS environment will then be created on a storyboard and assessed by potential users via a questionnaire.

Chapter 6 Designing CRESS

6.1 Introduction

In the previous chapter a definition of the CSCR domain was provided, which demonstrated that the CSCW and CSCL domains by themselves are not rich enough to encompass the requirements of collaborative research. An additional five research spaces were identified as necessary components for a CSCR domain.

In this chapter the application of the CSCR domain to the specific needs of supporting a Collaborative Research Environment for Students and their Supervisors (CRESS) will be analysed with a view to obtaining the specific set of tools required for the design of a specific version of a CRESS interface. Versions of the interface would differ according the arrangement and selection of the toolset. Each faculty (Physics, Medicine, Engineering, Computer Science etc.) will have their own toolset requirements.

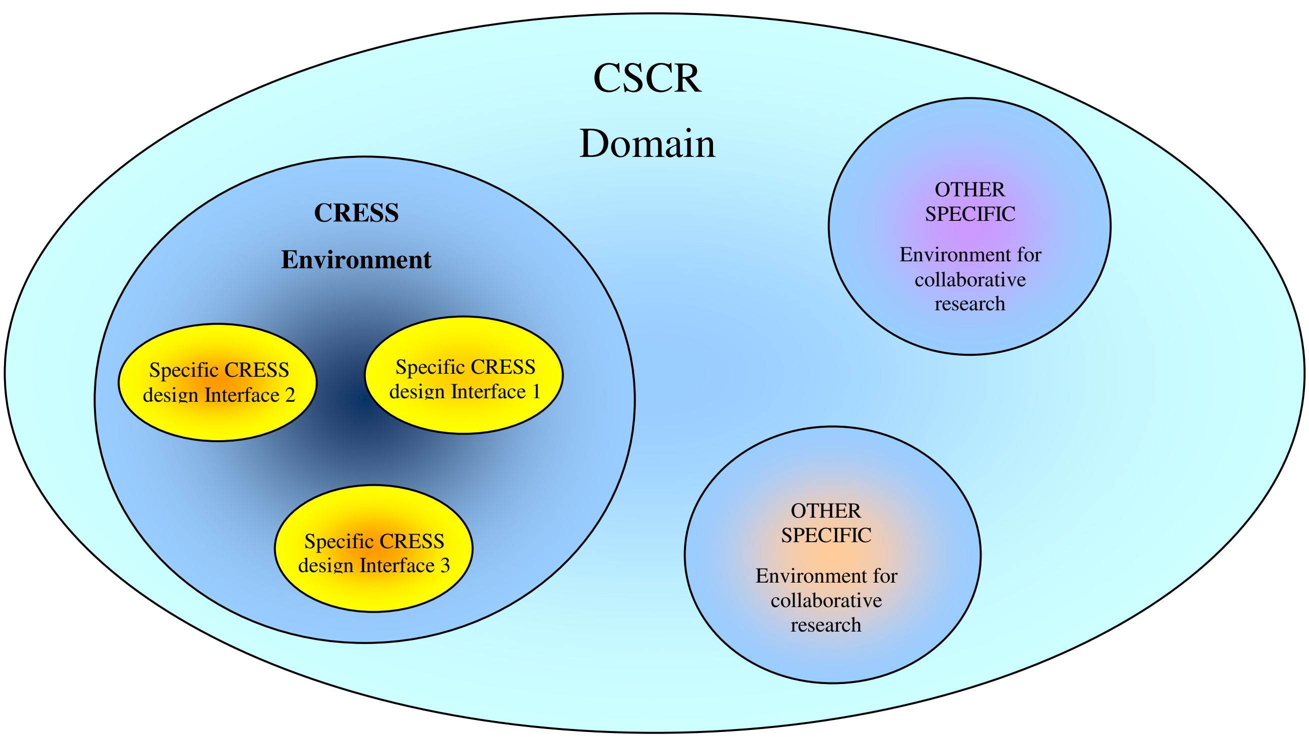


Figure 9 Relationship between domains, environments and interfaces

Figure 9 shows the relationships between domains, environments and interfaces. The CSCR domain is defined by the set of 14 specific spaces, while the CRESS environment will be shown to be defined by 42 specific tools, and the interface is defined by a specific arrangement of those tools.

6.2 Analysis of appropriate categories and tools for CRESS

The methodology of Lindgaard et al (2006) will be followed which concentrates on User-Centred Design and originally began with brainstorming and then called for three iterations of design, prototyping and usability testing. A detailed breakdown analysis will be undertaken to determine the advantages and disadvantages of a range of tools, drawn from the analyses of e-laboratories. These tools are to be considered in the light of the requirements for the specific CRESS environment.

Lindgaard et al (2006) will be followed except that the first-stage, brainstorming session, will be replaced with a detailed analysis of pre existing environments to identify user interface elements. This will involve the analysis of 13 e-laboratories and three VLEs to determine a range of tools which have been broken down into a set of 14 logical categories.

In order to determine the most relevant tools which might be applied in the construction of a CRESS environment the analyses have been based upon an assessment of advantages and disadvantages for each tool set with reference to the needs of collaborative research. The final set of tools is defined in Table 10 which summarises the toolset to be employed initially in the new specific CRESS interface.

The particular toolset for CRESS which will be arrived at by the advantage-disadvantage analysis will provide only a preliminary "scorecard" of tools. These tools will be fully tested as to their utility by means of detailed questionnaires given to a range of users working in collaborative environments including students and supervisors, and it is the results of the survey which will be the determining factor as to which tools are to be employed in CRESS. These will then be incorporated into a storyboard for further user analysis. This will provide a preliminary investigative model which can then be presented to potential users for further feedback.

Figure 10 shows the interrelationship of research elements and the framework into which the CRESS environment fits.

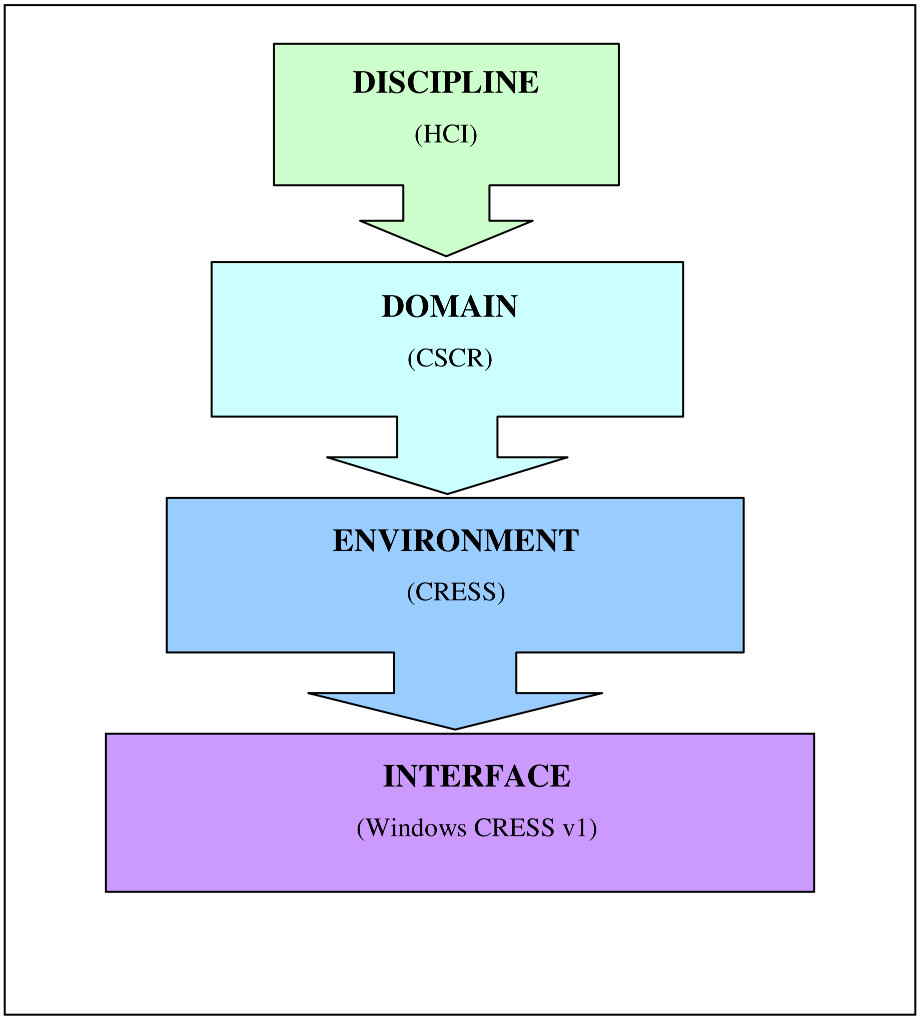


Figure 10 Relationship of Research Elements

6.2.1 E-laboratory Analysis

Thirteen different CSCL e-laboratory interfaces were analysed with a view to determining the range of tools available and the classification groups into which those tools belonged.

Argles *et al* (2006) have an e-learning laboratory called "*CECIL*" which is designed to enable pairs of students to collaborate in the writing of program code. The interface allows them to see the output of their work as well as a simulated LED display.

Bachler *et al* (2004) employ an instant message client called "*Buddy Space*" to facilitate multiple views of collaborative workgroups together with information about the location, attendance and recording of virtual meetings.

Baker *et al* (2002) have analysed commercial real time distributed groupware called "*Groove*". This contains a real time collaborative workspace based upon text and voice chat.

Berger *et al* (2001) have set up a CSCL environment called" *Le Scenario*" to support community health projects. Their environment stimulates social interaction in a face to face web based learning space which provides access to a range of knowledge sources.

Dalziel (2003) has developed an e-learning environment called "*Learning Design*" together with a learning activity management system "*LAMS"* which facilitates student run-time activity and teacher run-time monitoring.

Harper *et al* (2004) have created a three dimensional virtual learning environment referred to as the experimental team room "*ETR*". This allows participants to move freely around a virtual room set up like a standard meeting room. It also includes an electronic meeting assistant (*EMMA*) which provides a human face to interact with and to accomplish basic tasks in the environment.

Hosoya *et al* (1997) of Japan have developed a 3D virtual reality environment called "*HyClass*" based on "*CORBA*" which allows the user to walk around, pick up objects, move them from place to place and share them with other users, all in the form of representatives or avatars within the environment.

Kligyte *et al* (2001) have designed an interface named "*Fle3*" for the "*ITCOLE"* project which looks and acts much like a standard VLE which allows a limited degree of shared working.

Miao *et al* (2005) have been employing a CSCL tree-based script authoring tool called "I*MS-LD*" which can be used collaboratively to create learning scenarios for students.

Pekkola (2003) uses the "*VIVA*" interface to support peripheral awareness in a 3D virtual environment. This allows the use of common artefacts for framing activities in workplaces.

Walters' *et al* (2006) "*Mgrid*" framework provides a method for learning distributed computing. Although not properly a collaborative environment it does enable the rapid prototyping of distributed systems within a basic browser framework to enable security through a sandbox approach. This is designed for many machines to do the work of one.

Liccardi *et al* (2006) has produced a wiki system to improve workspace awareness to advance effectiveness of co-authoring activities. This co-authoring wiki system, "CAWS" is designed to improve the user's response to document development and to extend the area of workspace awareness.

Sim *et al* (2005) have discussed a Web/Grid Services approach for a Virtual Research Environment (VRE). They are working on "*CORE"* which is a project to develop a VRE to enable orthopaedic surgeons to collaborate in the design, analysis and dissemination of experiments. Individual user spaces are supplemented by templates for standard documents, a database for experiments, access to e-print archives and a limited discussion facility between collaborators.

6.2.2 VLE Analysis

A number of these tools are built in to standard VLE interfaces and may well be useful in the CRESS environment. Three VLEs have been considered: Blackboard/WebCT, Moodle and Elgg. These have been incorporated into Table 10 where a range of social interaction tools are particularly evident. Community creation and access authorisation tools are useful to set the boundaries of the collaborative group and provide a secure environment for the exchange of ideas.

Web 2.0 tags which are a community device to allow the marking of content for the purpose of facilitating rapid search may only have a limited use in this environment as the utility of tags is proportional to the number of users within the community group. In large communities such as flickr.com tags are immensely useful whereas in the much smaller groups of the CRESS environment their usefulness would be diminished.

Friend file sharing and **blogging** are both methods for making data available to a wider audience and would both be considered useful tools in a CRESS environment. Blogging can also play the dual role of a journal or log which can either be public or private, facilitating the process of reflection within the community.

RSS feeds provide a central point for the aggregation of widely published data sources and provide a customisable space in a portal framework, which can focus the interests of a particular research group.

Peer review assistance would be useful in a number of areas. The provision of a database of academic peers and papers would assist research but this may be difficult to provide internally to a CRESS environment. A fuller database is usually available on dedicated websites such as ACM, BCS, arxiv etc., which perform this kind of role more adequately. All that may be required in the CRESS environment is a link to the external databases.

Finally **public spaces** and **private spaces** can both be useful in this environment where the former allows individual contributors to formulate their work prior to sharing and public spaces allow the canvassing of opinion of a wider audience to raise public issues.

Table 10 shows the various toolkit elements employed by each of the interfaces and VLEs mentioned above, where the x mark in the table indicates that the feature is implemented in the e-laboratory. The results show that apart from login and access tools the most utilised tools are **text chat** and **file depository** with a score of 8 out of 16. The second most popular tools are **scheduling** and **forum** with a score of 7out of 16, and the third most popular tools are the **help pane**, the **message board** and the **collaborative working window** (Whiteboard) with a score of 6 out of 16.

CSCR CSCL CSCW

CATEGORY SPACES	TOOLS	Argles SIM20	Bachler “Buddy Space”	Baker et al “Grove Space”	Berger	Dalziel “LAMS”	Harper et al ”ETR”	Hosoya et al “HyClass”	Kligyte et al “Fle3”	Miao et al “IMS-LD”	Pekkola “VIVA”	Walters et al “M-Grid”	Liccardi CAWS: A co-authoring Wiki	Sim et al Web/Grid Services VRE	Blackboard	Moodle	Elgg	total
Administration Space (including security tools)	Login	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	16
	Access/authorisation Tools	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	16
	Recording /Replay Facility		x															1
	Instant Messaging Recording		x													x		2
	Assistive Agent						x											1
	Help Pane	x		x					x						x	x	x	6
	Information Link Map		x						x	x					x			4
	Scenario/Control flow Tools									x								1
Communication space (including Identification space)	Text/ Chat	x		x			x	x	x		x				x		x	8
	Audio/Voice			x			x	x			x							4
	Still Picture		x						x						x	x	x	5
	Video		x				x	x										3
	Instant Messaging		x								x					x		3
	Forum				x				x				x	x	x	x	x	7
	Message Board/News					x					x		x		x	x	x	6
	Avatar (Representations)							x										1
	Presence Indicator/Information		x	x							x		x			x		5
	Location Identifier		x				x				x							3
	Focus Indication		x				x				x							3
	Participant Data		x										x	x		x	x	5
Scheduling space	Scheduling Tool		x		x		x		x			x			x	x		7
	Task Setting		x							x					x	x		4
	Task Monitoring		x		x					x			x		x			5
Shared working space	Whiteboard			x					x	x	x				x			5
	Collaborative Working Window	x		x				x	x				x				x	6
	3D Environment						x	x										2
Product Space	Output Window	x											x					2
	Simulations	x												x	x			3
Reflection Space	Reflective Journal/Private					x							x			x	x	4
Social Interaction Space	Community Creation												x				x	2
	Tags (marking Content)												x				x	2
	Friend (file sharing)												x				x	2
	Blog (Public + Private)												x	x		x	x	4
	RSS feed to centralize data														x	x		2
Assessment / Feedback Space	Assessment														x	x		2
	Feedback														x	x	x	3
Supervisor Space	Private area for tutors														x	x	x	3
Knowledge Space	Contribution Database				x			x	x				x	x				5
	Academic database													x				1
	Repository					x			x		x		x	x	x	x	x	8
	PowerPoint Slides		x				x									x	x	4
Privacy Space	Private Space													x	x	x	x	4
Public Space	Public information space														x	x	x	3
Negotiation Space	Peer Review assistance												x	x		x		3
Publication Space	Schemas/Templates													x			x	2
	Publishing assistance													x	x	x	x	4

Table 10: Analysis of tools available to diverse e-learning systems

6.3 Categorisation and Selection of the appropriate tools for CRESS

Following the analysis of the CSCR domain in Chapter five the services provided were factored into a number of distinct logical categories as follows:

• Administration	
• Communication	
• Scheduling	
• Sharing	**CSCW**
• Product	
• Reflection	
• Social	
• Assessment/Feedback	**CSCL**
• Supervisor	
• Knowledge	
• Privacy	
• Public	
• Negotiation	**CSCR**
• Publication	

Forty-six tools in these 14 categories have been identified as being utilised within CSCW, CSCL and CSCR environments. The tools above are colour coded to correspond with the three areas in tables 11 to 24. The tools are now examined for inclusion in the CRESS interface.

