CAWriter: using an Activity System perspective to inform the design of tools to support early career Ph.D. candidates

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Declaration

I, the undersigned, declare that this work has not been previously submitted as an exercise for a degree at this or any other University, and that, unless otherwise stated, is entirely my own work.

Jake Rowan Byrne

February 2014

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Related Publications

Byrne, J. R., & Tangney, B. (2010). *CAWriter: A CSCW/CSCL Tool to Support Research Students' Academic Writing.* Paper presented at the 24th BCS Interaction Specialist Group Conference, Dundee, Scotland.

Byrne, J. R., & Tangney, B. (2012). "CAWriter" a Computer Supported Collaborative Tool to Support Doctoral Candidates Academic Writing: A Pedagogical and Human-Computer Interaction Perspective. In A. Juan, T. Daradoumis, M. Roca, S. E. Grasman & J. Faulin (Eds.), *Collaborative and Distributed E-Research: Innovations in Technologies, Strategies and Applications.* (pp. 181-205): IGI Global.

Summary

This thesis adheres to the view that the purpose of a Ph.D. is to both make a significant contribution to knowledge and to provide the candidate with the skills necessary to conduct "independent" research, culminating in a professional qualification. This work advocates the proposition that to make a significant contribution to knowledge will manifest from a “Knowledge Work” process and that the skills necessary are acquired through a process of environmental and sociological enculturation. The literature review develops the idea that writing, as a creative process, is synonymous with and a subset of this “Knowledge Work”. The literature review culminates in the development of an Activity System that creates a theoretical framework with which to describe the Ph.D. process and a set of design heuristics distilled from the literature which highlight elements to be considered when design for the Ph.D. process: pedagogical contexts, activities and skills.

Within the Computer Science context within which this research is being conducted and participatory action research methodology, a computer program toolkit, CAWriter, was designed to support novice Ph.D. candidates with their early dissertation writing activities and act as a technology probe for this class of application.

This toolkit was developed through an iterative Participatory Design process and was evaluated using a set of design heuristics developed based on the literature review. The system was evaluated by six single session users and four one to five month users. The findings indicate that the designed tools do in fact largely support the skills and activities as the four users demonstrated extensive use of a variety of the embedded tools. However there is still room for improvement and only early stage activities are supported, leaving room to expand the system to cater for more advanced activities such as collaboration, data analysis and revision.

The central contributions of this work are an Activity System to describe the Ph.D. process, a set of design heuristics listing the necessary skills and activities to be supported by tools aimed at supporting Ph.D. candidates or novice researchers in general. Finally a tool, CAWriter, is presented and evaluated with real users in legitimate context, as an encapsulation of aforementioned design heuristics and Activity System perspective of the Ph.D. process.

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1. Introduction

"Could it be that Nature is not a lifeless book that has been put at our disposal to decipher, but a living book, which is still in the process of being written?" (Nicolescu, 2002)

This thesis adheres to the view that the purpose of a Ph.D. is to both make a significant contribution to knowledge and to provide the candidate with the skills necessary to conduct "independent" research, culminating in a professional qualification. This work advocates the proposition that this significant contribution to knowledge will manifest from a “Knowledge Work” process and that the skills necessary are acquired through a process of environmental and sociological enculturation. The literature review develops the idea that the writing, as a creative process, is synonymous with and a subset of this “Knowledge Work”. A computer program toolkit, CAWriter, was designed to support novice Ph.D. candidates with their early dissertation writing activities as they conduct their “Knowledge Work”. This involves an explicit system view of the Ph.D. as a process, the activities involved and the skills required.

The term Ph.D. or Philosophiae Doctor, literally means a degree awarded for the love of knowledge. This does however raise questions such as what knowledge is and how can we contribute knowledge or even create new knowledge? This is where we start our investigation; through a review of the literature we make an attempt at answering these questions by first taking the perspective of the Ph.D. candidate as a knowledge worker. As a knowledge worker, the Ph.D. candidate works with knowledge from its most basic level, manipulation of signs, up to more complex systems such as the use and creation of mental schemas, domain perspectives and ultimately the creation of a thesis or dissertation. These mental schemas once expressed, in some semiotic form or 'gestalts', are projections of the researcher's philosophical perspective of the system they are trying to describe; whether this is explicit or implicit is another matter. It is only when we reach the frontiers of these shared constructs and push through these boundaries that we make any significant contribution to the cultural body of knowledge. We should however still realise the limitations of what we know and what claims we can make about our contributions and how they might emerge. In order to highlight this gap between the "known" and unknown and how we may transcend it we introduce the Emergent Design concepts of System-Meta-System duality, where new elements are added to our system view as they emerge from the possibilities of the Meta-System, and relate them to the evolutionary epistemology perspective of trial and error in knowledge formation.

Having laid down the proposition that Ph.D. knowledge work largely consists of the manipulation, either physically or mentally, of symbolic artefacts, we explore the writing process as an explicit example of this process. We argue that writing is a multifaceted process involving a range of different symbolic manipulation processes, ranging from idea generation to revision. Aitchison and Lee (Aitchison & Lee, 2006) suggest that writing is a "knowledge-creating" rather than merely knowledge-recording activity. This view is supported by Sharples (Sharples, 1999), who argues writing is a creative design process and Bereiter and Scardamalia (Bereiter & Scardamalia, 1987) who suggest that formal writing occurs through a dialogue, whether that be internal or external, and is a "knowledge transforming" activity. These works provide an overview of the writing process in general, emphasising the dynamic iterative processes involved, but in order to specifically explore the dissertation writing process in more detail, we explore the Single approach to dissertation writing (Single & Reis, 2009) which sets out a comprehensive guide which covers a number of different phases involved in the production of a doctoral dissertation. Single's approach introduces a template from which to design tools to support dissertation writing.

Having explored the Ph.D. candidate as a knowledge worker and what this work entails, it is important to explore the social context within which these activities occur. As stated above the purpose of a Ph.D. is not only to make a significant contribution to knowledge but also to learn, through apprenticeship and enculturation, the essential skills needed to become an independent researcher (Gilbert, 2009). The Ph.D. candidate is usually located within some community of researchers and tacit knowledge is transferred and learnt while the Ph.D. candidate is engaged in legitimate learning experiences. The experiences are anything related to conducting research or collaborating with peers, academics and other members of their community. This form of largely tacit knowledge that is transferred between community members is known as situated knowledge and there are a number of pedagogical frameworks that may be used to view this aspect of the Ph.D. process; Cognitive Apprenticeship, Communities of Practice and Peer Learning (Austin, 2009; Cullen, Pearson, Saha, & Spear, 1994; Hasrati, 2005; Hopwood & McAlpine, 2007; Leshem, 2007).

These pedagogical frameworks provide an excellent description of the social context within which Ph.D. learning occurs, but they do not provide explicit guidance as to what a Ph.D. candidate needs to learn and acquire in order to become a fully-fledged researcher. In order to address this shortfall we shall explore further frameworks such as Bloom's Taxonomy and derivatives. Becoming a researcher involves the acquisition of a range of skills, such as organisational, expressive, cognitive and meta-cognitive (Holz et al., 2006). These skills are combined and utilised in variety of ways

throughout the dissertation and academic writing process are essential skills for any doctoral candidate to master (D. Boud & Lee, 2009).

Supporting doctoral candidates with their dissertation writing is a difficult and often tricky task for which the main responsibility lies with the supervisors (Paré, Starke-Meyerring, & McAlpine, 2009). There are also suggestions that supervisors may not have access to the resources to help them effectively support the dissertation writing process (Lee and Aitchison 2009). This issue is a crucial motivation of this thesis; to design and implement a tool-set to support early dissertation writing skills, with a special focus with regards to approaches to support a range of the skills as set out by Holz et al. and the wider literature. These perspectives provide a set of skills that both novice and advanced knowledge workers need to master, providing us with explicit skills that we can aim to support and design for. Once this is achieved and tested it may be deployed within a student-supervisor scenario, providing explicit supports and scaffolds for skills and activities common in the Ph.D. Process.

In order to develop a more comprehensive perspective of the Ph.D. as a process or system we look at how knowledge workers use technology and machines to help augment their work. We first explore a number of Human Computer Interaction theories, Distributed Cognition and Activity Theory, that show a number of parallels with the semiotic and tool mediated perspectives. These perspectives are further explored while discussing views on the fundamental nature of knowledge and how we can make use of these perspectives when trying to bridge the gap from theory to design. From here we explore the state of the art in writing related technologies, looking at supports for non-linear editing, concept mapping and collaborative systems.

Through the synthesis of the literature we argue that Emergent Design is a suitable theoretical perspective that provides an excellent boundary system we can use to describe the Ph.D. process, although perhaps not all Ph.D.s. It provides a construct within which we can describe how we perceive, create and share knowledge, while emphasising this as a process of active design.

Activity Theory, research skills and writing as creative design perspectives act as broad theoretical frameworks to inform the design of technology probes, or prototypes. An Activity System of the Ph.D. process (Figure 1-1) is developed based on an Activity Theory model to provide a holistic context with which to design these prototypes. As the literature on situated learning suggests, any learning activity should be based on legitimate tasks embedded within legitimate work practices. Using this theoretical perspective as a heuristic schema, prototypes were developed iteratively. These prototypes allow us to probe specific test cases that focus on specific organisational,

cognitive and meta-cognitive skills essential for the effective engagement in legitimately situated dissertation writing activities. The prototypes provide supports that include a non-linear approach to writing, organisational functionality, scaffolds to support higher order thinking and supplementary collaborative features.