The process that was used was an analysis involving a determination of the advantages and disadvantages of the utility of each tool. This was done on a category by category basis until an appropriate set of tools is arrived at for CRESS. Each of the tools required within these primary categories, see Table 10 were considered in detail. These Advantages and Disadvantages have been derived by checking each tool against current implementation and these represent the present assessment of a suitability for a CRESS environment.

Those tools which are specific to CSCW were considered in tables 11 to 15.

6.3.1 Administration Space Tools (Security, Recording and logging tools)

Description of Tools	Advantages	Disadvantages
Access/Authorisation Tools	○ Limits availability to authorised user ○ Limits access to specific areas ○ Accountability of actions through tracking	○ Usual security overheads
Login	○ Tracking	○
Recording/Replay of text (instant messaging)	○ Allows detailed analysis of ideas and content ○ Can be attended to at own time	○ Low storage overheads
Recording/Replay of audio	○ Medium level of communication	○ Medium storage overheads
Recording/Replay of video	○ Non verbal communication ○ Highest level of communication	○ High storage overheads
Recording/Replay of computer actions	○ Enhances visualisation and demonstration roles	○ Low storage overheads
Help Pane	○ A simple statement of important facts of the operation of the interface easily accessible	○ Help panes can obscure parts of the interface
Information link map	○ A menu of help in form of graphical display of links	○
Assistive agent	○ Interacts with the user to provide artificial intelligent help	○ Requires a high degree of sophisticated programming expertise ○ Will take a long time to develop
Scenario control flow tools	○	○ Specific to a particular task

Table 11 Evaluation of Administration tools

These administrative tools encompass **Help**, **Security** and **Recording**. Help tools include the use of the **interface control**, **information link maps** and a simple **help pane**. Additionally an **assistive agent** could be used employing artificial intelligence to provide a higher degree of help (setting up the scenario etc.) Recording tools include mechanisms for recording communication transactions both for the purposes of reviewing information and for logging and validation. This includes security for **authentication authorisation and accounting** in the proposed CRESS environment. This would require the implementation of basic methods such as **login** and **password** procedures etc.

Audio recording/replay can be included as a subset of **video recording/replay** which includes both moving pictures and sound. The replay of computer actions (recordable macros) which store keyboard presses and mouse movements can be useful for demonstration purposes particularly within a whiteboard portlet.

Both the help pane and the information link map would provide useful features in an accessible format with the link map providing a graphical index for quick access. These can be based on a simple hypertext (HTML) system and should be easy to set up and administer within the proposed CRESS environment.

The assistive agent is deemed to require too high a programming outlay to merit the advantages to be obtained.

The scenario control flow tools are specific to particular needs and don't apply to a generic CRESS interface and will be disregarded.

6.3.2 Communication Space Tools

Description of Tool	**Advantages**	**Disadvantages**
Text/chat	○ Can be recorded easily ○ More concise ○ Small file sizes	○ Higher degree of effort ○ Typing skills required ○ Absence of verbal communication ○ Absence of non verbal communication ○ Requires appointed time
Audio	○ Can be recorded easily ○ Immediacy ○ Easy of use	○ Absence of non-verbal communication ○ Increased file sizes ○ Requires appointed time
Still Picture	○ Quick visual identification	○ Slight increase in memory requirements
Video	○ Easily recordable ○ Immediacy ○ Ease of use	○ Highest file sizes ○ Requires appointed time
Instant Messaging	○ Instant alert to online user ○ Recordable ○ Can be used synchronously and asynchronously	○ Can distract from other work ○ Higher degree of effort ○ Typing skills required ○ Absence of verbal communication ○ Absence of non verbal communication
Forum	○ Asynchronous communication ○ Recordable ○ Track individual ideas through a thread	○ Lacks immediacy ○ Higher degree of effort ○ Typing skills required ○ Absence of verbal communication ○ Absence of non verbal communication
Message board/News	○ One to many communication ○ Useful news distribution	○ One way communication ○ Lacks immediacy ○ Higher degree of effort ○ Typing skills required ○ Absence of verbal communication ○ Absence of non verbal communication
Avatar (Representation of Participants)	○ Quick visual identification ○ Non-verbal communication	○ Large file size ○ Higher overheads in operating cost
Presence Indicator	○ Knowledge of Participants' presence ○ Low overheads	○
Location Identifier	○ Provides spatial indication	○ Not required in a non geographical environment
Focus Indicator	○ Identifies the speaker in synchronous communication	○
Participant Data	○ Indicates name and other information of each participant	○ May include irrelevant data
Email	○ E-record	○ Spam ○ Higher degree of effort ○ Typing skills required ○ Absence of verbal communication ○ Absence of non verbal communication ○ Not dedicated to CSCR
Voice message	○ Recordable	○ One way communication ○ Lacks immediacy ○ Absence of non verbal communication

Table 12: Evaluation of communication tools

These communication tools are for the exchange of information between collaborators. They include both synchronous and asynchronous tools.

Asynchronous tools include **forum** which allows threads of conversation to be maintained and a **simple message board** that allows one- off news items to be posted.

Synchronous tools are **text chat**, **audio/voice**, **video** and **instant messaging**. There is a clear preference for video over audio and audio over text as this mirrors more closely normal communication. However implementation is shown to be the reverse with the majority of interfaces using chat and the smallest number using video. It is likely that this is due to a higher degree of complexity in implementing the video feature which has resulted in this trend.

The implications for this are that for the CRESS environment the tools which bring the greatest degree of communication (**video)** are preferred over the more onerous to use tools (**chat**). In order to be rigorous it may be necessary to set up a communication interface with all three methods and determine which is the most widely used and in which circumstances.

The three tools for synchronous communication: Chat, Audio, Video have a distinct ordering in terms of ease of use. Audio and video are easier to use than chat (which requires typing). Furthermore they have a distinct ordering in terms of the amount of information that can be communicated. Audio can communicate more information than chat for the same amount of human effort, and correspondingly Video can communicate more information than audio for the same amount of human effort. For this reason Video will be preferred over Audio and Audio over chat. The proposed CRESS environment should contain Video communication, which can fall back to audio if required. It is debatable whether a chat facility is needed in these circumstances. It is acknowledged that some forms of chat e.g. MSN are more popular than some forms of audio e.g. Skype. However, there are a number of reasons for this including the longer establishment of MSN, the 'zero cost for all users' universality of MSN whereas Skype is not free for all users since payment is necessary for landline connections, and finally the issue that MSN now carries video conferencing which confuses the evaluation. In the proposed CRESS environment, where cost is not a factor for the individual user and resources are available for all collaborators, this level playing field will mean that the chat facility would not be expected to be as highly used as audio and video. It is therefore concluded that if file size is no object, then the chat facility may not be needed.

The asynchronous communication tools will however provide an additional benefit for those times when a real time appointment with other collaborators cannot be made. The **forum** or **bulletin board** can maintain discussion on particular themes or threads which allows collaborators time to think between posting ideas.

Email is a universal tool which, though connected is still outside the CRESS environment and does not need to be incorporated. However, if users felt it more convenient, a link button could be incorporated in the interface to launch the email client.

Message board/News announcements would be particularly useful to supervisors and administrators. This is an element which could be incorporated in the first prototype.

Instant messaging is considered to be too distractive an element to be incorporated into the first prototype. However, this needs to be kept under review so as not to limit the interface and rule out a degree of functionality which some users might find useful.

Identification Tools

Identification tools are an essential component of communication. There are a number of elements which receive automatic identification when groups meet together face to face but which have to be engineered into the interface when people are meeting online. These include a participant's presence online (logged in), their personal data (name, position etc.), a **focus indicator** (that declares when they are talking). In addition participants can be represented by **avatars** representing images of the participants. A **location identifier** is sometimes used (particularly in 3D environments).

Identification can be made on three levels. At the lowest level that representation can be a simple name as a presence indicator. At the next level presence may be indicated by a still picture to enable immediate recognition. At the highest level an avatar may be used as a representative within the virtual environment which may include a 3D world. **Avatars** provide more than a graphical representation and may indicate emotions and other non-verbal communication such as gestures, body language etc. As a 3D or virtual world will not be used in a CRESS environment, avatars will not be considered a priority. However a still picture will add to the communication and recognition of participants and may be useful for the proposed CRESS environment.

Presence and **Focus** indicators were perceived not to have disadvantages and these will also be included.

Participant's data would also be required to differentiate between students, supervisors and administrators as well as an indication of their IP address and geographical location.

Location identifiers within a 3D world would not be required in the proposed CRESS environment.

6.3.3 Scheduling space tools

These enable meetings to be set to facilitate the online synchronous communication. It is also used to provide individual task setting and monitoring to enable progress on joint work to be checked and validated. These will not only facilitate appointments for synchronous discussion but also enable tasks to be set and monitored.

Description of Tool	**Advantages**	**Disadvantages**
Scheduling Tools (Calendar)	○ Facilitates setting up of online meetings ○ Allows Collaborators to show availability	None
Task Setting	○ Allows supervisors and others to set timetable of activities and deadlines	None
Task Monitoring	○ Allows all participants to view ongoing progress ○ Amount of task completion ○ Can be charted	None

Table 13 Evaluation of Scheduling space tools

Each of the three tools above has clear advantages and no observable disadvantages. It is therefore recommended that all three items are adopted in the CRESS environment.

6.3.4 *Shared Working Space Tools*

Description of Tools	Advantages	Disadvantages
Whiteboard	○ General area for working allowing a wide range of use ○ Brainstorming ○ Discussion, ○ Summarising of ideas	○ Cannot deal with specific needs such as programming (cannot compile) ○ Primitive method of drawing
Collaborative working window	○ Dedicated to particular tasks	○ Cannot be used for general tasks
3D environment	○ Indicates location of participants and artefacts within a 3D world	○ High programming, memory overheads ○ Not always required for collaboration

Table 14 Evaluation of shared working space tools

Working spaces are particular to the tasks which are being performed. These will involve a range of tools tailored to the different working practices and needs. In some circumstances, a simple whiteboard may suffice while in others a dedicated collaborative working window will be needed. The proposed project will be concerned here with generic workspaces. If required specific tools could be added as modules at a later time.

It is not clear at this stage whether a whiteboard would be useful in a CRESS environment. However, the whiteboard is one of the most popular collaborative working spaces according to our survey results as shown in Table 26 so it is felt that it should be included and it is worth investigating from a user standpoint before dismissing it as a viable CRESS tool.

Dedicated working spaces, such as the programming environment CECIL or a dedicated reviewing space such as CAWS, which are created to handle a specific task will be interesting only to those for whom the specific task will be important. This kind of dedicated working space is best left as an additional feature to be added as a module at a later time for those who have a specific need for it. It would not be required in a generic CRESS environment. In the same way an output window is too specific. A simulated display is also dedicated to a particular process and is not required. 3D environments would be onerous to program without a large programming team and would not serve any essential purpose in the envisaged CRESS interface.

6.3.5 Product Space Tools

Description of Tools	Advantages	Disadvantages
Output window	○ Shows results of calculations or programming or the end product of a process (Graph from equation)	○ Takes up space on the interface which may not be required by many users
Simulated display	○ Shows in diagrammatic form the operation or working of some part of a process (programming)	○ Task specific and has no wider user beyond a particular instance

Table 15 Evaluation of Product space tools

This category includes those tools which provide an area for displaying an outcome of the work which is done or under development. This can be viewed as an extension mechanism that is used to specialise a particular CSCR environment such as CRESS. This may include room for showing the results of a compiled computer program or it may demonstrate graphically the display of some predetermined outputs given a set of inputs such as a binary display or specifically tailored dashboard instrumentation. These would probably be highly customised and research dependent. In general the proposed CRESS environment would have a limited requirement for highly specialised displays and could be omitted after the first iteration.

Those tools which are specific to CSCL will be considered in tables 16 to 19.

6.3.6 Reflection Space Tools

Description of Tools	Advantages	Disadvantages
Reflective journal	○ Personal and private space for individual contributors to record their reflections on the research process	None

Table 16 Evaluation of Reflection space tools

One of the key features to emerge from recent pedagogical theory is the importance of personal reflection in the role of learning. The main tool to be adopted to assist this process is a personal journal or log which allows an individual collaborator to look back upon recent advances in knowledge acquisition or changes to their research through the writing up and recording of their personal journey and exploration of new found knowledge.

6.3.7 Social Interaction space tools

Description of Tools	**Advantages**	**Disadvantages**
Community Creation	• Allows the construction of private groups focused upon a particular research subject • Facilitates multiple research groups within the interface	• None known as yet
Tags (marking Content)	• Allows rapid searching of varied data according to web 2.0 methods	• Communities may not be large enough to allow full use of social tagging
Friend (file sharing)	• Set permissions for who may be allowed download and share files	• Theft of ideas
Blog (Public + Private)	• Blogging is an important part of social communication • Allows reflective comments as well as public ones	• Theft of ideas
RSS feed to centralize data	• Acts as a central gathering section for information publishing for other parts of the web	• Some important sites may not have RSS feeds

Table 17 Evaluation of Social interaction space tools

These are tools which encourage the development of communities within and without the CRESS environment and might involve the creation of tags for marking content, friends for sharing, and communities for the concentration of group effort. All of these tools will be included in the first iteration of the CRESS environment.

6.3.8 Assessment/Feedback Space Tools

Description of Tools	**Advantages**	**Disadvantages**
Assessment	• **Mostly used in CSCL** • **Can mark stages within Postgraduate Degrees**	None
Feedback	• **Essential for monitoring progress**	None

Table 18 Evaluation of Assessment/Feedback space tools

The student/supervisor relationship is not an equal one. The flow of information between the two will be of a different character, quantity and quality. The nature of the information flow from student to supervisor may be exploratory and tentative whereas the information flow in the opposite direction may be regulative and defining. This latter feedback provides the student with the boundaries within which the student needs to work as well as the encouragement and guidance to move forward in the right direction. An appropriate feedback tool is therefore incorporated into the CRESS environment.

6.3.9 Supervisor Space Tools

Description of Tools	Advantages	Disadvantages
Private area for supervisors	• **Allows unfettered discussion**	None

Table 19 Evaluation of Supervisor space tools

This is privileged for the supervisor and deals with their own evaluation of the student's work. It may also afford the opportunity for supervisors to discuss the student's work amongst themselves in a private area to which the students have no access. This provides the opportunity for open and honest debate without worrying the student's response to it. This may take the form of a private chat channel or private forum.

Those tools which are specific to CSCR will be considered in tables 20 to 24.

6.3.10 Knowledge Space Tools

Description of Tools	Advantages	Disadvantages
Database of PowerPoint Slides and Notes etc	○ Essential to track contributors ○ Provides information for security gateway	None
Database of research contributions	○ Tracking and assigning ownership of work done	None
Repository	○ File space for the uploading of documents and files ○ Protected area accessible only by the team	None
Academic database	○ List of key authors and publications in the field	None

Table 20 Evaluation of Knowledge space tools

This space is designed as a depository for finished work prior to publication as well as for the whole range of documents, papers, and research links etc. which provide the underpinning background knowledge for the research that is taking place. This would involve databases which hold the depository and provided an index and full reference capability such as EndNote.

Behind the interface there needs to be a mechanism for storing the information. In particular this will encompass a depository for lodging documents, proposals, papers in progress, research links, PowerPoint slides etc.

The advantages clearly outweigh the disadvantages for all four tools; therefore all will be incorporated into the CRESS environment.

6.3.11 Privacy Space Tools

Description of Tools	**Advantages**	**Disadvantages**
Private Space	○ Private area for individual work prior to sharing with collaborators	None

Table 21 Evaluation of Privacy space tools

This is the private area for individual research work prior to sharing with other collaborators. This is concerned therefore with work in progress as it evolves over the research project period. Work from here will eventually uploaded into the feedback space where supervisors can review and comment upon it.

6.3.12 Public Space Tools

Description of Tools	**Advantages**	**Disadvantages**
Public information space	○ Public area to publish work in progress surveys for feedback	None

Table 22 Evaluation of Public space tools

This is a data and information gathering and disseminating area prior to formal publication. The need for this kind of space may arise from recruitment of the public to surveys or the gathering in of opinions and inviting contributions from a wider area.