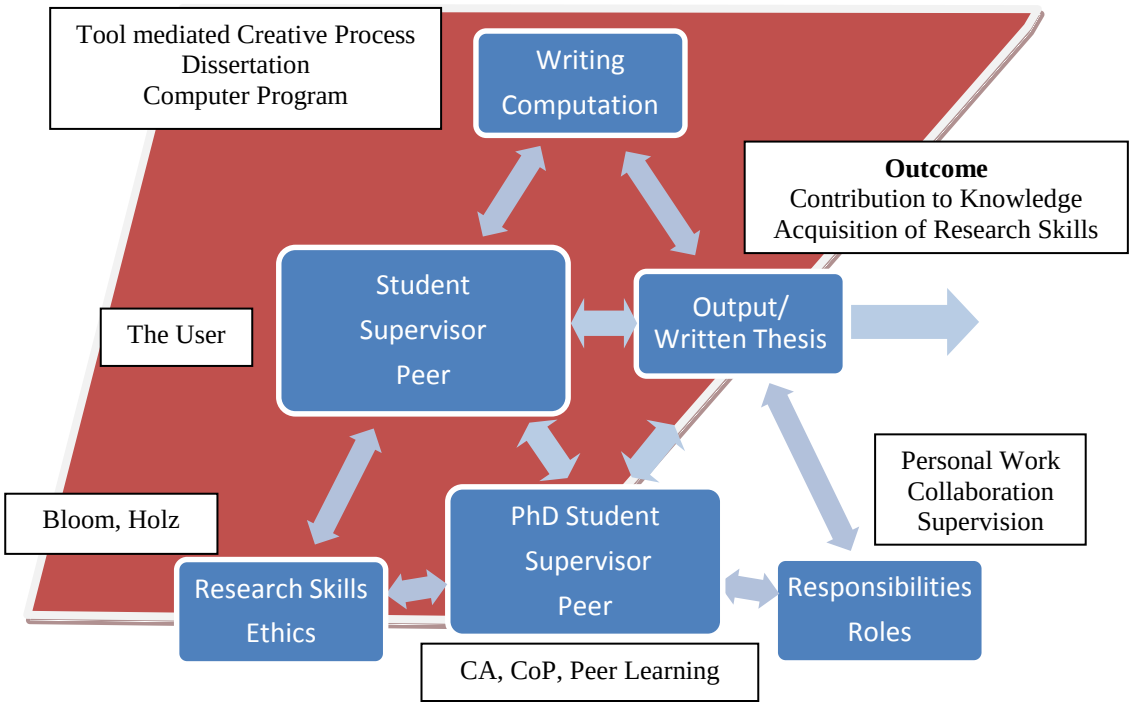


Figure 1-1 Activity Systems for Ph.D. Process (red: research focus)

An iterative development process culminated in CAWriter, the design presented in chapter 4. An empirical study of CAWriter was conducted to explore how and if the designs, based on an activity system schema of dissertation activities, can effectively support the skills and activities they were designed to facilitate. This involved the exploration of what activities, such as literature review supports, conceptual frameworks etc., may be used to scaffold these skills.

The research questions explore the usefulness of the tools designed according to the activity system, in supporting dissertation writing related activities and the skills that they require. Sub-questions explore if there is evidence that the designed tools facilitate the activity systems they designed to support? Are the tools usable? User experience is also a factor and will be judged on the user's perspective and observations on using the tool. These questions shed light on how effective the prototype both supports cognitive and other higher order thinking skills and how it performs as a general productivity tool. Addressing these questions will provide tentative answers

as to whether the tools provide support for knowledge work and the essential skills needed to conduct 'independent' research.

This thesis adopts a Participatory Action Research (PAR) methodology (Creswell, 2005 ; Kemmis & Wilkinson, 1998; Whyte, 1989) to help guide its research process. The PAR approach promotes the idea that an individual, from within a community, can identify an issue and implement some action in an attempt to address that issue. It is an iterative process and requires the researcher to be reflexive and adapt to observations, thus it is another instance of the Emergent Design approach. As the author is himself a member of the doctoral candidate community, it is this community of doctoral candidates that was the initial focus, with the view that the findings may be applicable to support doctoral candidates in general.

The PAR methodology was complimented by a Participatory Design (PD) approach (Muller, 2002) that entailed the implementation of a series of three Future Technology Workshops (FTWs) (Vavoula & Sharples, 2007) and two PD sessions involving Ph.D. students, supervisors and relevant colleagues. These workshop sessions were largely prototyping and testing sessions that explored both current and emergent activities within the Ph.D. process, as well as assessing the prototypes as they developed. Combining the information garnered from these sessions with a review of existing tools the dissertation writing process was highlighted as an area that receives little support beyond basic organisational and productivity tools.

In the early stages of the research a number of prototypes to support various activities related to doctoral work were iteratively developed. Through an iterative process of refining the focus of the research these prototypes culminated in the development of CAWriter, a tool that aims to provide supports for early dissertation writing activities. CAWriter is a unique piece of software that combines and tightly integrates elements from existing referencing, word-processing and concept mapping systems and adds scaffolds to support higher order thinking. Thus providing the users with a system that is quick to learn and easy to use, providing them with an instant overview and access to all their work while they draft a document. It builds on the skills promoted by Holz et al. and implements a number of the steps found in the “Single System”. This combination and tight integration of supports makes CAWriter unlike existing tools available today.

Evaluation was conducted in an iterative fashion, using an array of datasets. Initially the Future technology Workshops and participatory design sessions explored the community’s perceived requirements for any future tools related to Ph.D. activities. The results of these sessions informed the design of an initial prototype, which acted as a technology probe for future dialog with the

community and the development of CAWriter, the dissertation writing focused prototype. The prototypes were evaluated using participatory heuristic evaluation (Muller, Matheson, Page, & Gallup, 1998), usage data, artefacts, interviews and observations. This testing phase was conducted with a core group of 4 domain expert users, HCI specialists, and Ph.D. candidates. As the prototypes progressed and usability concerns were addressed, heuristic evaluations were implemented with a total of 11 Ph.D. candidates to explore the users experience and satisfaction with the developed tools. Finally four interviews, prototype usage data and observation notes were used to answer the research questions.

The major contributions of this work are the creation of an Activity System perspective with which we may view the Ph.D. process, with an eye towards designing support tools. The thesis also provides a breakdown of sub-Activity System perspectives of a range of early Ph.D. activities and tasks. A set of design heuristics are collated from the literature to offer guidance to those interested in designing systems to support the Ph.D. process. These sub-activity systems and design heuristics are embodied in a tool, CAWriter. CAWriter was evaluated based on 4 user studies using the tool in legitimate and situated Ph.D. activities. Finally the transdisciplinary approach to designing real world applications, with a focus on legitimate activities rather than laboratory experiments provides readers with an alternative approach to designing real world systems, especially as a participant within a community.

The chapters of this thesis are transdisciplinary in nature and provide a rich set of contributions to a number of fields. Chapter 2, the literature review, provides a new theoretical perspective that may be used to frame the Ph.D. process, opening up new pedagogical insights, incorporating existing theories and helping to bridge theory and design. The Synopsis of Chapter 2 would be of interest to those designing tools or applications for Ph.D. candidates or researchers in general. Chapter 3 provides an overview of the Transdisciplinary, Participatory Action Research and Participatory Design approaches taken in this thesis and outlines the evaluation methodologies used in the evaluation of this thesis, and would be of interest to those looking at research methodologies that are relevant when designing tools for complex community practices such as research, learning, design thinking. Chapter 4, CAWriter, the creation of the tool to support the Ph.D. process using the framework developed in Chapter 2, this chapter will be of interest to those studying aspects related to Human Computer Interaction, Design and Computer Science. Chapter 5 explores how prototypes emerged from a non-linear design process, giving a little insight into the not so straight forward workflow that goes into producing a Ph.D. Chapter 6 outlines the findings of the user studies and participatory design sessions. The research questions are

answered within the limitations of the available data, an opportunity is also taken to conduct a meta-analysis of this work as framed by the Emergent Design process. This chapter is of interest to those looking for qualitative insights into the Ph.D. process from the case studies. Chapter 7 finally concludes the thesis addressing the limitations of this work and potential future research.

2. Literature Review – Analysis of Problem

This chapter develops a perspective of the Ph.D. process as an activity that involves the rich dynamic of tools, social engagement and the acquisition of research skills. It is important to note that there is no claim that the perspective taken within this thesis is the only or even the best perspective with which to view the Ph.D. process, but the argument is made that it captures the rich, dynamic and complex processes involved in conducting Ph.D. research and can act as a schematic perspective or system within which we can design, implement and test tools. As the chapter develops it will become evident that this dissertation practices what it preaches, in the sense that a certain perspective, schema or world view is developed as a framework within which the Ph.D. process may be viewed.

In order to explore the Ph.D. process in any detail, an exploration of the main aims of the Ph.D. process is required. The literature is largely unanimous on this topic and suggests that there are two central aims, firstly to make a significant contribution to knowledge and secondly as a professional qualification that demonstrates the Ph.D. candidate's ability to conduct "independent" research.

The first aim, that of making a significant contribution to knowledge, is the more classical purpose of a Ph.D.. This opens up questions about what constitutes knowledge and how one may contribute to it? The first section of this chapter attempts to explore these questions by first looking at the Ph.D. candidate as a *"knowledge worker"*. In order develop a thorough description of what "*knowledge work"* is, it is necessary to explore some of the research and philosophical discourse relating to knowledge development and knowledge claims. A number of authors, such as Vygotsky, have built upon Pierce's work on signs and symbols. These perspective provide the view of the knowledge worker as someone that works with knowledge at its most basic level (the sign) up to more complex systems such as mental schemas, systems, domain perspectives or theories. Popper's (Popper, 2002) view of World 3 Objects or Bereiter's (Bereiter, 2002) view of abstract artefacts allow us to view these schemas, perspectives or theories as entities that become independent of the original creator and may be shared and worked upon by other knowledge workers. For example this may be a contemporary Ph.D. student extending Einstein's theory of general relativity. It is only when the researcher reaches the frontiers of these shared knowledge constructs and push beyond these schemas that any significant contribution to knowledge is made.

The limitations of this new knowledge should however still be realised and how those limitations may affect the claims that can be made about these contributions. Popper's theory of falsification explores how these schemas are explored through a process of trial and error, and that, generally, one cannot prove anything true, but one may only claim what cannot be true. It may be argued that proof is possible in certain cases in pure mathematics or computer science, but these systems are always limited by the self-referential nature of such schemas as described in Gödel's Theorem (Hofstadter, 2000). Although a proof may exist it may be falsified if a new element is introduced that contradicts the previous schema. We advocate an evolutionary epistemology, within this research. This perspective influences and permeates the choice of research methodology, Participatory Action Research, the software development process, Wild/Agile/Extreme programming, and the Ph.D. process as described in this chapter. These all represent highly adaptable, reflexive and autopoietic processes. Knowledge Work is the process with which the Ph.D. candidate explores existing knowledge schemas and creates hypotheses and theories in order to create new schemas, thus making a contribution to knowledge.

The perspective of knowledge work as the manipulation and augmentation of abstract conceptual artefacts and schemas, provides a foundation for the development of socio-technical systems, in other words how knowledge workers use technology and machines to help augment their work. A number of Human Computer Interaction (HCI) theories such as, Distributed Cognition and Activity Theory, have built upon the works of Vygotsky (1978), Peirce (1868), and show parallels with the work of both Skagestad (1993) and Bereiter, where work is usually mediated through the use of some sort of tool. These HCI theories are used as a bridge from theory to design. The distinction between tools and symbolic representation becomes blurred and synonymous. The development of tools is seen here as the natural evolution of humanity, where our bodies no longer mutate, but we create and develop external organs, *'exosomatically' or 'extra-personally'* in the form of tools.

One of the most explicit and significant developments of this *'exosomatic'* nature is exemplified in the writing process. The writing process is largely conducted through the manipulation, either physically, virtually or mentally, of symbolic artefacts. As the written thesis is generally the artefact with which a Ph.D. candidates contributions to knowledge are judged, this makes the thesis and writing process central to the "knowledge work" of a Ph.D. candidate. Despite the obvious importance of writing in the Ph.D. process, there have been suggestions that writing is not explicitly supported in current Ph.D. programs (D. Boud & Lee, 2005). In order to help develop more explicit supports it is necessary to develop a schema within which we can frame the Ph.D. writing process, before we can look at the technological arts that may help embody these processes and supports.

Research exploring the writing process reveals that it is one of Creative Design and "knowledge transformation", as much as record keeping activity. This transformative nature of writing, as knowledge work, is the first hint at the Ph.D. as Emergent Design, i.e. creating something new with intent. It is not simply picking up a pen and writing, but a multifaceted process involving a range of different symbolic manipulation and cognitive processes. There are a wide variety of approaches to writing and different techniques that may be used throughout the process; a review of a small subset of these techniques highlights the symbolic manipulation nature of these approaches. It becomes evident that modern knowledge work is inherently a socio-technical activity where the use of tools and machines augments our cognitive abilities and in turn shapes and informs our work. In order to put some structure on this dynamic process and relate it explicitly to Ph.D. academic writing the "Single system" is reviewed as social practice framework that provides a simple heuristic schema around which to develop a socio-technical system.

The overview of writing activities and practices, and their importance to the Ph.D. process provides the foundations for the development of a socio-technical system, however there are a number of existing studies and technologies that have explicitly focused on the writing process. A brief state of the art in writing related technologies that encapsulate the creative nature of writing is reviewed, with a focus on non-linear editing, concept mapping and collaborative systems.

Having developed the perspective of Ph.D. candidates as knowledge workers and the relation it has to the writing process, it is important to explore the sociological context within which this work is occurring. The Ph.D. candidate is usually located within some community of researchers, at a university for example. Tacit knowledge is transferred and learnt by the Ph.D. candidate as they are engaged in legitimate learning experiences while collaborating with peers, academics and other members of their research community. Transfer of tacit knowledge happens through a process known as situated learning and a number of pedagogical frameworks advocate the Ph.D. process as an example of such a context: Cognitive Apprenticeship (Lave & Wenger, 1991), Communities of Practice (Johnson, 2001; Lave & Wenger, 1991; Miao, Fleschutz, & Zentel, 1999; E. Wenger, 1998b; E. C. Wenger & Snyder, 2000), and Peer Learning (Boud & Lee, 2005). These theories show us that knowledge is a socio-cultural construct and the social context will bias and influence the direction of the knowledge work, whether this is for the better or worse.

These pedagogical frameworks provide a description of the context within which Ph.D. learning occurs, however they do not provide explicit guidance as to what a Ph.D. candidate needs to learn and acquire in order to become fully fledged 'independent' researchers. In order to address this omission, this thesis explores Bloom's Taxonomy (Bloom, Krathwohl, & Masia, 1956) and

derivative frameworks to help elucidate the subtleties of the Higher Order Thinking required by Ph.D. candidates. Works like that of Holz et al. (2006) build and extend on Bloom's taxonomy to provide an explicit set of skills necessary for those within a research context. For example, activities such as reviewing the literature involve the analysis and evaluation skills. These frameworks identify a number of skills that both novice and advanced knowledge workers need to master, providing us with explicit skills which can be used to design supports.

Due to the social context of the Ph.D. process a number of works from the Computer Supported Collaborative Work/Learning field are explored. This provides a number of Heuristic schemas with which we can design collaborative and knowledge development features. These range from broad communication and awareness technologies, to tools to collaborate on knowledge building and argumentation development.

This chapter finishes with a synthesis of the literature that promotes an activity theory system model of the Ph.D. process where the dissertation writing process is largely creative in nature, where the frontiers of knowledge are approached and superseded. These ideas are then used to describe a set of design heuristics that will be used to design tools to support this creative process. It is important to note that this formulation emerged over a period of time as the research developed, and is the result of such a creative and transformative process, that is the nature of Ph.D. knowledge work.

2.1. Contributions to Knowledge

This section explores how contemporary research into learning and human computer interaction provide a novel perspective both of knowledge contributions and what working with knowledge can entail. A number of works over the last decade have advocated semiological perspectives of both knowledge and learning. These perspectives argue that learning and knowledge work occur through a process of symbolic manipulation and mediation. These ideas have been extended by Palmer (2009), Popper (1963) and Bereiter (2002) to create a perspective where these symbolic systems may be viewed as entities in their own right which may be worked upon, evolve, propagate and die, with many parallels with evolutionary biology. We shall now discuss how these ideas relate to the Ph.D. process and to contributions to knowledge in general.

A major criteria for awarding a Ph.D. is to make a contribution to knowledge. This opens up questions about what is knowledge and how could we contribute to it? The first section of this chapter attempts to explore these questions by first looking at the Ph.D. candidate as a *"knowledge*

worker". In order to develop a thorough description of what "*knowledge work"* is, it is necessary to explore some of the leading research and philosophy discourse relating to knowledge development and knowledge claims.

A number of works, such as that of Vygotsky, have built upon Pierce's work on Signs and symbols, providing the view of the knowledge worker as one that works with knowledge at its most basic level (the sign) up to more complex systems such as mental schemas, domain perspectives, conceptual artefacts or theories. As we will see in the following section Popper's view of "World 3 Objects" or Bereiter's view of abstract artefacts allow us to view these schemas, perspectives or theories as entities that become independent of the original creator and may be worked on by other knowledge workers. It is only when the researcher reaches the frontiers of these shared constructs and pushes through these boundaries that any significant contribution to knowledge is made (Palmer, 2008). The limitations of this new knowledge should however still be realised and how those limitations may affect the claims that can be made about these contributions. It is these boundaries that the Ph.D. student explores as part of knowledge work.

2.1.1. Knowledge as a System of Artefacts

The central tenet of this section is to highlight an alternative view of knowledge, whereby it is not only found, as it is traditionally viewed, in the individuals mind, but is distributed across both multiple minds (as conceptual artefacts) and physical artefacts (as books, tools, etc.). This has further been developed to include the "virtual realities" and computer interfaces that have developed over the last number of decades. This alternative view of knowledge has been hinted at in various forms over the past century or more.