6.3.13 Negotiation Space Tools

Description of Tools	**Advantages**	**Disadvantages**
Peer Review assistance	○ Facility to email draft copies for validation before publishing ○ Requires a database of peers who have agreed to provide review feedback	None

Table 23 Evaluation of Negotiation space tools

It is sometimes a long and difficult process to arrive at an agreed course of action during the research cycle amongst collaborators with differing views. Negotiation together with arbitration may be required at times to find the way forward. The use of Peer evaluation may well be central to this process. Accordingly a negotiation space is expected to provide tools for lengthy detailed argumentation as well as the introduction of Peers or Arbitrators external to the immediate research group.

6.3.14 Publication Space Tools

Description of Tools	**Advantages**	**Disadvantages**
Publishing assistance	○ Automatic uploading of finished contributions to publication and e-print sites	None
Schemas and Templates	○ Provides Formatting and Styles for particular Journal Publication	None

Table 24 Evaluation of Publication space tools

The publication of the final paper could not occur until a number of processes have been completed including document checking for style, format as well as content, argument, coherence etc. This can be assisted with the use of schemas and templates and will also certainly involve a peer review process. Following this assistance with specific journal requirements, style sheets, and final submission rules to the relevant publication channels will be needed.

6.4 Listing the requirements for CRESS

The foregoing analysis has resulted in the determination of the tool requirements for the CRESS interface which are shown in Table 25. The analysis shows that 37 tools are required for the creation of the envisaged CRESS environment and that a further 7 tools have been considered at this stage to be unnecessary. These include administrative tools, two communication tools (which related to a three dimensional environment) and a further two tools that also refer to 3D environments. Another two tools were considered to be suitable for reviewing at a later stage.

CSCR CSCL CSCW

CATEGORY SPACES	TOOLS	Required	Not Required	Review
Administration Space (including security tools)	Login	x		
	Access/authorisation Tools	x		
	Recording /Replay Facility	x		
	Instant Messaging Recording			x
	Assistive Agent		x	
	Help Pane	x		
	Information Link Map		x	
	Scenario/Control flow Tools		x	
Communication tools (including Identification tools)	Text/ Chat	x		
	Audio/Voice	x		
	Still Picture	x		
	Video	x		
	Instant Messaging			x
	Forum	x		
	Message Board/News	x		
	Avatar (Representations)		x	
	Presence Indicator/Information	x		
	Location Identifier		x	
	Focus Indication	x		
	Participant Data	x		
Scheduling tools	Scheduling Tool	x		
	Task Setting	x		
	Task Monitoring	x		
Shared working space	Whiteboard	x		
	Collaborative Working Window	x		
	3D Environment		x	
Product Space	Output Window	x		
	Simulations		x	
Reflection Space	Reflective Journal/Private	x		
Social Interaction Space	Community Creation	x		
	Tags (marking Content)	x		
	Friend (file sharing)	x		
	Blog (Public + Private)	x		
	RSS feed to centralize data	x		
Assessment / Feedback Space	Assessment	x		
	Feedback	x		
Supervisor/Tutor Space	Private area for tutors	x		
Knowledge Space	Contribution Database	x		
	Academic database	x		
	Repository	x		
	PowerPoint Slides/Notes	x		
Privacy	Private Space	x		
Public	Public information space	x		
Negotiation	Peer Review assistance	x		
Publication	Schemas/Templates	x		
	Publishing assistance	x		

Table 25 Summary of tools required for deployment in the CRESS environment

The use of the aforementioned tools will be illustrated in a number of scenarios in the following section. Questionnaires will also be used to provide potential user feedback to check the usefulness of the proposed tools upon which appropriate modifications will be introduced.

6.5 SCENARIOS

The CRESS interface will be used in a number of different ways by different collaborators. This will depend upon their status (whether supervisor or student), their abilities (good, medium or poor), their diligence (hard working or lazy) and their degree of occupation (busy or unoccupied). In this section a number of common scenarios will be considered. Scenarios will fall into three main groups; those concerned with the student centred view, those concerned with the supervisors' centred view and those concerned with the administrators view.

Student centred scenarios will be presented which demonstrate a range of student activity. A full categorisation and selection of appropriate tools is made and three scenarios are provided to illustrate instances of its use to promote an interface design that models real life activity.

A scenario showing five types of students including good, medium, bad, problem and a mature student working from home will be presented. This will demonstrate collaboration between a supervisor and a student, rather than collaboration between students, which reflects the one-to-one relationship that is most common during PhD research programs. A supervisor centred scenario will be showing two supervisors, one of them keen the other one being very busy. One additional scenario is provided showing details of the administration environment.

6.5.1 CSCR Student Scenario 1

Abigail is a Postgraduate research student on a computing course at Southampton University. When she enrolled on the course she was provided with two supervisors and an internal examiner. She lives over a 100 miles away from the University and is involved in distance learning with only occasional face to face meetings. The online **C**ollaborative

Research **E**nvironment for **S**tudents and **S**upervisors (CRESS) has been provided to support her research.

When Abigail **logs** onto the CSCR portal she is provided with a number of tools. The first area she looks at is the **notice board** which contains a message from David her supervisor: "*Can we meet up today at 2pm to review the latest draft of the conference paper? – David"* She notices in the **message centre** that her other supervisor Gary has sent a message saying that he is available. She then consults her online **calendar** to check her own availability and sees that she is also free. At the message centre she confirms her attendance.

Since Abigail has some time before the meeting she reviews the **forums** to which she has subscribed to see if there is any further news on some of the issues she has raised with fellow students. She has found the forums useful for triggering dormant ideas for further development. There is one very interesting suggestion for her line of enquiry which she decides to keep by saving it to her **private file space** and **tagging** the information. This can be followed up for further research later.

She then goes to the **RSS** link to view her aggregated information area. Abigail has subscribed to a number of news feeds for pre-prints and publication papers in her field at arxiv, ACM, BCS, etc. Here she sees links to the papers and abstracts that have been published that week which she can follow up to build up her knowledge bank.

Abigail now looks at the **tasks area.** She sees that she has three short term tasks to deal with, one of which is the completion of a scenario. The task bar shows that this is half finished. She then goes to the **file depository** where she downloads the latest version of the scenario and works on it. She then uploads the worked on scenario to the file depository. Abigail then downloads the latest version of the conference paper to review it before the meeting.

At 2pm the **video/audio** area is activated and she is alerted to it by a sound and a picture of David in the main **communication window.** Abigail switches her camera on and clicks the record button so that she can have a record of the meeting. A picture of herself is seen in one of the smaller windows. After another sound alert a picture of Gary appears in a third smaller window. All three people are in audio visual contact and the focus is indicated by a **highlighted button** on the **participant window.** The draft document is moved onto the **whiteboard** so that all can see the paper and all can make amendments and add comments to it. The **focus indicator** shows who is able to make amendments at any one time. Abigail clicks the **full screen button** to enlarge the **whiteboard**. The **video window** is still overlaid on the top area of the screen allowing all participants to see and hear while the whiteboard is being worked on.

David highlights areas for change to the document which appear on the screen for all to see as he comments on them. Abigail then makes some changes in real time and adds notes for later development. Gary also adds his thoughts and recommendations. At the end of the session Abigail has a document with clear indication of what changes need to be made. Through the **recording** of the meeting Abigail can also refer to the comments again later if she has a query. Through this collaborative knowledge building process Abigail is steadily compiling this work into a knowledge artefact which can be added eventually to the team's knowledge portfolio held online in the **file depository**.

A new meeting was agreed in a week's time and this was entered into the calendar and **task scheduling window** and the video session ended.

Abigail now connects to her **Blog** and writes a brief account of the meeting and her thoughts about the way it went and what she learned from the experience and which avenues she still has to explore. This **reflective log** will be kept private to Abigail or shared with the project group at her discretion.

She also has access to a **public Blog** which acts as a means of publishing her thoughts to a wider audience.

This research process where different findings, claims, contentions and concepts have come together, through the use of the CRESS interface, using her analytical skills to add to and clarify knowledge building enabling her to slot various insights and acquired understandings onto a constructed scaffold of problem solving and problem solutions.

Tools used in scenario 1:

- Calendar
- Scheduling Window

- Logs
- Notice Board
- Message Centre
- Forums
- Private File Space
- Tagging
- RSS
- Tasks Area
- File Depository
- Video/Audio
- Video Window Recording
- Communication Window
- Focus Indicator
- Highlighted Button
- Participant Window
- Whiteboard
- Full Screen Button
- File Depository
- Blog
- Reflective log

6.5.2 CSCR Student/Supervisor Scenario 2

Alice, Bob, Chris, Dave, Edwina are five students of **good**, **medium**, **bad**, **problem** abilities and the last is a mature student working from home. Their Supervisors are **Joe and Kevin** who are keen and busy respectively. Once a week, all seven agree to meet online in order to update each other on progress made and report to the supervisors, and discuss further project plans. Chris often misses the meeting but is able to drop in and view the **recordings** of the dialogue and the **videos** at a later time.

During the first part of the meeting the students discuss together the status of the project. This can be done via **video conferencing** or by **chat** supported by a **whiteboard** to externalise ideas for brainstorming. During this time the supervisors can just be observing the interaction process in the background without getting directly involved. This would give them freedom of informal assessment. During the dialogue action points can be raised which can be set into the **task scheduler** and apportioned to the appropriate collaborator. There is no need to write up minutes as everything is available on **archive recording**. The task scheduling system can be programmed to send reminders as deadlines approach and can indicate how much of the task has been completed. Additional meetings can be set up by supervisors via the **notice board** and programmed into the **calendar** for automatic notification. Alice who is the keenest of the students keeps up to date notes in her online private journal which enables her to reflect and evaluate on the discussions that take place. At times Kevin is too busy to attend the meeting and often needs to re-schedule. Sometimes this is not possible and Joe has to take the meeting alone. When Kevin and Joe have some specific detailed advice they usually use the **message centre** (chat) rather than the **video recording** as this provides clear written details which can be more easily reviewed than rewinding the video a number of times.

The students have been collaborating on a paper for **publishing** through the interface. Each has been allocated a section to write with a deadline in the scheduler. As each section is completed it is uploaded into the **file repository** where each collaborator has access to it. Alice and Bob usually upload their files first and they review each others work early in the process. Chris is often late with his submissions and regularly needs to be prompted via the automated scheduler. Supervisors can also intervene directly if he is holding up the work. Dave is hampered by dyslexia and he prefers to have all of his contributions by video rather than message board. Alice has agreed to provide learner support assistance in the area of English and writing skills. They have set up their own **community** to facilitate this. In addition Dave's uploaded files are especially checked by Alice or a third party. Because of the openness of the file repository each student can **peer-review** each other's work using review annotation to enable multiple revisions until everyone agrees with the final documentation. **Templates** are available through the interface for the appropriate journal.

Edwina, the mature student has never met the other's but she plays a full role through online communication. Edwina does not feel that she has missed out in any of the collaborative work by being separated through living some distance away. The CRESS environment has prevented her from feeling isolated.

Joe and Kevin meet once a week in the private supervisor area to discuss Students progress or lack of it, and to set schedules leading to the **publication of papers**. This ensures that weaker students are receiving the attention they need.

Prior to the deadlines for the 9months report and mini thesis for the upgrade the Supervisor's have been reading and **annotating students work online**. This provides immediate feedback allowing the student to re-write/re-construct their work for re-submission for further feedback. This iterative supervision process leads more rapidly to the final production of the 9months report/ mini thesis for the scrutiny of the internal examiner.

The completed version can be adapted as a conference paper at the supervisor's discretion. The first draft of the proposed conference paper is then uploaded for **supervisor review**. Supervisors can then provide further **feedback online** and a final draft is re-submitted to Joe and Kevin for publication through the interface.

Tools used in scenario 2:

- Recordings
- Videos
- Video Conferencing
- Chat
- Whiteboard
- Task Scheduler
- Archive Recording
- Calendar
- Notice Board
- Message Centre

- Video Recording
- Publishing
- File Repository
- Peer Review
- Templates
- Publication Of Papers
- Annotating Students Work Online
- Supervisor Review
- Feedback Online

6.5.3 CSCR Administration Scenario 3

Albert is the CSCR environment administrator. His first and primary task is to ensure the security of the system. He issues and administers **logins** and maintains the **authorisation** and **access tools**. Albert regularly monitors the system for unauthorised entry; he does this via standard security procedures including real time monitoring as well as post application analysis using the **logging system.** Albert also is engaged in providing **incremental back-ups** for all generated data. This includes the **video and instant messaging recordings.**

He is also the first point of call if anything goes awry with the system and for points of query as to how the system is used. Based upon the queries he receives Albert constructs **FAQs** and as required incorporates these into new help pages which he writes for the **Help Pane.** When he has time he also updates the **information link map** which is an online graphical index of all the CSCR environment features.

Tools used in scenario 3:

- Logins
- Authorisation
- Access Tools
- Logging System
- Incremental Back-Ups
- Video

- Instant Messaging Recordings
- FAQs (Help page)
- Help Pane
- Information Link Map

A storyboard of the first draft of the CRESS interface can be found in Appendix A.

6.6 Questionnaires and Pilot Survey Evaluation

User feedback was an essential component in arriving at the most useful set of tools for the CRESS interface. This feedback was obtained through a questionnaire process where potential users of the software were identified and their views determined and analysed. This **will need** to be fed back into the design process to produce a modified storyboard. The iterative process **will need** to go through a number of stages before a final design is adopted.

In determining the population and sample appropriate to this investigation, research students and their supervisors were designated as the prime participants. The selection of the pilot questionnaire respondents was determined by the need to choose actual researchers engaged in active collaborative research. These were chosen from the Learning Societies Laboratory (LSL) within the School of ECS at the University of Southampton. LSL is a successful and thriving research community that has been in existence for five years in a large research area of ECS. The questionnaires were distributed to 16 active PhD research students and 3 research supervisors.

Dumas and Reditch 1999 have established that five to twelve testers are a sufficient sample for on-line usability testing. However, the more testers there are the more representative the findings will be across the user population. (Preece Rogers & Sharpe 2002, p. 441)

The guidelines of Cohen, Manion and Morrison (2006, pp. 245-266) are followed for the design of the CRESS interface questionnaire. These cover a number of steps from ethical issues to processing the data. These issues were worked through in sequence as appropriate though a degree of recursion may be necessary. The following list summarises these guidelines.

1. **Ethical Considerations**
2. **Question Planning**
3. **Choice of structured semi- structured and unstructured questions**
4. **The use of dichotomous and multiple choice questions**
5. **Decision as to which Likert rating scale to use**
6. **Questionnaire layout**
7. **Creation of the covering letter**
8. **Piloting issues**
9. **Processing of questionnaire data**

Ethical issues were considered and the anonymity, confidentiality and non traceability of the respondents were guaranteed. The research was not harmful to the participants. The research potential could improve the respondents' situation and the respondents had the right to withdraw at any stage or not to complete the questionnaire. The questionnaire was designed so that it did not contain items which were offensive, intrusive, misleading, biased, misguided, irritating, inconsiderate, impertinent or abstruse.

The main purpose of the questionnaire was to find out how well the participants' own collaborative interface rates against the CRESS categorisation of tools determined by foregoing analysis. A subsidiary purpose was to find out which tools were not available in the collaborative interface under analysis and whether users felt that such tools should be made available. A flowchart was not deemed necessary for this type of questionnaire.

In designing the questionnaire it was important to relate the questions to the categories being examined. By opting for a multiple choice questionnaire it was possible to provide a statistical analysis of student requirements and therefore this method was adopted. For this reason every question had a choice of five possible answers which allowed the user to rate the features on a Likert scale from 1 “not useful” to 5 “very useful” (Oppenheim 1992). One additional bivalent question was included asking participants to say whether a particular tool was desirable or not. This questionnaire therefore expected to obtain both nominal (numbered data e.g.1-5) and ordinal (sequenced preference) data (Cohen and Manion pp251). A copy of the questionnaire and its covering letter is found in Appendix B.