Although some elements can be attributed all the way back to Aristotle and Socrates, it is Charles Peirce's work that utilizes modern terminology and it is his relating of these ideas to the scientific method that make him a good starting point for Western thought on the subject. Peirce explored thinking as a process of signification: the production and interpretation of signs (Skagestad, 1993). Peirce argues for a semiological interpretation of knowledge where it is the external representations as signs and symbols and that the ongoing interpretations of these representations is of more significance than the ephemeral thought residing in the individuals mind. Therefore the process with which one produces and interprets these representations is at the heart of our understanding of knowledge in general. What is important here is the apparent blurring in distinction between knowledge and the externalised tools used to work with and modify knowledge. This perspective

hints at a view of knowledge as a dynamic process or system rather than as a static or localised phenomenon.

"For higher functions, the central feature is the self-generated stimulation, that is, the creation and use of artificial stimuli which become the immediate causes of behaviour." (Vygotsky, 1978, p. 39)

These externalised artefacts acts as memory aids in the thinking process and help augment cognitive processes by diverting attention towards knowledge work rather than memory. Popper goes even further, where these externalised objects take on a life of their own, reminiscent of Dawkin's (2006) meme. Popper takes a pluralist view of reality, which is divided into three "Worlds". World 1 is the physical world of natural objects and events, the perspective familiar to materialists and positivists. World 2 is the world of the human thought and mental perceptions, this view is familiar to psychologists, interpretivists and similar qualitative disciplines. Finally World 3 is populated with human artefacts and concepts that are embodied World 2 conceptual artefacts found residing in the physical World 1. These World 3 'objects are autonomous artefacts that may be physical like a tool, or a scientific theory such as the "General Theory of Relativity". The interaction of Worlds 2 and 3 populates our reality with the signs and symbols as discussed by Peirce and Vygotsky.

These ideas have been advocated in recent times by Cognitive Psychologist, Carl Bereiter (2002). Bereiter's work promotes the idea that knowledge is not something that is merely contained within the individual's brain but that it is something that may be worked on conceptually or physically and may be both physically and socially distributed. The next section will discuss this higher form of "work" which will be referred to as "knowledge work".

2.1.2. Knowledge Work

"Work is not merely the production of predetermined and already designed objects. Rather, there is radical work that produces new things, which, in turn can change the world either in part, or sometimes, as a whole." (Palmer, 2009, p. 280)

Palmer's thesis outlines a specific perspective of Knowledge Work. Although there are many types of work, what is of interest here is the "radical work" where ideas or concepts are added to or altered. Carl Bereiter's work complements Palmer's approach, where he argues that society and educationalists need to shift their focus to this perspective where knowledge is worked upon and developed, if we are to teach students to be effective participants in the "Knowledge Age". Knowledge is not seen as something that is merely passed on, but it is an active process where

autonomous knowledge artefacts can be shared, created, managed, improved and applied. The point here is that knowledge work should be viewed in a similar way as other work is, it is usually focused on or utilises artefacts or objects of some sort, knowledge work is no different but sometimes it deals with more abstract conceptual artefacts not necessarily found in normal work.

"Here, we will define work in its preeminent status as the production of Emergence within humanly produced artifacts, the arising of which is part of the Emergent Event. This is an essential type of work that utterly transforms the world as part of the Emergent Event. All other transformations are degenerate modes of that most radical type of work." (Palmer, 2009, p. 279)

Palmer's use of the term Emergence can be paralleled with what has been referred to as a contribution to knowledge: although it has even more far reaching connotations. As we have discussed, knowledge is no longer only the slave of the mind, but can be viewed as emerging autonomous artefacts that may take on a life beyond their creators and may even shape peoples actions and thought without their explicit awareness.

Palmer's work focuses on the pinnacle of achievement, in what he considers the higher levels of Being. His thesis essentially deals with the emergence of new ideas or Designs. The word Design means to "mark out", and shows striking similarities with the arguments made previously about knowledge work being an activity mediated through signs and symbols. The central point about Emergence is that when a scholar frames their worldview as some schema or "system", they use that framing and the skills they have acquired to help them reinterpret these systems. This reinterpretation of their current system view allows them to push the boundaries of that system in order to discover new insights, possibilities or limitations. A new system may be created, once these new insights and interpretations have been reincorporated from what Palmer refers to as the “meta-system”. It is this process that is the basis for modern scientific research, but it is important to realise that these systems are always just worldviews, perspectives or projections and that an encompassing "meta-system" will always be on the boundaries of their current projection of reality. This has consequences for claims to truth and fact, but it does provide a framework that can easily incorporate discovery and creativity. The issue of claims to truth and fact are discussed in the following sections.

2.1.3. Knowledge claims

What claims can we make to true knowledge? What are the limitations of our knowledge? The answers to these questions will influence how we work with knowledge and how we can design for

this work. Realistically there are no true answers to these questions, as we shall see, but that what is possible is the creation of socio-culturally and temporally accepted world views that can be used to explore and transform certain knowledge domains.

In order to explore the frontiers of knowledge and how one may work on knowledge, we first need to explore the literature that considers the limits and boundaries to our knowledge claims. Epistemological issues and arguments about knowledge validity and creation can help shed some light on this subject.

"I have sometimes compared the human situation in the quest for new knowledge with the proverbial situation of a blind man who searches in the dark room for a black hat which is - perhaps - not there. This is not saying much: but it indicates that the searcher at least acts as if he had a problem. I have often added that the trial movements of the searcher will not be completely random. ... ... that the searcher has a problem to solve, and that this means that he has some knowledge, however fuzzy, previously acquired by essentially the same trial-and-error method; this knowledge serves as a guide, and eliminates complete randomness." (Popper, 1987, p. 117)

As the quote from Popper above comically suggests, no person can actually know anything for sure, but it's the attempted pursuit that is of importance. Popper's view here is a product of his theory of falsification, where theories cannot be proved, but rather, can only be falsified, supporting his epistemological perspective of knowledge evolution through a process of trial-and-error. One may argue that there other perspectives that differ from Popper's perspective or even others that may differ in only small positions: positivism, post-positivism, interpretivism, phenomenology etc. This diversity of perspectives only reinforces Popper's pluralistic view of knowledge where there is a World of very different abstract artefacts, such as theories, methods, beliefs and tools. No matter what theoretical perspective one takes, a perspective is simply a mental schema or ontology within which to frame and transform knowledge.

The idea here is to frame a perspective of knowledge as an evolutionary process, thus providing a framework within which we can view the Ph.D. student as an agent that actively works to shape and evolve collective knowledge.

In a paper by Bateman (1995), he discusses what is meant by ontology, he starts by defining the original use of the word, from a philosophical perspective.

"Ontology was first and foremost an attempt to reveal the essential nature of what can be, of what exists, of reality" (Bateman, 1995)

Bateman goes on to state that one cannot go much further here, as the proposition is so broad. In an effort to ease this issue, "be" is interpreted to mean what can be accepted as a world-view, shared meaning or understanding. Our understanding of the world is built using language, as a socio-semiotic construct. This view is consistent with the view that knowledge is constituted of mentally symbolic constructs and understanding is a process of continual negotiation (Barab & Duffy, 1998; Bereiter, 2002; Peirce, 1868; Skagestad, 1993; Vygotsky, 1978). Bateman goes on to say that this is what constitutes formal ontologies and as a result they are in a constant state of flux.

"The formal semiotic ontology is provided by fundamental dimensions such as stratification, metaredundancy/realization, paradigmatic alteration, and syntagmatic chaining." (Bateman, 1995)

This fits with Popper's evolutionary epistemology which promotes the perspective that concepts evolve and change. It also suggests that for a collaborative learning community to be effective, the learner must be involved in the formation of the ontologies that are used within the community. Knowledge work is this collaboration and involvement, and any augmentation to the perspectives or schemas within that community may be considered as a contribution to knowledge.

"As spacetime projections of intelligible organizational templates, schemas are fundamental to our relationships to everything in our environment, including ourselves. When we do science, we are trying to understand and unlock the design of nature in a way that goes beyond our schematic projections. But when we implement the design of artifacts, we are using the schemas as the basic templates for the objects that we will produce through our design activities. Those objects are artificial, not natural." (Palmer, 2009, p. 20)

Palmer's quote here summarises what we have discussed the last section. Knowledge and science are both formed of schemas or projections which we design and augment so that we can explore the boundaries and limitations of these very same schemas. It also again blurs the distinction between concept artefacts constructed of signs (words and language) and the tools we use to work on and with these signs. The following section explores the significance of these tools and looks at contemporary Human Computer Interaction theories that may provide a means with which knowledge work activities may be viewed as the interaction of tools, cognitive functions and temporal goals.