The questionnaire was constructed to tightly define the possible answers. Only closed questions were used in order to generate frequencies of response suitable for statistical analysis. The questions fall into two types: dichotomous (yes or no) and rating (1-5) scales. No open or contingency questions were used. **The total number of respondents was 19. This means that the lowest possible score on the Likert scale was 19 and the highest possible score was 95. The average value from this sample is 57 (see Appendix C for survey data).**

The eighteen most popular tools scored 3 or more on the Likert scale giving a score of 57 or more in total. These were found to be as follows:

Popularity	**Facility**	**Score**	**Percent**
1	Login	82	86.3%
2	Access Authorisation	77	81.1%
3	Forum	74	77.9%
4	Public Information Space	70	73.7%
5	Output Window	68	71.6%
6	Collaborative Working Window	67	70.5%
6	Presence Indicator	67	70.5%
8	File Depository	66	69.5%

9	News Board	64	67.4%
9	Task Setting	64	67.4%
11	Friend File Sharing	63	66.3%
11	Task Monitoring	63	66.3%
13	Community Creation	62	65.3%
13	Contribution Database	62	65.3%
13	Participant Data	62	65.3%
16	Help Pane	61	64.2%
16	Instant Messaging	61	64.2%
16	Peer Review Assistance	61	64.2%

Table 26: Eighteen Most popular tools

The first two of these facilities **login** and **Access/Authorisation** were recognised as essential for the administration of the interface and security by 86% and 81% of the respondents respectively.

After security, **forums** are considered the most essential collaborative facility by 78% of the respondents. This too is no surprise as forums or bulletin boards are universally used as the primary method of asynchronous communication within VLEs (Moodle, Blackboard, WebCT etc). A particular form of this is the **News Board** (67**%)** which is the same as the forum except that it is limited to supervisor and administrator access.

More surprising is the high score at 74% afforded to **public Information space** as this may not previously have been considered an essential facility in a collaborative environment where all participants form a closed group who know each other. This may be considered as a two way facility were carefully selected information can be made public and brought before a wider audience. On the other hand it also affords the opportunity for feedback to be obtained from the public domain which might find its way into the research data.

The next two items were the **output window** with 72**%** and the **collaborative working window** 71**%**. These two are both concerned with the display of work in progress. It may be possible to combine both of these features into a single module. It may also be possible to combine this with a **whiteboard** application as this affords similar utility.

The **presence indicator** (71%) is a central part of a synchronous communication system where more that two participants are engaged. It is surprising therefore that video and audio communications did not rate more highly in the pilot survey. Speculation on this would be unwise without further data. A primitive presence indicator which simply shows who is online and logged into the research environment would be straightforward to implement but it would have no real utility without **audio / video communication channels**. In addition the **participant data** (65**%)** utility can be incorporated.

The value of a file depository was recognised as an important element. However this can be improved by incorporating instead a file **repository** (70%) which allows for both depositing and updating of work in progress. This work can be tracked in the contribution database which allows a clear allocation of the work done by each individual contributor. The **Friend file sharing** (66%) utility can be incorporated by simply adding the facility to tag individual files with the property of being able to be shared with named individuals. This can also be linked with **community creation** (65%)**.**

Task setting (67**%)** and **task monitoring** (66**%)** were rated very similarly as they work more effectively together and could be combined into one utility.

The **help pane** (64**%)** came fairly low down the list presumably because the type of respondents who answered the questionnaires were part of the school of Electronics and Computer Science and were expected to be experienced with computer interfaces. This may not be the case with other faculties who might therefore be expected to score the help pane more highly.

Instant messaging (64**%)** was among the lower scores; the reasons for this are not clear but it may be due to the fact that this kind of communication is intrusive to working online.

Peer Review assistance (64%) has also scored low. It appears therefore that most of the sample respondents might not be engaged in publishing and therefore might see limited value in the Peer Review process. **It would be unwise to speculate on this point without**

further data. This however does not diminish its value to the research community and the main survey will need to take this into account.

Conversely the 10 least popular tools having a rating below the average score of 57 are listed in Table 27

Least Popular	**Facility**	**Score**	**Percent**
1	Avatar	28	29.5%
2	Assistive Agent	32	33.7%
3	Scenario Control Flow tool	37	38.9%
4	Location Identifier	38	40.0%
5	Publishing Assistance	39	41.1%
6	3D Environment	41	43.2%
6	Tagging	41	43.2%
8	Simulation	42	44.2%
8	Reflective Journal	42	44.2%
10	Assessment Marking	43	45.3%
10	Supervisor Space	43	45.3%

Table 27: Ten least popular tools

The least popular tools were **Avatars and Assistive Agent**s with only 29.5% of respondents requiring this feature. These require a high degree of programming skills and artificial intelligence and it may be that the latter has not reached a sufficient level of sophistication in order to establish their usefulness to the respondents.

The **Scenario Control Flow** tools (39%) is a specialise learning device which enables users to examine a particular learning and research scenario in order to gain a better understanding of the mechanisms of interface use. As there was no explanation of this in the questionnaire it was likely that most respondents did not understand the nature of the tool but this has not been established.

The **Location Identifier** (40**%)** is associated with the position of participants in a **3D environment** (43%)**.** However, a number of respondents may have understood this to be the global location of the collaborators. The implication to draw from this is that more explanation is needed on the questionnaire.

Publishing Assistance was not rated highly at 41% and this may be due to the fact that most respondents were not engage in publishing research papers. **It is uncertain as to why this survey produced a low result and further speculation would not be helpful without additional information.**

One of the really surprising results in the light of the growth of Web2.0 is the low rating of 43% given to **tagging**. This is one of the primary tools of social networking and is a vital component of such sites as Flickr, Digg, Del.icio.us etc. The addition of tagging allows for the creation of metadata which might be considered valuable to search more effectively file repositories.

Simulation at 44% is a specialised rather than a general tool which represents the workings of a particular program or scenario. Therefore, most respondents may not have chosen this utility because it is not applicable to them. Without this specialist need it would not be included in the CRESS interface.

The Reflective Journal at 44**%** had a surprisingly low score as it is strongly advocated by educationalists in having an important role in the learning/research process. However, it is clear that learners/researchers of this survey do not share this view. It is felt that this is too important to the field of research to be ignored in the CRESS interface and will be included.

The last two utilities of **Assessment Marking and Supervisor Space** both at 45**%** exclusively concern only one type of user which was not represented adequately in this pilot study as only three supervisors took part.

In summary a range of facilities has been identified as being unimportant by the pilot survey. These include Avatars, Assistive Agents, Scenario Control Flow Tools, Location Identifiers and 3D environments. These will not be included in the first design of the CRESS interface. A 3D environment may be suitable for specialised uses in other faculties such as medicine. However the programming overhead and the increased complexification required to realise this utility would put it beyond the scope of a generic CRESS interface.

If it was felt necessary to include this 3D utility, a purpose build module could be created and substituted for the 2D working environment such as the whiteboard.

Other utilities which had a low rating including Publishing Assistance, Tagging, Reflective Journal, Assessment marking and Supervisor space will be included for the reasons given above. In many cases the pilot study did not contain enough responses from research supervisors to give a satisfactory sample.

General Lessons from the pilot questionnaire

In addition to the specific results obtained above, a number of other considerations have been brought to light which will be instrumental in redrafting the questionnaire for the survey.

One principle is that more description may be needed alongside each tool in order to explain its function. Without this, different respondents may assume different uses. Table 28 shows the set of utilities which will be included in the storyboard.

Administration	YES	NO	Product Space	YES	NO
Log in	✓		Output Window	✓	
Access/Authorization	✓		Simulation		✗
Recording Replay Facility	✓		Reflection Space		
Instant messaging recording	✓		Reflective Journal/Blog (private)	✓	
Assistive agent		✗	Social Interaction Space		
Help pane	✓		Community Creation	✓	
Information link map	✓		Tagging	✓	
Scenario Control Flow tools		✗	Friend file sharing	✓	
Communication			Blogs(Public)	✓	
Chat	✓		RSS Feeds	✓	
Audio/Voice	✓		Assessment/Supervisor		
Still Picture of Participant	✓		Assessment, Marking	✓	
Video	✓		Feedback	✓	

Administration	YES	NO	Product Space	YES	NO
Instant Messaging	✓		Private Supervisor (Space)	✓	
Forum	✓		Knowledge Space		
News board	✓		Contribution Database	✓	
Identification			Academic Database	✓	
Presence indicator	✓		File Depository	✓	
Focus indicator	✓		Power Point Slides	✓	
Location identifier		×	Private Space		
Participant data	✓		Private Space	✓	
Avatar		×	Public Space		
Scheduling tools			Public Information Space	✓	
Calendar	✓		Negotiation Space		
Task Setting	✓		Peer Review Assistance	✓	
Task Monitoring	✓		Publication Space		
Shared working Space			Schemas and Templates	✓	
Whiteboard	✓		Publishing Assistance	✓	
Collaborative Working Window	✓				
3D Environment		×			

Table 28: Summary of utilities selected by the Pilot Study

The results of the pilot study analysis will assist the re-design of the questionnaire and the storyboard for the CRESS interface. This can be constructed either using a monolithic portal framework or as a set of discreet Web2.0 services. The advantages of the former include consistency of the environment which would appeal to users familiar with web page structures displayed in browsers. Alternatively the web services approach would provide flexibility and individuality of use enabling collaborators to employ their tools of choice in a range of options available.

It will be worthwhile examining both approaches in order to see which is the most useful in deployment. Stage one **should** involve the construction of a monolithic interface by examining a range of portal frameworks to determine which is the most appropriate for adoption. The second stage **should** consider the deployment of the web2.0 services approach. An analysis and comparison of the two different approaches **should** then be undertaken.

6.7 Analysis of Portal Frameworks

Following on from the three Scenarios and the Pilot Questionnaire results a suitable toolset for the proposed CRESS interface has been derived. Each of the three scenarios produced a specific range of needed tools, and these have been combined together into a single toolset which has been moderated and refined by the use of the questionnaire results. These results enabled the prioritisation of the tools by a user group of 16 research students and 3 research supervisors. The next stage involved the identification of the most appropriate vehicle for the deployment of the derived toolset for CRESS. This has led to the examination of an envisaged portal structure analysis to realise the appropriate container for the CRESS interface. Two avenues are available at this point. The first of these envisages the container as a monolithic structure such as a portal framework where all the tools are contained within as functional elements. The second would be based on the Web 2.0 paradigm where each of the functional tools are discreet elements on the desktop and are in the most part constructed from pre-existing social networking tools. The analysis that has taken place so far is able to be translated into either of these two conceptual models.

There are a wide number of portal frameworks available for the development of the CRESS interface. A brief survey according to cmsmatrix.org shows that there are over 500 portal software developments suites. Not all of these are suitable however for a collaborative virtual research environment as they do not contain the necessary tools which have already been indicated as necessary for the determination of such a domain. A short list of 10 portal frameworks which come closest to having the tools for research have been selected from various sources (including supervisor recommendations and popular usage) and analysed according to the information available by the criteria which has been laid out for the envisaged CRESS interface previously as shown in table 1.

CATEGORY SPACES	TOOLS	Moodle	Ugforge	Liferay	Jboss	Gridsphere	Elgg	J Porta	DotNetNuke	Oracle	Light Portal	Sakai with Agora	CRESS Required	CRESS Not Required
	Count	24	11	8	6	13	20	6	13	15	13	39	37	
Administration Space (including security tools)	Login	x	x	x	x	x	x	x	x	x		x	x	
	Access/authorisation Tools	x										x	x	
	Recording /Replay Facility											x	x	
	Instant Messaging Recording	x												
	Assistive Agent													x
	Help Pane	x		x	x		x	x				x	x	
	Information Link Map													x
	Scenario/Control flow Tools													x
Communication space (including Identification space)	Text/ Chat	x				x					x	x	x	
	Audio/Voice											x	x	
	Still Picture	x		x			x				x	x	x	
	Video									x	x	x	x	
	Instant Messaging	x								x		x		
	Forum	x	x			x	x		x	x	x	x	x	
	Message Board/News	x	x				x	x	x		x	x	x	
	Avatar (Representations)													x
	Presence Indicator/Information											x	x	
	Location Identifier													x
	Focus Indication											x	x	
	Participant Data	x		x		x	x		x			x	x	
Scheduling space	Scheduling Tool (calendar)	x	x	x				x	x	x		x	x	
	Task Setting	x	x				x			x	x	x	x	
	Task Monitoring	x	x				x			x	x	x	x	
Shared working space	Whiteboard											x	x	
	Collaborative Working Window /wiki	x	x	x			x		x	x		x	x	
	3D Environment													x
Product Space	Output Window												x	
	Simulations													x
Reflection Space	Reflective Journal/Private	x											x	
Social Interaction Space	Community Creation				x	x	x					x	x	
	Tags (marking Content)	x		x			x						x	
	Friend (file sharing)												x	
	Blog (Public + Private)	x				x	x		x			x	x	
	RSS feed to centralized data	x				x	x	x	x		x	x	x	
Assessment / Feedback Space	Assessment	x										x	x	
	Feedback	x							x		x	x	x	
Supervisor Space	Private area for tutors	x										x	x	
Knowledge Space	Contribution Database									x			x	
	Academic database									x			x	
	Repository (shared files)		x		x		x			x	x	x	x	
	PowerPoint Slides	x										x	x	
Privacy Space	Private Space	x										x	x	
Public Space	Public information space											x	x	
Negotiation	Peer Review assistance												x	
Publication Space	Schemas/Templates (doc archive)	x	x				x					x	x	
	Publishing assistance									x			x	
OTHER	Layout customization				x	x	x	x		x		x		
	email				x	x						x		
	Search								x					
	Banner								x					
	Still image slides (Gallery)					x	x		x					
	Lists/Links					x	x		x	x	x			
	Mobile Device Support (including Pod)			x			x							
	Themes			x			x							
	User surveys		x							x				
	Feature request tracking		x											
	Bug tracking		x											
	External Websites									x	x	x		
	Manage Groups											x		
	Tests and Quiz											x		
	Web content											x		
	Worksite set-up											x		
	Syllabus											x		
	Movie casting											x		

Table 29: Analysis of Portal Frameworks

Table 29 shows the analysis portal frameworks against CSCR category tools. Moodle has been included although it is not strictly a portal framework but a VLE, it can tailored to a degree where it can be used effectively as one. It can be seen that the most closely matching portal framework is Sakai with 39 matching points.

A summary of all the matching points is shown in the portal frequency analysis see Table 30

Portal Framework	Matching Points
Sakai	39
Moodle	24
Elgg	20
Oracle Portal	15
Light Portal	13
DotNetNuke	13
Gridsphere	13
Ugforge	11
Liferay	8
Jboss	6
J Porta	6

Table 30: Portal Frequency Analysis

It is clear that the Sakai/Agora Framework has almost twice as many matching points as the next nearest Portal framework analysed.

6.7.1 *Gap Analysis: Sakai/Agora*

Although the Sakai Framework has the highest score of 39 points it is nevertheless important to perform a Gap analysis to find out exactly which tools required for CRESS are already available and which would need to be customised. The results of this can be

CSCR Categories	ALREADY AVAILABLE in Sakai/Agora	Corresponding Tool in Sakai / Agora	NOT AVAILABLE In Sakai/Agora	Required by CRESS
Administration Space (including	Login	Sakai: Permissions and Roles		x
	Access/authorisation Tools	Sakai: Permissions and Roles		x
	Recording /Replay Facility	Agora: Session recording		x
	Help Pane	Sakai: Help tool		x
Communication tools (including Identification tools)	Text/ Chat	Sakai: Chat room; Agora: Chat		x
	Audio/Voice	Agora: Video conferencing		x
	Still Picture	Sakai: Profile		x
	Video	Agora: Video conferencing		x
	Forum	Sakai: Discussion tool		x
	Message Board/News	Sakai: Announcement tool		x
	Presence Indicator/Information	Agora: Video conferencing		x
	Focus Indication	Agora: Video conferencing		x
	Participant Data	Sakai: Profile		x
Scheduling	Scheduling Tool (calendar)	Sakai: Schedule tool		x
	Task Setting	Sakai: My Workspace		x
	Task Monitoring	Sakai: My Workspace		x
Shared	Whiteboard	Agora: Shared Desktop		x
	Collaborative Working Window (wiki)	Sakai: Wiki tool		x
Product	Output Window	Agora: Shared Desktop		x
Reflection	Reflective Journal/Private	Sakai: My Workspace		x
Social Interaction	Community Creation	Sakai Membership tool		x
			Tags (marking Content)	x
	Friend (file sharing)	Sakai: Resources tool		x
	Blog (Public + Private)	Sakai: Wiki tool		x
	RSS feed to centralized data	Sakai: News tool		x
Assessment / Feedback	Assessment	Sakai: Post'em		x
	Feedback	Sakai: Post'em		x
Supervisor	Private area for tutors	Sakai: Discussion tool		x
Knowledge			Contribution Database	x
	Academic database (Google scholar etc.)tool)	Sakai: Web content		x
	Repository (shared files)	Sakai: Drop Box tool		x
	PowerPoint Slides	Sakai: Drop Box tool		x
Privacy	Private Space	Sakai: My workspace		x
Public	Public information space	Sakai: Site Info tool		x
Negotiation			Peer Review assistance	x
Publication	Schemas/Templates (doc archive)	Sakai: Resources tool		x
Additional Features available in Sakai	Layout customization email Search Banner Still image slides (Gallery) Lists/Links Mobile Device Support (including Pod) casting Themes User surveys Feature request tracking Bug tracking External Websites Manage Groups Tests and Quiz Web content Worksite set-up Syllabus Movie casting			

Table 31: Sakai/Agora Tool Gap Analysis with CRESS requirements

seen in Table 31 .