2.2. Thinking with Machines

"Human evolution proceeds, largely, by developing new organs outside our bodies or persons: 'exosomatically', as biologists call it, or 'extra-personally'. These new organs are tools, or weapons, or machines, or houses. Noting that other animals build lairs, nests, and dams, Popper points to the greater role played by exosomatic organs in human evolution, stressing the higher functions of language already postulated by Bühler: 'Yet the kind of exosomatic evolution which interests me here is this: instead of growing better memories and brains, we grow paper, pens, pencils, typewriters, dictaphones, the printing press, and libraries. These add to our language - and especially to its descriptive and argumentative functions - what may be described as new dimensions. The latest development (used mainly in support of our argumentative abilities) is the growth of computers.' " (Skagestad, 1993, p. 163)

The idea that we can use machine and tools to support our cognitive faculties has surfaced in many other works including some mentioned above under contemporary cognitive models such as cognitive apprenticeship and in theories such as distributed cognition and activity theory (Engeström 2008; Hollan, Hutchins, & Kirsh, 2000; Lave & Wenger, 1991; Resnick, 1987; Skagestad, 1993; E. C. Wenger & Snyder, 2000) and probably most explicitly in a research context with Vannevar Bush's vision of the Memex(Bush, 1945). Two theories, distributed cognition and activity theory have been extensively used in designing human-computer-interactive interfaces (Blandford & Furniss, 2006; Collis & Margaryan, 2004; Fjeld et al., 2002; Halverson, 2002; Hollan, et al., 2000; Jaworski & Goodchild, 2006; Matthews, Rattenbury, & Carter, 2007; Rogers, 2006; Wright, Fields, & Harrison, 2000) and should help in bridging the gap between theory and practice.

2.2.1. Human-Computer Interaction Approaches

The perspective of knowledge work as the manipulation and augmentation of abstract conceptual artefacts and schemas, provides a foundation for the development of socio-technical systems, in other words how knowledge workers use technology and machines to help augment their work. A number of Human Computer Interaction (HCI) theories such as Distributed Cognition and Activity Theory, show a number of parallels with the works of Peirce, Skagestad and Bereiter, where work is usually mediated through the use of some sort of tool. These HCI theories are used as a bridge from theory to design. The distinction between tools and symbolic representation becomes blurred and can become synonymous.

2.2.2. Distributed Cognition

Distributed cognition is a framework that looks at cognition as system that is distributed socially, temporally and externalised (Holland, Hutchins et al. 2000), which contrasts with the more traditional ideas where cognition would classically be viewed as solely occurring in the learner's head. This can be useful to get an overview of a particular learning situation, the people involved, their roles, and what artefacts are used to support it.

Distributed cognition is good as a general framework to conceptualise a cognitive system, but does not emphasise a step-by-step guide to the process (Halverson 2002) making it difficult to analyse and distinguish the multifaceted nature of the doctoral program.

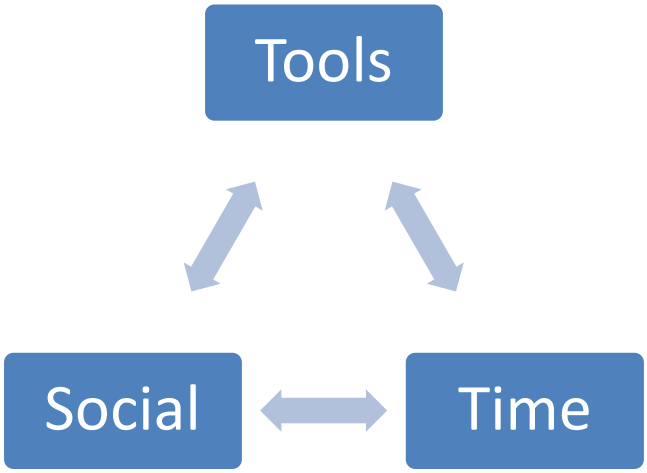


Figure 2-1 Distributed Cognition

Oatley (2000) mentions three forms of distributed cognition that emphasize the different interactions that occur within collaborative communities, temporal distribution, social distribution and externalization. These forms of distribution are not to be taken independently but as aspects of a dynamic interaction of the three.

Temporal distribution is the distribution of cognition over time, this allows an individual to adapt their behaviour as time goes by, that is they are able to learn to act differently for the future. It also plays a major role in cultural transmission, which develops from the social and sentimental goals of affiliation. Temporal distribution allows for an individual's beliefs to converge with those of the wider community, thus promoting empathy and the resulting affiliation and identification.

Social distribution allows for humans to distribute their cognition in order to overcome some of the defects of individual cognition, such as bias. This factor is very important in the progress of scientific knowledge as discussed by Popper (Popper, 1963), whereby knowledge evolves not from confirmation of theories, but by seeking disconfirmation, as peer-reviewed systems endorse. Social discourse also provides a source of dissonance, as members of the collaborative environment may introduce new concepts, with the added benefit or trust and identification between the participants, thus providing both the resources and motivation to alter their belief structure. Oatley also proposes that this form of distributed cognition is what gives rise to affiliation, as it arises from the desire to accomplish common goals that would not be attainable by the individual.

These ideas may be expanded upon if the ideas of communities of practice are explored (Barab & Duffy, 1998; Lave, 1993; E. Wenger, 1998a). Interactions with the environment are not just viewed as producing socially accepted meanings but also produce identities that relate to and interact with the social environment. This promotes a sense of purpose and meaning for both the individual and the wider community. It is suggested that concepts should not be viewed as "self-contained entities" but rather as tools that can only be understood through use. This view compliments Oatley's third form of distributed cognition, externalization.

Externalization is a process that allows the conversion of difficult to perform tasks to something that is relatively easy to accomplish, through the use of technology. Language and writing are used as examples of such externalization. Writing allows us to refine our use of language allowing us to read, edit, transform and rewrite what we have written. There is some support for the idea that socially distributed and externalized cognition have both technological (Resnick, 1987) and "verbal-emotive" (Forsyth & Eifert, 1996) expressions. In Forsyth and Eifert's work they claim that language is not only "verbal-emotive" but also "social-verbal" where "semantic conditioning" and "emotional meaning" are to be considered.

2.2.3. Activity theory

Activity theory builds largely on the work of Vygotsky, as discussed previously, where cognition is mediated via external stimulus such as tools, language and social interactions. Engeström (2000) developed this further by adding details such as community, rules of activity and the division of labour. This provides a very rich and detailed framework under which to explore activity.

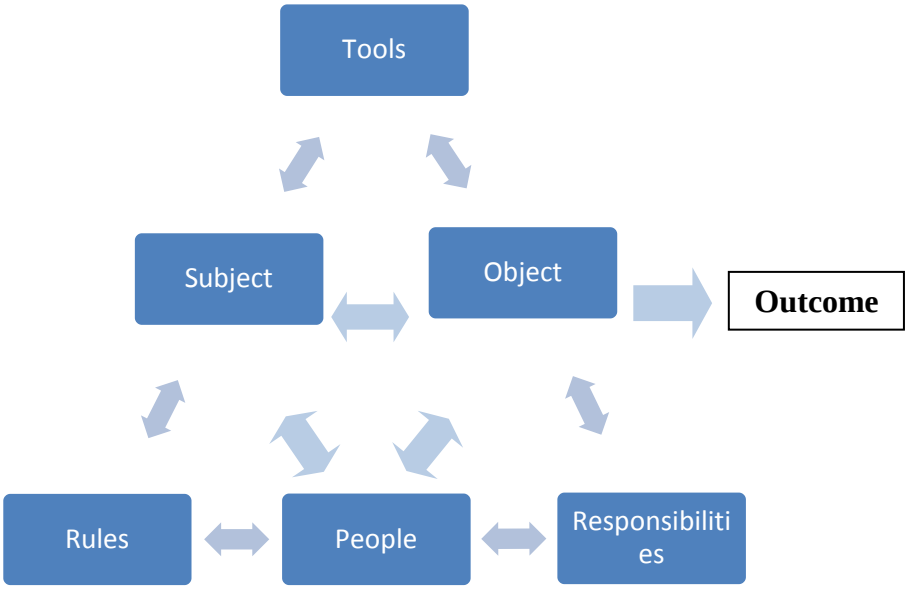


Figure 2-2 Activity Theory Systems

Activity theory allows for a more granular view of activities, whether they are sub-activities or larger motivational activities. Although it provides a richer framework to explore activities it can be harder to learn initially due to its complex conceptual structure (Halverson, 2002).

There are also suggestions that Activity Theory may be good for highlighting tensions in varied activities (Hopwood & McAlpine, 2007) that may be involved within a complex social process such as the professional development of a Ph.D. candidate i.e. activities related to the Ph.D. thesis and professional development such as teaching, attending conferences, workshops, etc.

"the personal computer must be evaluated not simply on the basis of the greater efficiency with which it enables us to carry out familiar tasks, but on the basis of the value of the new modes of thinking this machine enables, inspires - or perhaps enforces." (Skagestad, 1993)

2.3. Writing in Doctoral Education

As writing and writing related activities are explicit examples of the knowledge work described above, it is clear that they require further enquiry with a particular focus on their relevance to doctoral education. The previous sections have discussed knowledge work and human-computer

interaction theories, but do not deal with the central activity related to doctoral work, the production of a written thesis. Building on the activity focus of Activity Theory, the following section looks at academic writing as a number of activities that are interlinked. The first is to look at the thesis writing process as a creative design activity. The second is to acknowledge the social context within which the creative process occurs. Finally tools and technologies are reviewed that may offer design heuristics and guidelines that might help to support both the activity itself and the social context within which it is embedded.

"when it comes to doctoral-level candidature, however, there has been almost deafening silence. Instead, as Paré et al. [2009] note, apart from one-to-one work with supervisors, doctoral students in many disciplines are left to learn the normalising ways of writing and speaking in their research communities by observation and trial and error. And, as they demonstrate, supervisors are often poorly equipped to address the need." (Lee & Aitchison, 2009)

Lee and Aitchison (2009) highlight that academic research writing is a crucially important, yet inadequately supported process in doctoral education as opposed to undergraduate studies.

2.3.1. Writing as Creative Design

Palmer's idea of Emergent Design that helps frame a view of writing as one Creative Design. His view is focused on Design in general but numerous mentions are made to writing as a clear instance of a design process, whether explicit or not. These ideas have been reiterated by Skagestad, Sharples and others.

"Quoting Pea(1993) 'We should reorient the educational emphasis from individual, tool-free cognition to facilitating individuals' responsive and novel uses of resources for creative and intelligent activity alone and in collaboration. Such an education would encourage and refine the natural tendency for people to continually re-create their own world as a scaffold for their activities.'"(Bereiter, 2002, p. 81)

Pea, as quoted by Bereiter, again reiterates the view that cognitive activities should acknowledge the role tools play. Through the use of such tools the learner continually creates a world view which they can use to guide their work and scaffold their processes. This thesis argues that the doctoral dissertation process is analogous with this perspective, where the Ph.D. candidate works on their literature review, research methodology and overall framework, as abstract semiological systems, through an iterative and knowledge creating activity.

The suggestion that writing is a *"knowledge-creating"* rather than merely knowledge-recording activity is further supported by Sharples where he suggests that writing may be viewed as a creative design process (Sharples, 1999). This is traced back to the knowledge transforming model of writing found in the Bereiter and Scardamalia work in *"The Psychology of Written Composition"* (1987).

"Design: A plan or scheme conceived in the mind and intended for subsequent execution; the preliminary conception of an idea that is to be carried into effect by action; a project." (Dictionary, 1989)

The definition of design from the Oxford English Dictionary, shows how a scheme or plan is linked to action through the design process. One point of concern with this definition is the phrase *"in the mind"*, as has been emphasised in the previous sections, the idea that cognition is located wholly in the mind is questionable. Tools play a major role in the design process and external representation and interpretation is an essential part of the process that seems missing from the standard definition.

In Sharples work there is regular reference to visual representations, during the planning stages right through to the construction of arguments as one develops one's prose. These visualisations come in a range of different forms including; note networks, mind maps and flow charts. This suggests that a wide range of graphical and semiological representations are important throughout the writing process.

Sharples work provides a starting place with which to model writing activities, as a creative process. Having a more detailed model of the creative process will allow us to design tools that try to facilitate various aspects of the model. The following section deals with this creative process in more detail, with the hope to adopt a more succinct model for creativity.

2.3.1.1. Creative Phases

Creativity is a complex and often difficult subject to define, with multiple definitions being developed over the past century (Warr & O'Neill, 2005). Thankfully Warr and O'Neill have conducted an excellent review of the creative process as it relates to design. They analysed the seminal works in the area and condensed the various approaches into a simple table (Figure 2-3). Here there are four main phases described: Analysis of the problem, Generating Ideas, Evaluating Ideas and Donating. Analysis of the problem can involve early preparation, collection of relevant

notes and content, fact-finding and task presentation. Generating ideas involves the creation, incubation, discovery and illumination of ideas. Both the Analysis and Generative activities are reminiscent of Sharples use of notes networks, mind mapping and flow charts. Evaluation of ideas requires verification and validation of ideas. Donation only arises due to Shneiderman's work on the topic, but this is viewed as critical in the context of this work as this represents the Ph.D. dissertation and the contribution to knowledge.

<table>
<tr><th>Models</th><th colspan="2">Analysis of Problem</th><th colspan="2">Generating Ideas</th><th>Evaluating Ideas</th><th>Donating</th></tr>
<tr><td>Wallas</td><td colspan="2">Preparation</td><td>Incubation</td><td>Illumination</td><td>Verification</td><td>X</td></tr>
<tr><td rowspan="2">Osborn</td><td colspan="4">Idea Generation</td><td rowspan="2">Idea Evaluation</td><td rowspan="2">X</td></tr>
<tr><td colspan="2">Fact-finding</td><td colspan="2">Idea-finding</td></tr>
<tr><td>Amabile</td><td>Problem or task presentation</td><td>Preparation</td><td colspan="2">Response generation</td><td>Response Validation</td><td>X</td></tr>
<tr><td rowspan="2">Shneiderman</td><td colspan="2">Collect</td><td colspan="3">Create</td><td>Donate</td></tr>
<tr><td colspan="6">Relate</td></tr>
</table>

Figure 2-3 Amalgamation of Creative Phases (Warr & O'Neill, 2005)

This model is a powerful addition as provides a rich set of tasks and goals that can be used to develop richer activity systems around which tools can be designed. However, it does not provide explicit design heuristics for the technological support of the creative process. The next section will explore how Cognitive Dimensions may provide such a set of heuristics, we shall see that Wood's (1993) has developed a framework that is highly relevant to creative Ph.D. writing activities.

2.3.1.2. Cognitive Dimensions for Idea Sketching

Cognitive dimensions provide the designer with a framework to both help in the development and evaluation of an "*information-based artefact*" (Green, 1989; Green & Blackwell, 1998). They focus more on broad, easy to understand dimensions with which a non-specialist can either design to support or evaluate an existing system against. There is a trade-off between ease of use and the level of depth of analysis, meaning that it may not be suitable for highly detailed analysis but should make an excellent choice for non-specialists and those collaborating with participants unfamiliar with HCI techniques.

Although Green developed 13 dimensions in the original framework, another work that focuses on Cognitive Dimension of "idea sketches" is of more relevance (Wood, 1993). Wood's Cognitive Dimensions were developed based on both Green's dimensions and on observation and interviews conducted with Ph.D. students as they collaborated together while preparing papers for publication. It is highly relevant to the issue of designing tools to support academic writing as it provides a

comparison to conventional media, such as pen and papers, and makes explicit reference to “mind maps” and “spider diagrams”, both of which are relevant to the design of concept mapping spaces and how they ultimately relate to the production of a written document. Wood provides a set of 8 main Cognitive Dimensions with a number of sub dimensions ().

Table 2-1).

Table 2-1 Wood’s (1993) Cognitive Dimensions for Idea sketching C.C. Wood

Delayed Gratification	How much effort and delay is involved in creating a representation. It is sometimes important to get ideas down quickly and conventional media is often better for this.
transparency	Can the user be unconscious of the system and concentrate on the task? It is important that the interface does not demand cognitive resources. Computers are more opaque than paper!
richness	Does the representation include many graphical marks, redundant encodings, etc, because it is quick and easy to make it so? Richness facilitates perceptual cueing.
Terseness	Are there few symbols per idea? Terseness allows overview, structurability, lower delayed gratification and in turn higher richness. Conventional media seem to favour terseness.
overview	Can the user perceive much of the representational structure at once? Overview favours accessibility and structurability. Conventional media afford better overview.
structurability	Is the user's ability to reorganise the structure facilitated by and increase in accessibility and lowering of viscosity which results from terseness?
visible area	Is there a large display area for the representation? A large visible area, combined with terseness, supports overview and structurability.
Perceptual cues (typographical)	Can the user produce many typographical marks easily? Typographical cues are facilitated by low delayed gratification and help accessibility by providing an access structure.
Perceptual cues (graphical)	Can the user easily produce graphical marks like clustering, linkng, etc? Graphical cues may not be produced on computer due to low richness.
Accessibility	Can the user access information with ease? Where idea labels are continuously perceived they help maintain elements in working memory and assist long term memory retrieval.
location through perceptual cues	Do perceptual cues help the user direct attention to the relevant parts of the representational structure? Computers do not generally allow such rich perceptual access structures.
facilitation through terseness	Does terseness assist the user in directing attention to the required parts of the representational structure? Conventional media seem to allow this more.
meaning through perceptual cues	Can perceptual cues be used to carry meaning, or provide context which facilitates the recall of meaning? Conventional media may facilitate recall with perceptual cues more than computer.
Premature commitment	Is the user forced to make choices too early in the task, or can she explore different options fully with the representation? Many idea sketchers use ambiguous notes.
downsliding	Is the user drawn into fine grained production of grammatical sentences, when they are trying to operate at a more global, exploratory level? Downsliding leads to premature commitment.
finished character	Does the typographical character of a representation fairly reflect its provisionality, or does its finished looking character mislead the user? Computer text can lead to downsliding.
Viscosity	Does the representation offer high resistance to editing? Computer "cut and paste" should reduce viscosity, but it is not a great problem for conventional media.
exhibits evolution	Does the representation display its history, as well as its current state? History is likely to be diaplayed if deletion is difficult, and may provide context which assists encoding and recall.
temporariness	Is there much investment in the representation, or is it intended to be thrown away shortly after production? Temporariness overcomes viscosity, and discourages premature commitment.
Formalness	Does the representation unambiguously carry meaning for someone with the right background and language, or does it rely heavily on context for interpretation? Idea sketches are informal.
faithful conveying	Can the representation be used for asynchronous communication with others or the self? Informal idea sketches are often unintelligible outside the context of their production.
semantic potential	Can the representation mean different things? Semantically potent representations are quicker to produce, terser, avoid premature commitment, and lower viscosity.

These dimensions may be used to inform prototypes and tackle usability issue early on in the process. They may also be used later in the process in order to evaluate an existing design and inform improvements or alterations to the design.