This analysis reveals that all tools are already available in the Sakai/Agora Portal Framework except for:

- Tags (marking Content)
- Contribution Database
- Peer Review assistance
- Publishing assistance

These tools have been shown to be essential to the functionality of the CRESS environment and if they cannot be found as ready made portlets they will need to be constructed from scratch for the purpose of completing the full research environment.

6.7.2 Portal Analysis Summary

The purpose of this section has been to find as closely a matching set of CSCR tools within an existing portal framework as possible. An analysis of 10 portal frameworks has resulted in establishing Sakai/Agora as the most applicable framework with only four tools missing from the package.

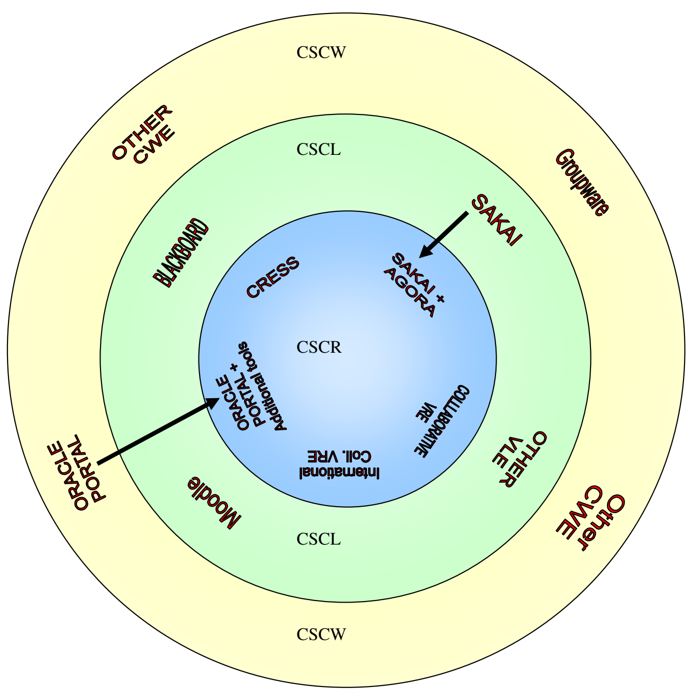


Figure 11 Domain Diagram

The Analyses in chapter 6 of the mini thesis have produced and established a set of tools which are suitable for the CRESS interface. Figure 10 shows the relationship of the CSCW, CSCL and CSCR domains and the positioning of the various collaborative learning and research environments within those domains. It can be seen that some environments (e.g. Oracle portal) which have been designed for the CSCW domain can be useful within the more restrictive CSCR domain provided that additional tools are developed. In particular attention is drawn to the Sakai Portal Framework which is suitable for use within the CSCL domain but with the addition of the Agora toolset and other portlets can be made suitable for CRESS within the CSCR domain.

6.8 Summary

This chapter began with the basic research question, which concerned

> ***"What are the significant issues in designing a CSCR system to support research students and their supervisors to work on collaborative research?"***

The CSCR domain has been defined in such a way as to enable analysis, design and construction of many specific and individual interfaces or a range of collaborative research faculties. The analysis of the requirements for the specific CRESS interface has been considered in detail namely a collaborative research environment for the support of students and supervisors.

The methodology of Lindgaard *et al* (2005), was followed except that his first-stage, brainstorming session was replaced with a detailed analysis of pre existing environments to identify user interface elements. This has involved the analysis of 13 e-laboratories and three VLEs to determine a range of tools, which have been broken down into a set of 14 logical categories. A specific toolset for CRESS has been arrived at, which will initially be incorporated into a storyboard for user analysis.

Future work may involve the building of a CRESS environment which will be based upon full usability analysis. Stage two could involve prototyping, initially in storyboard form, which should be submitted to potential users for initial usability feedback. A prototype could be produced from this and handed over to developers for the construction of the user interface package. This would lead onto usability testing to determine the adequacy of the user interface concepts. Once the basic framework has been established specific plug-in modules may be incorporated for specific needs by specific faculties. Lindgaard *et al.'s* original methodology called for three iterations of design, prototyping and usability testing. However they were not able to maintain this in practice. It is envisaged that at least two or three iterations would be required to provide a stable and usable CRESS environment.

Chapter 7 Conclusion and future work

7.1 Conclusion

This thesis started with a research question that asked what were the significant issues in designing a CSCR system to support research students and their supervisors to work on collaborative research.

In order to deal with that question a route was taken which led to an examination of HCI and its sub-disciplines of CSCL and CSCW. This examination showed that there was a lack of a coherent approach within HCI, with different authors presenting different principles which led to the realisation that the discipline was fragmentary and disjointed and lacked a coherent, universally accepted approach.

In order to develop a coherent approach for designing a CSCR system an HCI author frequency analysis was undertaken to draw out the most commonly accepted HCI principles that would form the fundamental underpinning of the CSCR structure.

From there the HCI principles were supported with pedagogical insights from CSCL which have been based upon the theories of Piaget, Vygotsky and Bruner.

The next stage was the consideration of the research environment itself and the impact that this had upon the design of a computer supported collaborative research system. At this point it was felt that a strong position had been reached for presenting a definition for the structure of a CSCR domain. This was defined in such a way as to encompass the complete range of all possible collaborative research environments including commercial/industrial as well as academic collaborative research environments. In addition new definitions of CSCW and CSCL were proposed which incorporated them into a single framework that brought them together within the new field of CSCR.

From this point it was felt that a check was needed on the correctness of approach. A questionnaire was produced which sought feedback from a range of research students and supervisors. In addition to this, scenarios were constructed to check all the way through that the design of the specific environment CRESS proceeded on the right lines. From this the initial design specifications for CRESS was produced. The next stage involved the identification of the most appropriate vehicle for CRESS which was found by examining a range of portal structures and identifying a particular portal framework by undertaking a gap analysis. This now brings the work of this thesis to an appropriate conclusion.

The work is now ready to be taken forward and implemented through a software development process either as a monolithic interface or as a Web2.0 framework so that its functionality can be tested. The final stage would involve the creation of a fully functioning CRESS interface which would need to undergo full usability testing and checking to see if it had achieved the goal that was set out in the research question.

As has been pointed out in a recent edition of Scientific American (May 2008, p. 48), many researchers are wary of the openness that Web 2.0 tools promote. This kind of research that uses the Web 2.0 framework might be called **Research 2.0**, and for some this might be considered a dangerous step. "Putting your serious work out on blogs and social networks feels like an open invitation to have your lab notebooks vandalised- or worse your best ideas stolen by a rival" (Waldrop 2008). However, with appropriate safeguards Research 2.0 can be considerably more productive than conventional methods.

The progress of this thesis is summarised in the form of Work Packages (WP1-WP14). Their inter-relationships are shown in Figure 12.

Work Package diagram

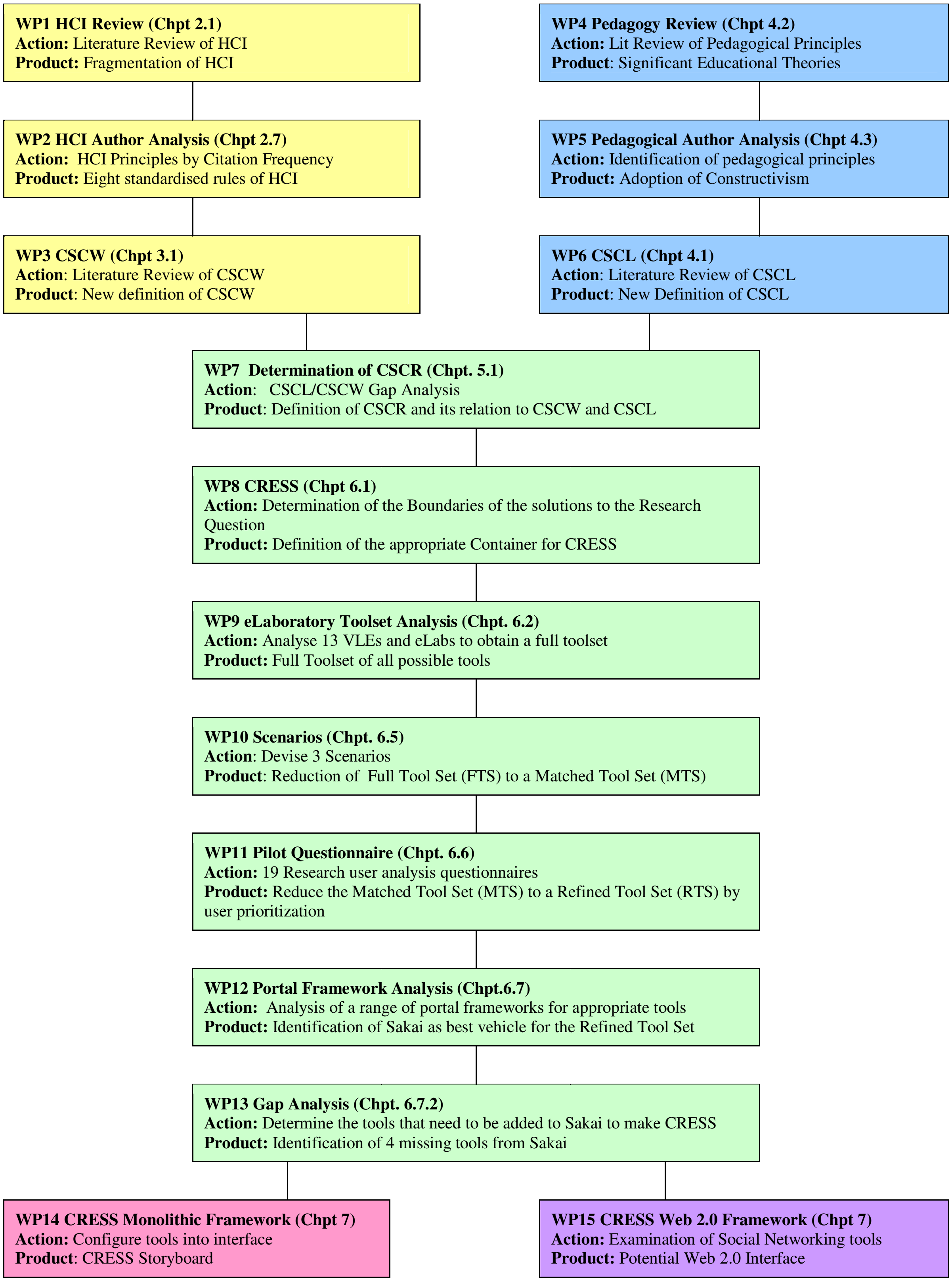


Figure 12:Work Package Diagram

7.2 The Research Question

> ***"What are the significant issues in designing a CSCR system to support research students and their supervisors to work on collaborative research?"***

This project has answered the research question with the hypothesis that the CRESS environment facilitates effective communication between students and supervisors during the research process in an online CSCR environment.

It has been demonstrated that effective communication is supported by CRESS which contains a range of utilities that encompass a set of 14 separate spaces comprising the CSCR domain. The nature of these utilities was determined through an examination of a number of e-laboratories and VLEs and their toolsets categorised and assessed for their appropriateness for CRESS. A specific toolset was arrived at, which could initially be incorporated into a storyboard for user analysis. This comprised 42 separate communication tools, which have been assessed for their suitability for the specific case of facilitating student/supervisor research. It was found that these tools are an appropriate basis for further CSCR environment analysis.

7.3 Future Work

The advent of Research 2.0 technologies has already gone some way to facilitating collaborative relationships via the internet. Many of the social networking tools already in existence and found on such sites as Facebook, MySpace, DIGG, Stumbleupon etc. provide mechanisms which can be utilised for the purposes of a CRESS environment. It is envisaged that as Research 2.0 becomes more pervasive and endemic throughout the internet this will come to be seen as the primary vehicle of computer supported collaborative research.

Future work would involve the building of a CRESS environment, which would be based upon full usability analysis. Prior to any further development a clear decision would need to be made as to which model, a monolithic framework or a Research 2.0 approach would be adopted. In the case of a monolithic framework this would involve prototyping, initially in storyboard form, which would be submitted to a large sample of potential users for initial usability feedback. A prototype would have to be produced from this and handed over to developers for the construction of the user interface package. This would lead onto usability testing to determine the adequacy of the user interface concepts. Once the basic framework has been established specific plug in modules may be incorporated for specific needs by specific groups. Lindgaard *et al.'s* original methodology called for three iterations of design, prototype and usability tests. However, they were not able to maintain this in practice. It is envisaged that at least two or three iterations would be required to provide a stable and usable monolithic CRESS environment.

Should a Research 2.0 approach be adopted then functionality will be the key issue around which various users will adopt their own social networking tools in order to match the functionality required. Difficulties may need to be confronted over establishing a coherent usability testing framework for diverse Web 2.0 tools and interfaces.

7.4 Concluding Remarks

The most significant finding here has been the clarification of the relationship between CSCW, CSCL and CSCR. Prior to this study there has been no clear differentiation between these domains. It has been found that CSCW is that subset of HCI, which is exclusively concerned with collaborative working. Furthermore, it has been found that CSCL is that subset of CSCW whose boundary is constrained by educational theory to encompass only that kind of collaborative work, which falls into the category of collaborative learning. Finally it is been found that CSCR is that subset of CSCL, which is exclusively concerned with the collaborative discovery of new knowledge. See figure 1.

The second most significant finding has been the defining of the CSCR domain. This is introduced as a concept for the first time here in this research, and represents a new field of study. CSCR is defined by 14 collaborative research spaces that define the domain as shown in table 9. This domain is a universal concept in that it contains all possible collaborative research environments be it medical, mathematical, physical etc. with their own selection of collaborative tools.

It is acknowledged that challenging tasks lie ahead. The many issues raised in this thesis still await concrete solutions but it is believed that this study has shown the road to meeting that challenge.

References

INDEX OF RESEARCHED REFERENCES

Abowd, G. D., and Beale, R., (1991) Users Systems and Interfaces: A unifying framework for interaction. In D. Diaper and N. Hammond, Editors, *HCI'91: People and Computers VI,* pages 73-87. Cambridge University Press, Cambridge 1991 in Dix, A., Finlay, J. *et al*, (1992), Human Computer Interaction, 2nd ed., Prentice Hall, ISBN 0-13-239864-8.

Argles, D. and Wills, G. (2005) CECIL – A Language for Learning Hardware Design. In *Proceedings of EdMedia--World Conference on Educational Multimedia, Hypermedia & Telecomunications*, pp.4181-4188, Montreal, Canada. Kommers, P. and Richards, G., Eds.

Argles, D.A., Gee, Q., and Wills, G.B. (2005) Developing a Computing Degree to Encourage Widening Participation. *In Proceedings of the 6th Annual Higher Education Academy Subject Network for Information Computer Science* (York, UK, 2005) http://eprints.ecs.soton.ac.uk/10926/

Argles, D.A., Pau, R., and Wills, G.B. (2006) Towards Collaborative e-Learning: Teaching Hardware Architecture, *Submitted to 15th International World Wide Web Conference, Edinburgh, Scotland.* http://eprints.ecs.soton.ac.uk/11599/01/CecilColabLab.pdf

Bachler, M., Shum, S.B., Chen-Burger, J., Dalton, J., De Roure, D., Eisenstadt, M., Komzak, J., Michaelides, D., Page, K., Potter, S., Shabolt, N., Tate, A., (2004) Collaborative Tools in the Semantic Grid, KMI, The Open University, UK, AIAI, University of Edinburgh, UK, ECS, University of Southampton, UK http://eprints.ecs.soton.ac.uk/9439/01/ggf11semgrid-coakting.pdf

Baker, K., Greenberg, S., and Gutwin, C. 2002. Empirical development of a heuristic evaluation methodology for shared workspace groupware. In *Proceedings of the 2002 ACM Conference on Computer Supported Cooperative Work* (New Orleans, Louisiana, USA, November 16 - 20, 2002). CSCW '02. ACM Press, New York, NY, 96-105 http://portal.acm.org/citation.cfm?doid=587078.587093

Bannon, L. (1989) Issues in Computer-Supported Collaborative Learning, In: *C.O'Malley, editor. Computer SupportedCollaborative Learning, pp. 267-281,Springer-Verlag, Berlin* http://www.ul.ie/~idc/library/papersreports/LiamBannon/12/LBMarat.html

Bardeen, M., Gilbert, E., Jordan, T., Nepywoda, P., Quigg, E., Wilde, M., and Zhao, Y. (2005) The QuarkNet/Grid Collaborative Learning e-Lab, *Future Generation Computer Systems* Volume 22, Issue 6, May 2006, Pages 700-708 http://lanl.arxiv.org/ftp/cs/papers/0502/0502089.pdf

Barley, S., Dutton, W.H., Kiesler, S., Resnick, P., Kraut, R. E., and Yates, J., (2004) Does CSCW Need Organization Theory? *Proceedings of the 2004 ACM conference on Computer supported cooperative work. Chicago, Illinois, USA* p 122 – 124, 2004 ISBN:1-58113-810-5

Bartholome´, T., Stahl, E., Pieschl, S., and Bromme, R., (2006), What matters in help-seeking? A study of help effectiveness and learner-related factors *Computers in Human Behaviour* 22 (2006) 113–129 www.elsevier.com/locate/comphumbeh

Berger, A., Moretti, R., Chastonay, P., Dillenbourg, P., Bchir, A., Baddoura, R., Bengondo, C., Scherly, D., Ndumbe, P., Farah, P. & Kayser, B. (2001) Teaching community health by exploiting international socio-cultural and economical differences. In P.Dillenbourg, A. Eurelings & K. Hakkarainen. *Proceedings of the first European Conference on Computer Supported Collaborative Learning* (pp. 97-105), Maastricht, March 2001. http://newmedia.colorado.edu/cscl/euro14.pdf

Bouras, Ch. And Tsiatsos Th. (2002) Extending the Limits of CVE's to Support Collaborative e-Learning Scenarios http://ru6.cti.gr/ru6/publications/9786892.pdf

Bouras, C. *et al*, (2002) An Educational Community Using Collaborative Virtual Environments http://scholar.google.com/scholar?hl=en&lr=&q=cache:BH0G17T5b-0J:ru6.cti.gr/Publications/661.pdf+Collaborative+e-learning

Bourguin, G. & Derycke, A. (2001), Integrating the CSCL activities into virtual campuses: foundations of a new infrastructure for distributed collective activities, *Proc. of the European Conference on Computer Supported Collaborative Learning, Euro-CSCL 2001, Maastricht, The Netherlands, 2001, 123-130.* http://newmedia.colorado.edu/cscl/euro18.pdf

Boyle, P.A., Jung, C., and Wettig, T., (2003) The QCDOC supercomputer: hardware, software and performance, *ECONF C0303241 (2003) THIT003, [hep-lat/0306023].* http://lanl.arxiv.org/PS_cache/hep-Lat/pdf/0306/036023.pdf

Britain, S. (1998), A Framework for Pedagogical Evaluation of Virtual Learning Environments, London: *Joint Information Systems Committee.* http://www.jisc.ac.uk/index.cfm?name=project_pedagogical_VLE

Brocks, H.; Thiel, U., and Stein, A., (2003). Agent-Based User Interface Customization in a System-Mediated Collaboration Environment. In: Harris, D. et al. (Eds.): *Human-Centred Computing. Mahwah, New Jersey, London: Lawrence Erlbaum,* 2003, pp. 664-669 http://www.collate.de/publications/papers/fulltexts/brocksthielstein03-HCII.pdf

Bruner, J. (1960) The Process of Education, Harvard University Press, 2002

Bruner, J. (1966). Toward a Theory of Instruction. Cambridge, MA: Harvard University Press.

Bruner, J. (1973). Going Beyond the Information Given. New York: Norton.

Bruner, J. (1983). Child's Talk: Learning to Use Language. New York: Norton.

Bruner, J. (1986). Actual Minds, Possible Worlds. Cambridge, MA: Harvard University Press.

Bruner, J. (1990). Acts of Meaning. Cambridge, MA: Harvard University Press.

Bruner, J. (1996). The Culture of Education, Cambridge, MA: Harvard University Press.

Carroll, J.M. (1990) The Nurnberg Funnel: Designing Minimalist instruction for practical computer skill. Cambridge, M.A.: MIT Press, ISBN:0-262-0316390

Carroll, J.M. Rosson, M.B., Convertino, G. and Ganoe, C.H. (2006) Awareness and teamwork in computer-supported collaborations, *Interacting with computers* 18 (2006) pp21-46 www.sciencedirect.com

Cohen, L., Manion, L. and Morrison, K. (2006) Research Methods in Education 5th Edition, Routledge Falmer

Dalziel, J., (2003) Implementing Learning Design, *Proceedings of the 20th Annual Conference of the Australasian Society for Computers in Learning in Tertiary Education (ASCILITE)* http://www.ascilite.org.au/conferences/adelaide03/docs/pdf/593.pdf

Daniels, H., (2001) Vygotsky and Pedagogy, Routledge Falmer

The Dearing Report, (1997) 1st report, session 1997-98: report of the National Committee of Inquiry into Higher Education ("The Dearing Report") report with evidence, House of Lords papers 23 1997-98 Great Britain Parliament House of Lords Select Committee on Science and Technology Author: Phillips of Ellesmere, David Chilton Phillips Baron, Chairman.

De´tienne, Francoise (2006) Collaborative design: Managing task interdependencies and multiple perspectives, *Interacting with Computers* 18 (2006) 1–20 available from http://www.sciencedirect.com

Diaper, Dan and Sanger, Colston, (2006) Tasks for and tasks in human–computer interaction, *Interacting with Computers* 18 (2006) 117–138 www.elsevier.com/locate/intcom

Dillenbourg P. (1999) What do you mean by collaborative learning?. In P. Dillenbourg (Ed) *Collaborative-learning: Cognitive and Computational Approaches*. (pp.1-19). Oxford: Elsevier http://tecfa.unige.ch/tecfa/publicat/dil-papers/Dil.7.1.14.pdf#search=%22Dillenbourg%20%22What%20do%20you%20mean%20by%20collaborative%20learning%22%22

Dillenbourg, P. (2006) The solo/duo gap, *Computers in Human Behaviour* 22 (2006) 155–159 www.elsevier.com/locate/comphumbeh

Dix, A., Finlay, J., Abowd, G. D., and Beale, R., (1992), Human Computer Interaction, 2nd ed., Prentice Hall, ISBN 0-13-239864-8.

Dourish, P. (1998), Using Metalevel Techniques in a Flexible toolkit for CSCW Applications, *ACM Transactions on Computer-Human Interaction (TOCHI)* Volume 5 , Issue 2 Pages: 109 - 155 ISSN:1073-0516 http://delivery.acm.org/10.1145/290000/287676/p109-dourish.pdf?key1=287676&key2=0090878511&coll=portal&dl=ACM&CFID=452722&CFTOKEN=23284707

Engestrom Y, Miettinen R, Punamäki R-L, Pea R, Brown JS, and Heath C, Eds. (1999) Perspectives on activity theory (*Learning in Doing: Social, Cognitive & Computational Perspectives*).Cambridge: Cambridge University Press.

Ellis, A., Carswell, L., Bernat, A., Deveaux, D., Frison, P., Meisalo, V., Meyer, J., Nulden, U., Rugelj, J., and Tarhio, J. (1998). Resources, tools, and techniques for problem based learning in computing. *SIGCUE Outlook* 26, 4 (Oct. 1998), 41-56.

European ODL Liaison Committee Policy Paper approved by the Member Networks Released 17 November 2004, *Distance Learning and eLearning in European Policy and Practice: (2004)*, The Vision and the Reality, http://www.odl-liaison.org/pages.php?PN=policy-paper_2004

European ODL Liaison Committee, Policy Paper approved by the Member Networks and released 3 May 2006, *Learning Innovation for the Adapted Lisbon Agenda* http://www.odl-liaison.org/pages.php?PN=policy-paper_2006

Gagne, R.M. *et al* (1992), Principles of Instructional Design, 4th Edition, Wadsworth/Thompson Learning

Gill, Z (2002) Webtanks for knowledge management, *Computer-Supported Cooperative Learning* (CSCL) 2002. Boulder, Colorado. January 7-12, 2002. http://newmedia.colorado.edu/cscl/287.html

Grange, S. *et al* (2006) A Web/Grid Services Approach for Integration of Virtual Clinical and Research Environments, http://eprints.ecs.soton.ac.uk/12086/01/IHR2006.pdf

Graves, D. and Klawe, M. "Supporting Learners in a Remote Computer-Supported Collaborative Learning Environment: The Importance of Task and Communication," *Proceedings of Computer Support for Collaborative Learning (CSCL)*,Toronto, 1999. Vol. 34, No. 2, 2002 June, 125, SIGCSE *Bulletin Computer Support for Collaborative Learning (CSCL),* Toronto, 1999.

Haussler, M., Bromley LEA Promotes Innovation and Creativity Through Collaborative E-Learning Pilot!, http://www.google.co.uk/search?q=collaborative+e-learning&hl=en&lr=&start=30&sa=N

Handoko, L. T., (2005) SciBlog: A Tool for Scientific Collaboration, *Proceedings of the WKM 2004, preprint* http://arxiv.org/ftp/cs/papers/0508/0508061.pdf

Hannafin, Michael (2006) Disciplined inquiry and research in computer-supported learning *Computers in Human Behaviour* 22 (2006) 149–153, ISSN 0747-5632 CODEN CHBEEQ www.elsevier.com/locate/comphumbeh

Harper, L. D., Gertner, A. S., and Van Guilder, J. A. 2004. Perceptive assistive agents in team spaces. In *Proceedings of the 9th international Conference on intelligent User interfaces* (Funchal, Madeira, Portugal, January 13 - 16, 2004). IUI '04. ACM Press, New York, NY, 253-255. DOI= http://doi.acm.org/10.1145/964442.964496 http://www.citeseer.ist.psu.edu/cache/papers/cs/30314/

Hawryszkiewycz, I (1994) CSCW as a basis for interactive design semantics, *Proceedings of the workshop on Advanced visual interfaces*, Bari, Italy Pages: 213 – 215, 1994. ISBN:0-89791-733-2 http://portal.acm.org/citation.cfm?doid=6636972

HCI Bibliography : Human-Computer Interaction Resources: Citation Frequency Database - Most frequent Authors (on-line only resource) http://hcibib.org/authors.html

Hinze-Hoare, V. (2004) Four Principles Fundamental to Design Practice for Human Centred Systems, preprint lanl archive, http://lanl.arxiv.org/ftp/cs/papers/0409/0409041.pdf

Hinze-Hoare, V. (2006a) HCI and Educational Metrics as Tools for VLE Evaluation, lanl archive, http://lanl.arxiv.org/ftp/cs/papers/0604/0604102.pdf

Hinze-Hoare, V. (2006b) Further Evaluation of VLEs using HCI and Educational Metrics, lanl archive, http://lanl.arxiv.org/ftp/cs/papers/0604/0604103.pdf

Hinze-Hoare, V. (2006c) CSCR: Computer Supported Collaborative Research, http://arxiv.org/ftp/cs/papers/0611/0611042.pdf

Horn, D. B., Finholt, T. A., Birnholtz, J. P., Motwani, D., and Jayaraman, S. 2004. Six degrees of jonathan grudin: a social network analysis of the evolution and impact of CSCW research. In *Proceedings of the 2004 ACM Conference on Computer Supported Cooperative Work* (Chicago, Illinois, USA, November 06 - 10, 2004). CSCW '04. ACM Press, New York, NY, 582-591. DOI= http://doi.acm.org/10.1145/1031607.1031707

Hosoya, K., Kawanobe, A., Kakuta, S. and Sharma, M.(1997), Interactive Cooperative Learning System based on virtual shared space: HyCLASS.,*Proceedings of CSCL97,* Toronto. http://www.oise.utoronto.ca/cscl/papers/hosoya.pdf

Jennings, N., and Norman, T. J., Trilogy: An Agent Based Virtual Laboratory, *International Journal of Continuing Engineering Education and Life Long Learning* Issue: Volume 12, Numbers 1-4 / 2002 Pages: 201 - 213 http://www.ecs.soton.ac.uk/%7Enrj/trilogy.html

Joiner, R, Nethercott, J.H. and Richard R., (2006) Instructional design for effective and enjoyable computer-supported learning, *Computers in human behavior* 2006, vol. 22, no 1 (14 ref.), pp. 67-76 [10 page(s) (article)] ISSN 0747-5632 www.elsevier.com/locate/comphumbeh

Juby, B. and De Roure, D., (2002) “Real-Time Speaker Identification and Participant Tracking in The Access Grid", *In Proc. 4th Annual Postgraduate Symposium on the Convergence of Telecommunications, Networking and Broadcasting* (PG Net 2003), pp. 313-319, Liverpool, UK, 2003. http://www.ecs.soton.ac.uk/%7ddrj/realtime.html

Karam. M., and Schraefel, M. C., (2005) A Taxonomy of Gestures in Human Computer Interaction, *ACM Transactions on Computer-Human Interactions 2005*, Technical report, Electronics and Computer Science, University of Southampton, November 2005. http:/eprints.ecs.soton.ac.uk/11149/01/GestureTaxonomyJuly21.pdf

Kester, L., Lehnen, C., Van Gerven, P. W.M. , Kirschner, P.A., (2006) Just-in-time, schematic supportive information presentation during cognitive skill acquisition, *Computers in Human Behaviour* 22 (2006) 93–112, www.sciencedirect.com

Kirschner, P., Gerjets, P., , Instructional design for effective and enjoyable computer-supported learning, *Computers in Human Behaviour,* 22 p1-8 (2006) http://igitur-archive.library.uu.nl/fss/2006-1214-

211436/kirschner_06_instructionaldesignforeffectiveandenjoyablecomputersupportedlearning.pdf

Klawe, M. M., (1999) Computer Games, Education and Interfaces: The E-GEMS Project, *Proceedings of Graphics Interface '99. Kingston, ON.* http://www.graphicsinterface.org/cgi-bin/DownloadPaper?name=1999/203paper203.pdf

Kligyte, G. (2001). 'I Think I Know What Is Good For You?'. User Interface Design for a CSCL system. Master's Degree Work: *Master of Arts in New Media. Media Lab, University of Art and Design Helsinki UIAH, Finland.* [Online] http://www2.uiah.fi/~gkligyte/Fle3/final.pdf

Kozulin, A. Gindis, B. Agevey, S.V.,Miller, S.M. Eds. (2003), Vygotsky's Educational Theory in Cultural Context, Cambridge University Press

Krempel, L., (1993), Simple Representations of Complex Networks: Strategies for Visualizing Network Structure, 3rd European Conference for Network Analysis, Munchen, 1993 - pfp7.is.ocha.ac.jp,

Laister, J. and Koubek, A., (2001) 3rd Generation Learning Platforms: Requirements and Motivation for Collaborative Learning, *European Journal of Open and Distance Learning, 2001*. http://invite.fh-joanneum.at/download/icl_tj_paper_final.pdf

Lakkala, M., Rahikainen, M., and Hakkarainen, K. (Eds.). (2001). D2.1 Perspectives of CSCL in Europe: A review. Helsinki*: ITCOLE Project IST-2000-26249* http://www.euro-cscl.org/site/itcole/D2_1_review_of_cscl.pdf

Laurillard, D. (1993) Rethinking University teaching – A Framework for the effective use of educational technology, Routledge, London

Lave, J. and Wenger E., (1990), Situated Learning: Legitimate Peripheral Participation. Cambridge University Press. (Cambridge, 1990)

Lawless, N., Allan, J. (2004), Understanding and reducing stress in collaborative e-Learning, *Electronic Journal of e-Learning*, Vol. 2, Issue 1, 2004

http://www.ejel.org/volume-2/vol2-issue1/issue1-art15-lawless-allen.pdf

Lee, S., and Lee, Y.H.K. (1991) "Effects of Learner control versus Program Control Strategies on Computer aided learning of chemistry problems: for acquisition or review?" *Journal of Educational Psychology, 83, pp 491-49*

Leinonen, T., Virtanen, O., Hakkarainen, K., And Kligyte, G. 2002. Collaborative discovering of key ideas in knowledge building. *In Proceedings of the Computer Support for Collaborative Learning Conference* (Boulder, CO, Jan. 7-11, 2002). See also http://fle2.uiah.fi/ and http://fle3.uiah.fi/, and http://www2.uiah.fi/~tleinone/codi/codi_cscl.pdf