2.3.1.3. Single's System for Dissertation Writing

A large part of this knowledge work is through the manipulation, either physically or mentally, of symbolic artefacts, whether these are textual notes, sketches, final prose or mathematics. The next section of this chapter explores the writing process as one of Creative Design, where it is not simply opening up a word processor and typing, but a multifaceted process involving a range of different symbolic manipulation processes. In order to put a little structure to this dynamic process and relate it explicitly to the Ph.D. we will explore the "Single System" for dissertation writing.

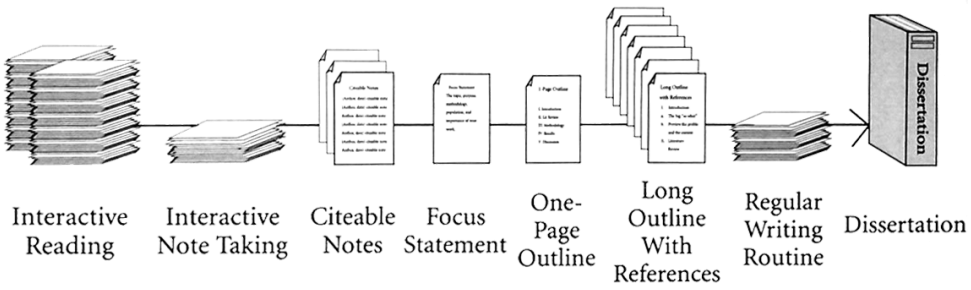


Figure 2-4 The 'Single System' for academic writing

Single (2009) sets out a comprehensive guide, the "Single System" (Figure 2-4), which covers a number of different phases involved in the production of a doctoral dissertation. The "Single System" offers a number of suggestions as to how each phase may be facilitated but there are no set rules or procedures that one must adhere to in order to progress. The process starts with what Single refers to as "interactive reading" which provides the student with the opportunity to familiarise themselves with the "expectations, structures, formats, and styles" found within the writing in their academic field(s) of study. This higher level study of writing allows them to cover future reading in a faster and more efficient manner. During the interactive reading phase, rough notes are sketched on the document highlighting various aspects e.g. the main point, results, theoretical approaches or methodologies etc.

"Interactive note taking" follows on from interactive reading. Here one collects the rough notes into more coherent notes on the paper, book or the text one is reading, and adds any other relevant

information, such as quotes. If well written these notes can negate the need to refer back to the original paper later on.

"Citable notes" are created from a synthesis of the interactive notes. These should be small notes that contain references and the "active ingredient" of the literature. The citable notes should help categorise and theme the literature so as to relate to one's own thesis topic. The idea being that a lot of time can be saved when it comes to writing prose, as one may refer to the citable note when outlining and then refer to the relevant interactive note if necessary. Again this reduces the need to refer back to the original papers.

The authors of this chapter argue that moving through the stages as presented so far in the "Single System" helps support the core cognitive skills of synthesis, analysis, evaluation and melioration. Creating coherent "interactive notes" necessitates analytical skills. Moving from interactive notes to citable notes requires the student to engage in synthesis, evaluation and melioration as they bring the ideas from a number of sources together into an original form.

Once the student has a good grounding in the literature, it is time to make an attempt at a research focus statement. Single describes a focus statement as a clear and concise guiding paragraph of between one and four sentences that communicates the essence of the dissertation. It is meant to focus the student's research direction and stop them veering off and wasting time in unnecessary areas. It must be concise, yet compelling to the student as they will be spending a number of years on the topic.

Single recommends group work for writing the focus statement, where groups of two ask a series of questions to explore the research domains they are interested in. Although the focus statement is a guiding tool for the student, there is no reason that it cannot change over time, as formulating it is an iterative process. The only thing that remains the same is that it is still concise and compelling.

After the focus statement has been formulated, a one-page outline is created. This outline regularly follows one of three common dissertation formats; thematic, data analytical and journal article. The first step is to brainstorm about where their work sits in the big picture, here a range of questions explore the implications and relevancy of their research beyond the scope that they would normally consider. The brainstorming should also tackle issues such as sources of data, methodologies, possible findings and theoretical concepts. Next, three main themes are to be highlighted from the students citable notes and understanding of the topic, again these are preliminary and may change,

but act as guidance in the process. These themes take their place as headings within the overall dissertation format as discussed above.

The long outline develops from the one-page outline. The headings from the one-page outline are expanded to include their own focus statements and sub-headings. Citable notes are then inserted into the appropriate sections, thus bringing references with them. This ultimately creates the basic structure of the dissertation on which to work.

A regular writing routine is recommended; meaning writing time should be set aside and adhered to. This provides time not only to write new content put also to revise previous writing. Single also suggests setting up a writing network to help work on ideas and motivate each other to write. Achieving a regular writing routine should also satisfy the need to attain the meta-cognitive skill of self-regulation, as set out by Holz et al.

Revision can take two forms, at the structural level or at the paragraph level (Single, 2009; Sharples, 1999). The structural level is organisational in nature, whereas the paragraph level dictates the flow and style of the work.

Single suggests a number of methods for paragraph level revision. One method to highlight is the idea of "smoothing", where each paragraph discusses one concept only. This may be achieved through numerous iterations, finally achieving one concept per paragraph. Single also suggests looking at the work of Strunk (2006), "The Elements of Style", as a reference when looking at sentences and paragraphs at a micro-editing level.

The "Single System" provides an excellent scaffold upon which to design a comprehensive tool to support dissertation writing. A number of innovative writing tools have been developed with functionality that coincidently reflect a number of the tasks found in the "Single System", the following section will explore two of these in brief.

2.3.1.4. Research Skills

The literature reviewed so far does not make explicit the skills novice researchers need to master. The wider pedagogical literature specifically addressing computer science doctoral training, the context in which this research is taking place, is limited except for a noticeable exception, an ACM taskforce paper on research methods in computing (Holz et al., 2006) which extends Bloom's taxonomy of higher order thinking skills (Bloom, Krathwohl, & Masia, 1956) for the domain of computer science doctoral training education. Holz et al. describes the research skills computer

science researchers need to master (Holz, et al., 2006). They categorise core research skills as ranging across a number of areas including: Organisational, Expressive, Cognitive and Meta-Cognitive. The extended framework covers "core skills", such as synthesis, evaluation and analysis, which are largely applicable to all scientific disciplines and a set of "specific skills". These specific skills include selecting papers, analysing the literature, writing research proposals and evaluating results. Of particular interest are those skills listed under cognitive skills, as these are rarely supported in existing virtual research environments (Carusi & Reimer, 2010).

The cognitive skills are:

Analysis:

"A thorough study to comprehend the structure of the learned content, its formal and logic way of organization, in order to detect the elements, outlooks, and methods this content is based upon." (Bloom et al., 1956)

The first phase of the creative model is analysis of the problem, meaning that Blooms taxonomy again aligns well with the creative processes. Activities such as preparation, fact finding, preparation and collecting help in the analysis of the subject of interest.

Synthesis:

"Establishing a whole new creation by combination of ideas from different sources, in a way that formats and molds will be created, and will stand at the basis of the new creation." (Bloom et al., 1956)

Synthesis aligns itself quite well with the generating of ideas phase in the creativity model discussed previously in section 2.3.1.1. This involves the incubation, relating, illumination, idea-finding, creating and response generation.

Evaluation:

"Judging the values in the ideas through use of standards of estimations, that will determine the accuracy level, purposefulness and practicality of the details." (Bloom et al., 1956)

Blooms evaluation aligns with the evaluating ideas creative phase. This involves attempting to verify, validate and evaluate ideas.

Melioration:

"The skill of selecting the appropriate amalgam of information and applying it to a solution of problems in situations, which arise at different times and places, thereby meliorating the amalgam." (Holz et al., 2006).

Melioration is similar to evaluation, but at a higher level. It involves critically reviewing the systems of schemas developed in the preceding phases so that they can be considered valid when applied.

Computation:

"At a loss for a better word, we termed the ability to cognitively manipulate active abstract objects computation." (Holz et al., 2006).

It is evident that these skills are invaluable to computer science research students, and with the possible exception of "computation", may be generalisable across any scientific discipline. Although computation may at first, not seem applicable, it may be applied to the writing process and knowledge work in general as per the arguments mentioned previously where writing is a process of manipulating abstract concepts and artefacts. Holz et al. also list a set of specific research skills associated with research. The specific research skills (Table 2-2) emphasise a number of early writing related activities such as reviewing and analysing the literature, writing research proposals, through to the final presentation of a written thesis.

Now that we have explored the Ph.D. candidates as knowledge workers and the place technology plays in their work, it is important to explore the social context within which this work occurs. The Ph.D. candidate is usually located within some community of researchers, usually at a university or some similar third level institution. Tacit knowledge may be transferred and learned by the Ph.D. candidate as they are engaged in legitimate learning experiences while conducting their research and collaborating and cooperating with their supervisors, peers, other academics and members of their community.

This form of knowledge transfer is known as situated knowledge and there are a number of pedagogical frameworks that have been advocated as describing the learning practices and context common in the Ph.D. process. Pedagogical theories and practices on doctoral training generally emphasise the social and collaborative nature of learning (D. Boud & Lee, 2009; Hopwood & McAlpine, 2007; Leshem, 2007; McCotter, 2001) Community of Practice (Johnson, 2001; Lave &

Wenger, 1991; Miao, et al., 1999; E. Wenger, 1998b; E. C. Wenger & Snyder, 2000), Cognitive Apprenticeship (Lave & Wenger, 1991) and Peer Learning (Boud & Lee, 2005) provide theoretical frameworks that best describe the social environments and practices in which doctoral candidates can be supported in the transition from novice researchers to legitimate members of the academic community.