Liccardi, I. Davis, H., White, S. (2007) CAWS: A wiki system to improve workspace awareness to advance effectiveness of co-authoring activities, *In Proceedings of CHI 2007* (in press)

Lindgaard, G., Dillon, R., Trbovich, P., White, R., Fernandes, G., Lundahl, S., and Pinnamaneni, A., (2006) User Needs Analysis and requirements engineering: Theory and practice, *Interacting with Computers* 18 (2006) 47–70 www.elsevier.com/locate/intcom

Lipponen, L. (2002). Exploring foundations for computer-supported collaborative learning. In G. Stahl (Ed.), Computer-supported collaborative learning: foundations for a CSCL community. *Proceedings of the Computer-supported Collaborative Learning 2002 Conference (pp. 72-81).* Mahwah: Erlbaum. http://newmedia.colorado.edu/cscl/31.html

McCarthy, J. F. and Boyd, D. M., (2005), Digital backchannels in shared physical spaces: experiences at an academic conference. In *CHI '05 Extended Abstracts on Human Factors in Computing Systems* (Portland, OR, USA, April 02 - 07, 2005). CHI '05. ACM Press, New York, NY, 1641-1644. DOI= http://doi.acm.org/10.1145/1056808.1056986 http://delivery.acm.org/10.1145/1060000/1056986/p1641-mccarthy.pdf?key1=1056986&key2=2396410611&coll=portal&dl=ACM&CFID=28656067&CFTOKEN=35770880

Miao, Y., Hoeksema, K., Hoppe, H. U., and Harrer, A. 2005. CSCL scripts: modelling features and potential use. In *Proceedings of Th 2005 Conference on Computer Support For Collaborative Learning: Learning 2005: the Next 10 Years!* (Taipei, Taiwan, May 30 - June 04, 2005). Computer Support for Collaborative Learning. International Society of the Learning Sciences, 423-432 http://portal.acm.org/results.cfm?coll=portal&dl=ACM&CFID=28656067&CFTOKEN=35770880

Maxwell, K. (2001) "The Maturation of HCI: Moving beyond usability towards holistic interaction", in Carroll J. ed "*Human Computer Interaction in the new Millennium*", Addison Wesley, 2001

Miettinen, M., Kurhila, J., Tirri, H. , (2005), On the Prospects of Intelligent Collaborative E-learning Systems, http://cosco.hiit.fi/edutech/publications/aied2005.pdf

Muller, M. J. and Wu, M. (2005), Multiple Users' Perspectives of Collaborative Activities in Complex Work1, *Position paper at ECSCW 2005 workshop, Activity – From a Theoretical to a Computational Context. Paris, September, 2005.*

Myers, Brad A.(1998) ,"A Brief History of Human Computer Interaction Technology." *ACM interactions.* Vol. 5, no. 2, March, 1998. pp. 44-54.

Naidu, S., & Jarvela, S. (2006) Analyzing CMC content for what? *Computers and Education* 46 (2006) p96-103

Nash, J.B., Plugge, L. & Eurlings, A. (2001). Defining and evaluating CSCL evaluations. In A. Eurlings & P. Dillenbourg (Eds.), *Proceedings of the European Conference on Computer-Supported Collaborative Learning* (pp. 120-128). Maastricht, The Netherlands: Universiteit Maastricht. http://newmedia.colorado.edu/cscl/euro120.html

Nemirovsky, P. (2003) Redefining Digital Audience: Models and Actions, *Human Computer Interaction INTERACT 03,* Published by IOS Press, © IFIP, 2003, pp 391-398 http://web.media.mit.edu/~pauln/research/publications.html)

Nielsen, J. (1993) Usability Engineering, Academic Press, London

Nurmela, K., Lehtinen, E., and Palonen, T. 1999. Evaluating CSCL log files by social network analysis. In *Proceedings of the 1999 Conference on Computer Support For Collaborative Learning* (Palo Alto, California, December 12 - 15, 1999). C. M. Hoadley and J. Roschelle, Eds. Computer Support for Collaborative Learning. International Society of the Learning Sciences, 54. http://newmedia.colorado.edu/cscl/ww315.html

Ørngreen, Rikke N. & Nielsen *et al* (2004) Investigating Possibilities for E-Learning – *An HCI Study with the Lundbeck Institute* - Working Paper No. 3 2004 http://www.inf.cbs.dk

Oulasvirta, A and Tamminen, S., (2004) Temporal Tensions and Human-Computer Interaction *CHI'04 Workshop on Temporal Aspects of Work, 2004.* http://www.cs.bath.ac.uk/%7Epwild/TICKS/chi-2004-workshop/Papers/Oulasvirta.pdf

Pekkola, S. 2003. Designed for unanticipated use: common artefacts as design principle for CSCW applications. In *Proceedings of the 2003 international ACM SIGGROUP Conference on Supporting Group Work* (Sanibel Island, Florida, USA, November 09 - 12, 2003). GROUP '03. ACM Press, New York, NY, 359-368. DOI= http://doi.acm.org/10.1145/958160.958218

Penuel, B. & Cohen, A,. (2003). Coming to the Crossroads of Knowledge, Learning and Technology: Integrating Knowledge Management and Workplace Learning in Ackerman, A., Pipek, V. & Wulf, V. (Eds) *Sharing Expertise: Beyond Knowledge Management*. MIT Press: Cambridge: MA, USA, http://domino.watson.ibm.com/cambridge/research.nsf/0/39aded617f8eaab985256920006b44f1/$FILE/ComingCrossroads.PDF

Penuel, W. R., Cohen, A. L., Trondsen, and E., Patton, K. (2000). *New Workplace Learning Technologies: Activities and Exemplars (*Technical Report 00-06). Cambridge, MA: IBM Watson Research Center. http://domino.watson.ibm.com/cambridge/research.nsf/0/d1f599951e84cf3085256920006af96f/$file/newworkplace.pdf

Penuel, W. R., Cohen, A. L.,& Roschelle, J. (2000). *Designing Learning: Cognitive Science Principles for the Innovative Organization* (Technical Report 00-05). Cambridge, MA: IBM Watson Research Center. http://domino.watson.ibm.com/cambridge/research.nsf/0/e134768101cbf7de85256920006aafga/$file/designinglearning.pdf

Postmes, T., Spears, R., Sakhel, K., & DeGroot, D. (2001).Social influence in computer-mediated communication: The effect of anonymity on group behavior. *Personality and Social Psychology Bulletin, 27, 1243Ð1254.* http://psy.ex.ac.uk/~tpostmes/PDF/postmesetalPSPB2001.pdf

Preece, J. Rogers, Y. *et al*, (1994), Human Computer Interaction, Addison Wesley, 1994.

Rahikainen, M.; Lallimo, J.; Hakkarainen, K. (2001). Progressive inquiry in CSILE environment: teacher guidance and students' engagement. In: *European Perspectives on Computer-Supported Collaborative Learning. Proceedings of the First European Conference on CSCL.* Dillenbourg, P.; Eurelings, A.; Hakkarainen, K. (eds.). Maastricht, the Netherlands: Maastricht McLuhan Institute, 520-528, http://www.helsinki.fi/science/networkedlearning/texts/rahikainenetal2001.pdf http://newmedia.colorado.edu/cscl/euro133.html

Raskin, J. (2000). The Human Interface, ACM Press.

Reinema, R.J., (2002), Workspaces of the Future, Thesis, published in accordance with the regulations of the University of Darmstadt, Germany. http://deposit.ddb.de/cgibin/dokserv?idn=967403502&dok_var=d1&dok_ext=pdf&filename=967403502.pdf

Rodriguez, M.A., "A Multi-Relational Network to Support the Scholarly Communication Process", *International Journal of Public Information Systems,* volume 2007, issue 1, pp. 13-29, ISSN: 1653-4360, LA-UR-06-2416, March 2007. http://www.soe.ucsc.edu/~okram

Sassenberg, K., & Postmes, T. (2002). Cognitive and strategic processes in small groups: Effects of anonymity of the self and anonymity of the group on social influence. *British Journal of Social Psychology,* 41, 463 – 480. http://psy.ex.ac.uk/~tpostmes/PDF/sassenbergpostmes02BJSP.pdf

Savidis, A., Stephanidis, C., (2006), Inclusive development: Software engineering requirements for universally accessible interactions, *Interacting with Computers* 18 (2006) 71–116, www.elsevier.com/locate/intcom

Scanlon, E., O'Shea, T., Smith, R. B. & Li, Y. (1997) Supporting the distributed synchronous learning of probability: learning from an experiment, paper presented at *The CSCL 97 Conference.* Available online at:http://www.oise.utoronto.ca/cscl/papers/scanlon.pdf (accessed 18 April 2004).

Schneiderman, Ben, (1998) Designing the User Interface, 3rd ed., Addison Wesley, Longman Inc. 1998.

Sendova, E., Nikolova, I., Gachev, G., Moneva, L. (2004) Weblabs: A virtual laboratory for collaborative e-learning, presented at *EduTech Workshop, WCCE 2004*, Toulouse, France http://www.weblabs.eu.com/papers/EduTech-WCCE_04_bulgaria.pdf

Silva Filho, A. M., de Barros, R. S., and Liesenberg, H. K. (2000). Designing User Interface for Web Interactive Systems. In *Proceedings of the 3rd IEEE Symposium on Application-Specific Systems and Software Engineering Technology (Asset'00)* (March 24 - 25, 2000). ASSET. IEEE Computer Society, Washington, DC, 9 http://math.uma.pt/wisdom99/papers/silva/silva.html

Shulman. Lee (1998), "Paedagogy", Learning curriculum & Assessment, Open University Cassette tape

Sim, Y.W., Wang, C., Gilbert, L., Wills, G.B. (2005) Towards a Collaborative Orthopaedic Research Environment, In *Proceedings of the IEEE 1st International Workshop on Service-Oriented Computing: Consequences for Engineering Requirements (SOCCER'05)*, Paris, France. http://eprints.ecs.soton.ac.uk/11151/01/core.pdf

Sim, Y. W., Wang, C., Carr, L.A., Davies, H. C., Gilbert, L., Grange, S., Millard, D. E., Wills, G. B. (2005) A Web/Grid Services Approach for a Virtual Research Environment Implementation In *Proceedings of the Workshop on Portals and Virtual Research Environments held in conjunction with the Fourth e-Science All Hands Meeting (AHM 2005), Nottingham, UK* http://www.core.ecs.soton.ac.uk/publications

Spears R, Postmes T, Lea M, Wolbert A. (2002). When are net effects gross products? The power of influence and the influence of power in computer-mediated communication. *J. Soc. Issues* 58(1):91–107 http://psy.ex.ac.uk/~tpostmes/PDF/spearsetal02JSI.pdf

Stahl, G. (2002). « Contributions to a theoretical framework for CSCL (Ed.), *Computer Support for Collaborative Learning : Foundations for Community*, Mahwah, NJ, Lawrence Erlbaum Associates, p. 62-71. http://newmedia.colorado.edu/cscl/81.html

Stokes, D. E. (1997) Pasteur's Quadrant, Brookings Institution Press Washington, DC

Strijbos, J. W., Martens, R., Prins, J., & Jochems, W. (2006) Content Analysis: What are they talking about? *Computers & Education*, 46 (2006) 29–48, doi:10.1016/j.compedu.2005.04.002. www.elsevier.com/locate/compedu

Sturzebecher, D., (2000),A Portable and Flexible Framework for CSCW systems, Thesis published by University of Braunschweig, Germany. Available from: http://deposit.ddb.de/cgi-bin/dokserv?idn=960647503&dok_var=d1&dok_ext=pdf&filename=960647503.pdf

Swaab, R., Tom Postmes, T., and Peter Neijens, P., (2004) Negotiation Support Systems Communication and Information as Antecedents of Negotiation Settlement, *International Negotiation* 9: 59–78, 2004. http://psy.ex.ac.uk/~tpostmes/PDF/swaabetalIN04.pdf

Tapola, A, Hakkarainen, K., Syri, J., Lipponen, L., Palonen, T., & Niemivirta, M. (2001). Motivation and Participation in Computer-supported Collaborative Learning. In P. Dillenbourg, A. Eurelings & K. Hakkarainen (Eds.), European Perspectives on Computer-Supported Collaborative Learning. *Proceedings of the First European Conference on CSCL* (pp. 585-592). McLuhan Maastricht, the Netherlands: Maastricht McLuhan Institute. http://www.helsinki.fi/science/networkedlearning/texts/tapolaetal2001.pdf

Valcke, M., and Martens, R., (2006) The problem arena of researching computer supported collaborative learning: Introduction to the special section, *Computers & Education* 46 (2006) 1–5, www.elsevier.com/locate/compedu

Vygotsky, L.S. (1978) Mind in Society: The development of higher psychological processes, M. Cole, V. John-Steiner, S. Scribner and E. Souberman (eds. and trans.), Cambridge, MA : Harvard University Press

Vygotsky, L.S. (1997), "Educational Psychology", St Lucie Press (Originally written 1921-23)

Wald, M. (2005), Enhancing Accessibility through Automatic Speech Recognition, *Proceedings of Accessible Design in the Digital World*. http://eprints.ecs.soton.ac.uk/12143/01/accessibledesignmw.doc

Waldrop, M. Mitchell (2008), Science 2.0, Scientific American, May 2008, Volume 298, Number.5, pp 47-51

Walters, R. J., Millard, D. E., Bernnett, P., Argles, D., Crouch, S., Gilbert, L. and Wills, G. (2006) Teaching the Grid: Learning Distributed Computing with the M-grid Framework. In *Proceedings of ED-MEDIA 2006--World Conference on Educational Multimedia, Hypermedia & Telecommunications*, pp. 3857-3864, Orlando, USA.

Walters, R. J., *et al* (2006) Teaching the Grid: Learning Distributed Computing with the M-grid Framework, http://eprints.ecs.soton.ac.uk/12181/

Wang, Q, Kessler, Glenn, Blank, D., Pottenger, W.M., (2002), Demonstration tools for Collaborative E-Learning, *ACM 2002 Conference on Computer Supported Cooperative Work (CSCW*), New Orleans, LA, Nov., 2002. http://www.cse.lehigh.edu/~dkessler/Publications/DemoToolsCSCW2002.pdf

Watts, L. and Reeves, A.J., An Identity Based Design Framework for Computer Mediated Communication systems http://www.bath.ac.uk/comp-sci/hci/projects/identidydesign.html

Weinberger, A. and Fischer, F. 2006. A framework to analyze argumentative knowledge construction in computer-supported collaborative learning. *Comput. Educ.* 46, 1 (Jan. 2006), 71-95. DOI= http://dx.doi.org/10.1016/j.compedu.2005.04.003

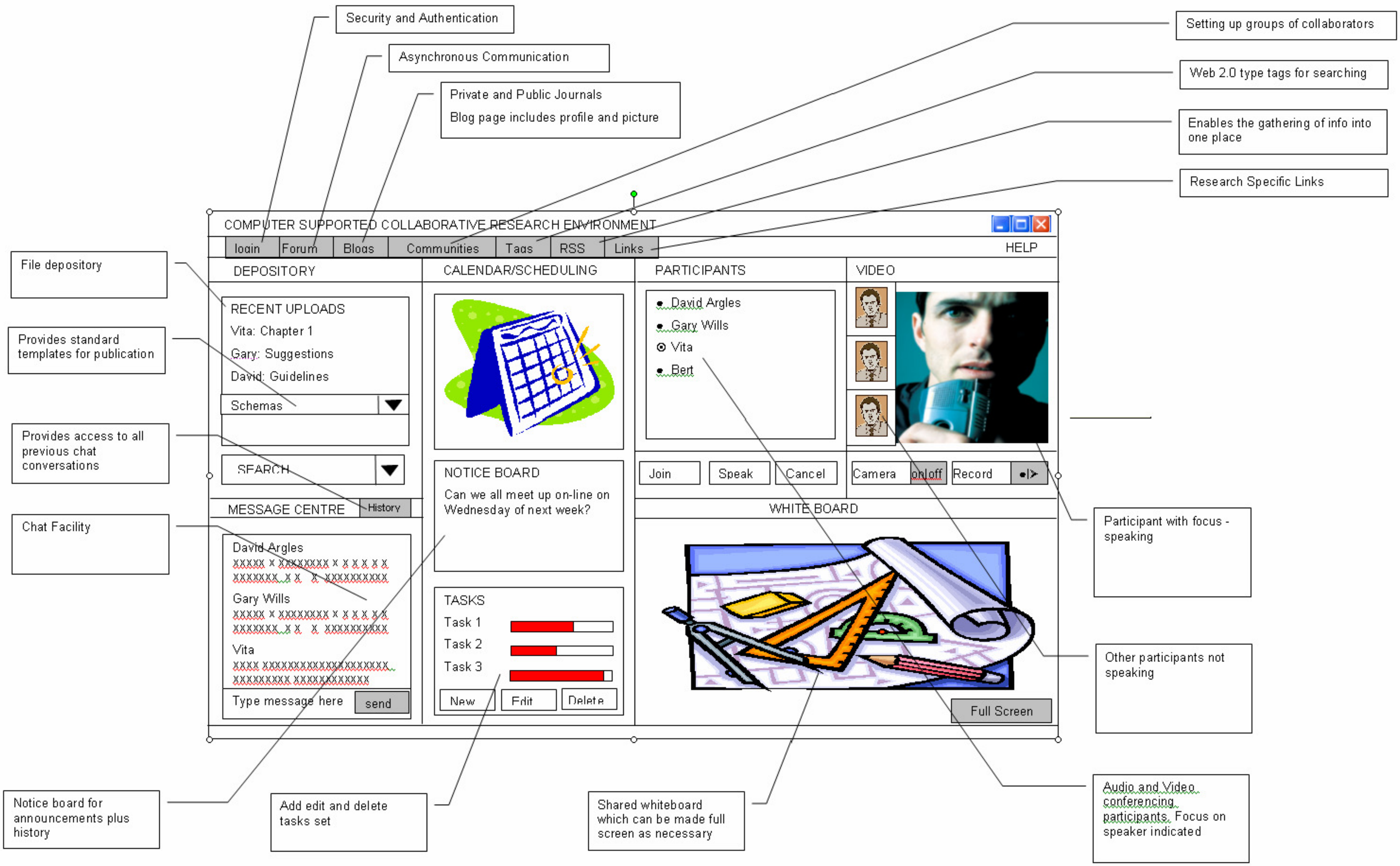
De Wever, B., Schellens T., Valcke, M., & Van Keer H. (2006). Content analysis schemes to analyze transcripts of online asynchronous discussion groups: A review. *Computers and Education,* 46, 6-28.

Wild, P.J. and Johnson, P.,(2004), Deepening Consideration of Temporal Factors in Task Knowledge Structures Position paper presented at, *Workshop on 'Temporal Aspects of Work for HCI'. CHI'2004*,. http://www.cs.bath.ac.uk/%7Epwild/TICKS/chi-2004-workshop/Papers/Wild%20and%20Johnson.pdf

Wills, G.B. (2005) VRE Architecture Design Notations, http://www.core.ecs.soton.ac.uk/publication/jisc_VRE_0705.pdf

Xu, Chengmao (2000), Interaction and Collaboration Mechanisms for Distributed Communities and Groups in Educational Settings, PhD thesis. Institut fur Informatik der Technischen Universitat Munchen, Munich, 2000. http://tumb1.biblio.tu-muenchen.de/publ/diss/in/2000/xu.pdf

APPENDIX A CRESS STORYBOARD 1



APPENDIX B QUESTIONNAIRE

Computer Supported Collaborative Research CSCR Questionnaire

Dear Survey Participant,

Thank you very much for participating in this study.

The aim of this project is to evaluate the interface requirements for a Computer Supported Collaborative Research CSCR environment. The results of the survey evaluation may feature in research papers and conference proceedings.

The main target groups for this survey are people who are using collaborative online environments to enable them to work/study together on a common task.

You will be asked to evaluate the tools needed for a computer supported collaborative interface by answering a set of multiple choice questions. This should take no longer than 4 minutes. This questionnaire is concerned about finding out how effective a computer supported collaborative interface is in helping people to work together to solve problems and assist them with their work practice.

We guarantee that all data will be used for research purposes only, will be anonymous, and will be treated absolutely confidentially. Your may stop or withdraw at any time from participation.

Many thanks for your assistance.

Vita Hinze-Hoare
Electronics and Computer Science
University of Southampton

I have read the above information and agree to participate in this survey by completing the questionnaire.

……………………………………………

……………………………………….

Signature Date

Prize Draw:

If you wish to be included in the Prize Draw for a Nintendo game console please enter your email address here

………………………………………………………………………………….

Instructions

Please complete the following questionnaire by rating the online tools that you use in your collaborative work.

Please rate the following Interface tools from 1 (not useful) to 5 (very useful). If you do not use a particular tool please indicate in the last box for acquisition or not.

What is the name of the online interface you are using?	
URL if available	

How would you rate the following on-line interface tools as to their usefulness for working together with others?

	Not useful 1	2	to 3	4	very 5	Would be useful to have
Administration						
Log in	☐	☐	☐	☐	☐	☐
Access/Authorisation	☐	☐	☐	☐	☐	☐
Recording Replay Facility	☐	☐	☐	☐	☐	☐
Instant messaging recording	☐	☐	☐	☐	☐	☐
Assistive agent	☐	☐	☐	☐	☐	☐
Help pane	☐	☐	☐	☐	☐	☐
Information link map	☐	☐	☐	☐	☐	☐
Scenario Control Flow tools	☐	☐	☐	☐	☐	☐
Communication						
Chat	☐	☐	☐	☐	☐	☐
Audio/Voice	☐	☐	☐	☐	☐	☐
Still Picture of Participant	☐	☐	☐	☐	☐	☐
Video	☐	☐	☐	☐	☐	☐
Instant Messaging	☐	☐	☐	☐	☐	☐
Forum	☐	☐	☐	☐	☐	☐
News board (provides news from supervisors)	☐	☐	☐	☐	☐	☐
Identification						
Presence indicator (shows who is online with you)	☐	☐	☐	☐	☐	☐
Focus indicator (shows who is talking at the time)	☐	☐	☐	☐	☐	☐
Location identifier (indicates where the person is)	☐	☐	☐	☐	☐	☐
Participant data (provides name and role)	☐	☐	☐	☐	☐	☐
Avatar (provides 3D representation of the users)	☐	☐	☐	☐	☐	☐
Scheduling tools						
Calendar	☐	☐	☐	☐	☐	☐
Task Setting	☐	☐	☐	☐	☐	☐
Task Monitoring	☐	☐	☐	☐	☐	☐
Shared working Space						
Whiteboard (sharing of graphical/formulae ideas)	☐	☐	☐	☐	☐	☐
Collaborative Working Window (shared area for working on documents together e.g. Wiki)	☐	☐	☐	☐	☐	☐

3D Environment	☐	☐	☐	☐	☐	☐
Product Space						
Output Window (shows results of work done)	☐	☐	☐	☐	☐	☐
Simulation (simulates working of tools used)	☐	☐	☐	☐	☐	☐
Reflection Space						
Reflective Journal/Blog (private)	☐	☐	☐	☐	☐	☐
Social Interaction Space						
Community Creation (allows setting up groups of collaborators)	☐	☐	☐	☐	☐	☐
Tagging (allows fixing of tags to describe uploaded items as in Flickr)	☐	☐	☐	☐	☐	☐
Friend file sharing	☐	☐	☐	☐	☐	☐
Blogs(Public) (online diary for everyone to see)	☐	☐	☐	☐	☐	☐
RSS Feeds (allows news and other information to be aggregated to your area)	☐	☐	☐	☐	☐	☐
Assessment/Supervisor						
Assessment, Marking	☐	☐	☐	☐	☐	☐
Feedback	☐	☐	☐	☐	☐	☐
Private Supervisor (Space)	☐	☐	☐	☐	☐	☐
Knowledge Space						
Contribution Database (keeps a record of the individual contributions to work done)	☐	☐	☐	☐	☐	☐
Academic Database (holds information about academic subject matter relating to you work)	☐	☐	☐	☐	☐	☐
File Repository (allows uploading and storage of your own files)	☐	☐	☐	☐	☐	☐
Power Point Slides	☐	☐	☐	☐	☐	☐
Private Space						
Private Space (an exclusive area for you to work in)	☐	☐	☐	☐	☐	☐
Public Space						
Public Information Space (on-line web space to publish results or interact with bodies outside)	☐	☐	☐	☐	☐	☐
Negotiation Space						
Peer Review Assistance (facility to obtain formal feedback on your work from your colleagues)	☐	☐	☐	☐	☐	☐
Publication Space						
Schemas and Templates	☐	☐	☐	☐	☐	☐
Publishing Assistance (facilities to enable you to submit your work for publication)	☐	☐	☐	☐	☐	☐
Additional Comments						

Can you finally tell us a little bit about yourself?

About yourself					
Sex	Male ☐	Female☐			
Age Group	18-25 ☐	26-35 ☐	36-45 ☐	46-55 ☐	56-65☐
Role	Undergrad ☐	Postgrad ☐	Lecturer ☐	Other ☐	

APPENDIX C: PILOT SURVEY DATA

Pilot Questionnaire

	Interface	Administration	Log in	Access/Authorisation	Recording Replay Facility	Instant messaging recording	Assistive agent	Help pane	Information link map	Scenario Control Flow tools	Communication	Chat	Audio/Voice	Still Picture of Participant	Video	Instant Messaging	Forum	News board	Identification	Presence indicator	Focus indicator	Location identifier	Participant data	Avatar
Questionnaire 1	UG forge		5	5	3	1	2	2	1	3		1	1	1	1	1	5	5		1	1	1	4	1
Questionnaire 2	UG forge		4	5	W	1	3	4	4	W		4	2	5	2	5	3	3		5	5	3	5	1
Questionnaire 3			5	5	5	3		2				4	1	1	1	4	5	5		4		1	2	1
Questionnaire 4			5	4	5		3	5	5	4		5	5	4	4	5	5	5		5	5	5	4	5
Questionnaire 5	Blackboard		5	5	4	4	3	5	5	3		5	4	2	3	5	5	4		5	2	2	4	3
Questionnaire 6			3	3	3	3	2	3	3	3		5	3	1	3	5	3	3		4	3	1	3	1
Questionnaire 7			5	5	2	4	2	3	3	3		2	2	4	3	4	4	4		4	4	2	3	2
Questionnaire 8	unsure		4	4	4	4	1	2	1	1		5	5	5	5	5				5	5	5	W	W
Questionnaire 9	CAWS/Facebook		5	5	4	4	W	2	W	W		5	5	4	4	5	4	5		4	4	3	5	3
Questionnaire 10	Facebook		5	5	5	4	4	3	3	5		5	5	5	5	5	5	5		5	5	3	4	3
Questionnaire 11	MSN		3		5	5		5				5	5		5	5				5	5			
Questionnaire 12	Uforge		5	5	1	1	W	5	5	W		1	5	3	W	2	5	5		W	W	1	5	2
Questionnaire 13	Uforge		4	4	W	W	W	3	3	W		1	1	1	1	W	3	3		W	W	1	4	
Questionnaire 14	Uforge.Ecs		4	2		W			W			W	W			W	5	1		W		W		
Questionnaire 15	Chinaren Class		5	5	4	4	3	3	2	4		2	1	3	1	2	5	5		3	2	1	2	2
Questionnaire 16			3	3		3	2	3	2	2		3	3	2	3	4	3	2		3	3	3	3	2
Questionnaire 17	Friendster.Lotus Notes		4	4	5	W	W	5	W	W		W	W	3	W	W	5	5		4	4	W	4	W
Questionnaire 18	not		4	4	4	4	3	3	4	5		4	5	5	5	4	5	4		5	5	4	5	1
Questionnaire 19	Ugforge		4	4	W	4	4	3	4	4		W	W	W	W	W	4	W		5	W	2	5	1
Questionnaire 20																								
			82	77	54	49	32	61	45	37	0	57	53	49	46	61	74	64	0	67	53	38	62	28

APPENDIX C: CONTD.

Scheduling tools	Calendar	Task Setting	Task Monitoring	Shared working Space	Whiteboard	Collaborative Working Window	3D Environment	Product Space	Output Window	Simulation	Reflection Space	Reflective Journal/Blog	Social Interaction Space	Community Creation	Tagging	Friend file sharing	Blogs(Public)	RSS Feeds	Assessment/Supervisor	Assessment, Marking	Feedback	Private Supervisor (Space)	Knowledge Space	Contribution Database	Academic Database	File Depository	Power Point Slides	Private Space	Private Space	Public Space	Public Information Space
	5	5	5		2	1	1		4	2		1		5	5	3	1	5		3	3	3		1	4	2	1		4		3
	4	3	3		5	5	1		5	4		2		4	5	5	2	5		3	5	3		5	5	5	5		3		3
						5	1					1		5	W	5	W			4	4	4		5	4	5			5		5
	3	4	4		4	4	4		5	4		4		5		5	4	4		4	3	4		4	4	4	4		4		5
	5	5	5		4	4	3		5	5		4		4	4	4	4	4		5	5	2		4	4	4	4		3		5
	4	5	5		W	2	1		3	3		1		3	3	3	1	4		3	3	3		4	3	3	2		1		3
	4	4	3		3	4	3		4	4		3		3	4	4	4	3		3	4	2		3	3	4	4		4		4
	W	W	W		5	5	5		5	W		W		5	W	5	W	W		W	W	W		5	5	5	W		1		W
	4	4	3		W	4	2		3	2		3		4	3	5	3	3		W	3	3		W	W	W	W		3		5
	5	5	5		5	5	5		5	W		4		5	W	5	5	5		W	W	W		W	W	5	W		5		5
	W	W			5	W	W																								
	4	5	5		3	5	2		5	W		5		5	W	4	5	W		1	5	1		5	W	5	W		5		5
	W	4	4		W	W	1		4	W		W		4	W	4	W	W		1	3	1		4	3	4	3		3		4
	W	W	W		W	3						W			W		W	W		W	W			4	W	2	3				W
	1	5	5		5	5	2		4	3		4		W	3	W	5	W		W	W	2		W	W	W	3		5		5
	3	3	3		3	3	1		3	3		2		2	3	3	3	3		3	3	2		3	3	3	3		3		3
	4	4	4		5	4	4		5	4		1		W	5	W	2	W		5	5	5		5	5	5	5		W		5
	3	3	4		5	5	2		4	4		3		3	4	4	5	4		3	3	3		5	5	5	5		4		5
	5	5	5		W	3	3		4	4		4		5	2	4	2	4		5	5	5		5	5	5	5		5		5
0	54	64	63	0	54	67	41	0	68	42	0	42	0	62	41	63	46	44	0	43	54	43	0	62	53	66	47	0	58	0	70

APPENDIX C: CONTD.

Negotiation Space	Peer Review Assistance	Publication Space	Schemas and Templates	Publishing Assistance	SEX	AGE GROUP	ROLE
	3		4	4	M	1	U
	5		5		M	1	U
	W		3	3	M	3	P
	4		4	W	M	2	P
	3		4	4	M	3	P
	3		3	3	M	1	P
	3		3	3			
	W		W	W	F	2	P
	5		5	4	F	1	P
	5		W	W	F	2	P
					F	5	O
	5		5	W	M	1	P
	3		1	1	M	1	P
	W				M	1	P
	5		W	4	F	1	O
	3		3	3	M	2	O
	5		5	5	F	2	P
	5		3	W	F	2	P
	4		5	5	M	1	U
0	61	0	53	39	0	32	0

APPENDIX C: CONTD.

Participant Comments

How does your CSCR classify collaboration? Is it a) working simultaneously in a single space or b) working in parallel in multiple spaces on a single revision of a resource.

I use a whole bunch of collaborative tools with separate interfaces in different scenarios. The only common interface to these is my desktop PC which I can customize however I want and remote to from anywhere on the net

I was unsure if I had to enter the name of the online applications which I am using anyways I considered the various video conferencing tools available for collaborative work while answering the questions

Please give the example of online interface or definition of online interface tools. In social interaction space please push this topic to next page

Not clear about the type of tools required at outset

All questions have been answered with Uforge in mind. Irrelevant technology/questions have been answered as not useful. Although it would be good for collaborators to communicate but with Uforge in mind it is more important to upload, share and mine uploaded data since it is a repository. A portal for collaboration may be an improvement

Added "Wouldn’t be useful" column. Some questions feel too context specific, e.g. supervisor space not always useful to all users. Some questions repeated (eg Blog twice)

SVN is invaluable for file sharing. Better communication, and in particular, reflection and blogging tools would be very useful. This survey was a little unclear what to I tick if I have not used the feature and do not think it would be useful. Needs a "Don’t know what it does" column and a would be useful column

Wording of instructions isn't clear. Seems to assume we are using a monolithic system in using lots of different tools to support collaborative working.

-able to replay the entire revision history of collaborative work

APPENDIX D: Research process elements.