Table 2-2 Holz et al. Specific Research Skills

1 Search Literature	12 Collect Data
2 Scan Papers	13 Verify Data
3 Select Papers	14 Analyse Data
4 Analyse Literature	15 Evaluate Results
5 Critique Literature	16 Draw Conclusions
6 Analyse Research	17 Identify Limitations
7 Critique Research	18 Link Research to Body of Knowledge
8 Formulate Research Questions	19 Connect Theory to Practice
9 Identify Ethical Concerns	20 Present Results: Oral
10 Choose Methodology	21 Present Results: Written
11 Write Research Proposal	22 Present Results: Other

2.3.2. Pedagogy in Doctoral Education

Lee and Aitchison (2009) emphasise the benefits of engagement with a community of writing practice, such as writing groups, for both the acquisition of writing skills and an in-depth understanding of how knowledge is created. Therefore, understanding the best practices and strategies within any domain is an essential element when designing a tool. This section reviews the pedagogical theories which are relevant to doctoral training.

"A community of practice is an intrinsic condition for the existence of knowledge, not least because it provides the interpretative support necessary for making sense of its heritage. Thus, participation in the cultural practice in which any knowledge exists is an epistemological principle of learning. The social structure of this practice, its power relationships, and its conditions for legitimacy define possibilities for learning (i.e. for legitimate peripheral participation)." (Lave & Wenger, 1991)

As described by Lave and Wegner, the concept of a Community of Practice (CoP) acts as a socially constructed interpretive framework within which doctoral learning occurs in a sociocultural-historical context (Cumming, 2008). Three principles summarise the characteristics of a community of practice: a shared domain of interest, engagement in mutual learning and knowledge sharing, and a shared repertoire of resources (Leshem, 2007). In both the works of Leshem (2007) and Cummings (2008) they suggest that the application of the CoP concept to doctoral programmes can support candidates in their learning of research practices. This may be achieved by fostering and developing communities that encourage the sharing of experience, knowledge and practice and in fostering legitimate participation both with their peers and supervisors.

Cognitive Apprenticeship builds on the traditional craft apprenticeship model where the learner acquires, develops and uses skills obtained from the practices of experts, through observation and collaboration in an authentic social context (Brown, Collins, & Duguid, 1989). In this view, and that of situated learning, the locus of learning, like in Distributed Cognition and Activity Theory, expands beyond the more traditional interpretation of learning taking place within the individuals' mind, to that of more socially distributed processes, in what Lave and Wegner call *"legitimate peripheral participation"* in a *"community of practice"*. Here the focus is on situated activities rather than simply the transference of factual knowledge. Participation not only influences the learner, but also the social practice in which the learner and experts are engaged; they are co-dependent and dynamic processes.

In keeping with the views taken by Boud & Lee (2005) and Hopwood & McAlpine (2007), it is appropriate to view the doctoral process as a good example of a cognitive apprenticeship model in action. The student learns from expert supervisors, research staff and peers, gradually moving towards "full participation" within the community.

Boud and Lee (2008) challenge the dominant focus on supervision and *"provisionism"* and suggest that a more appropriate pedagogic discourse should draw on the familiar notion of *"peer"* from the world of research. They support the notion that research occurs as part of a CoP and view the

research environment as a pedagogical paradigm in and of itself. They argue that the doctoral process has had little in the way of pedagogic practices applied to it and that it is approached almost wholly from a supervision perspective rather than that of a learning process.

In this context the term *"peer"* has two meanings, first in the sense of learning from and with fellow students, co-workers and collaborators. An example fitting with the theme that doctoral training is a collaborative and social practice; the "Single System" involves workshops and seminars, and argues that there are many benefits to peer reading and writing groups. Secondly in the sense of becoming a research peer moving from the vertical relationship of supervisor-student towards a more horizontal relationship of researcher as peer in a network of "*independent*" knowledge workers. Italics are used due to the argument that all knowledge work actively involves social aspects of one form or another.

In the pedagogical theories discussed above there is mention of the students learning skills and tacit knowledge through a process of enculturation. There is however, little that deals explicitly with what research skills are needed by the novice researcher in their transition to legitimate members of the academic community or what sort of technologies might be used to support the acquisition of these skills and facilitate collaborative practices. The following section makes an attempt to addresses this shortfall, with a short discussion of both technologies, viewed through the lenses of Computer Supported Collaborative Work/Learning, and of research and writing skills applicable to doctoral candidates.

2.3.3. Writing related technologies

As has been previously discussed, the idea that we can use machines and tools to support our cognitive faculties has been suggested in a variety of different cognitive models: cognitive apprenticeship, situated learning, and others (Resnick 1987; Lave and Wenger 1991; Skagestad 1993; Wenger and Snyder 2000). This section explores a number of existing technologies that are of relevance to research and writing activities, before discussing how these technologies may inspire designs to support the writing process.

We externalise our cognitive functions in order to help augment and reflect on our work processes. We do this with language, artefacts and methodologies, and use technology to do the same (Skagestad, 1993). This work also embraces Popper's "three worlds" interpretation and views this process as "symbolic manipulation", emphasising a semiotic perspective. This introduces computer technology into the process and proposes that now that computers can perform symbolic

manipulations themselves, it may free up some of our cognitive functions so that we may focus on other activities. As these technologies capture our conceptual artefacts in their design, these artefacts can become semi-autonomous thereafter, contain their own type of knowledge (Resnick, 1987) and can propagate and evolve beyond what the creator expected. This echoes Bereiter's interpretation:

"Further, our conception of how we think will determine how we structure those external things, just as their structure in turn guides the direction of our thinking." (Skagestad, 1993, p. 13)

Bateman (1995) posits the idea that language and their resulting ontologies are socio-semiotic constructs. Language is externalised and negotiated, but he does make a demarcation between formal and natural ontologies; here formal ontologies may be closer to our conception of real objects, whereas the natural ontology could be viewed as World 3 objects or conceptual artefacts such as ideologies or contexts. It is important to note that Bateman also views these ontologies as incomplete and always in a state of "flux".

If we take the idea of externalisation and apply it to Bereiter's and Skagestad's World 3 interpretations, we can extend the initial idea that technologies and language may be externalised so that it now includes the externalisation of conceptual artefacts. Therefore the idea that we should view conceptual artefacts just as we view technological or linguistic artefacts is justified. We must externalise objects before we can perform constructive operations on them. Otherwise we risk that they will remain implicit and therefore limit our creative exploration of our knowledge and thus our learning ability.

2.3.3.1. Writing Tools

The Writer's Assistant was developed primarily to focus on both the linear and non-linear activities involved in the writing process, rather than the simple linear functionality found in standard word-processors (Sharples, Goodlet, & Pemberton, 1989). Sharples et al. provide an overview of writing tasks and how they may be represented (Table 2-3). One of the main innovative outputs of the Writer's Assistant is the idea of multiple views of the emerging document. The notes view allows the writer to express ideas as notes and place them into an associative network. The linear view allows the writer to view the text from beginning to end and perform standard text editing activities. Finally the structured view allows the writer to create and alter the structure of the linear text.

Table 2-3 The Representation space for writing – (Sharples et al., 1989)

Organization of Items \ Type of Item	UNINSTANTIATED	INSTANTIATED
UNORGANIZED	1 Techniques: Brainstorming Representations: Idea-labels	2 Techniques: Note-taking (verbatim) Collecting quotes Representations: Notes
NON-LINEAR ORGANIZATION	3 Techniques: Following a thread Writing as dialectic Representations: Network of idea-labels	4 Techniques: Organizing notes Filing Representations: Network of notes
LINEAR ORGANIZATION	5 Techniques: Linear planning Outlining Representations: Lists of idea-labels Table of contents	6 Techniques: Drafting text Revising text Copying text Representations: Linear text

iWeaver (Shibata & Hori, 2002, 2008) is a more recent work that builds on Writers Assistant, and it also provides multiple representations of document. The representations differ from the Writer's Assistant in that it uses what they call a "ContextMap" view instead of a "Notes Network". They argue that the ContextMap view is easier to transform into linear text and requires fewer graphical objects to describe relations, using proximity and location rather than the arrows and lines of Writers Assistant's Notes Network. The OutlineTree and DocumentView are similar to the structured and linear views in the Writer's Assistant.

The Outline view, although innovative at the time Writer's Assistant was developed, is now common in a number of modern word processors. However, there is little in modern word-processors that have adopted anything similar to the ContextMap or Notes Network paradigms. Modern concept and mind mapping programs would be the closest tools to resemble both of these views.

2.3.3.2. Concept Mapping

"The value of the iconic representation, Peirce repeatedly insisted, lay in the possibility it afforded of performing experiments on our thoughts, by changing some elements in the diagram and literally seeing new relations appear." (Skagestad, 1993)

The work on both Writer's Assistant and on writing as creative design suggest that an essential part of the writing process is planning, brainstorming and the networking of notes and ideas (Sharples, 1999; Sharples et al., 1989).

Concept maps have been advocated as beneficial in managing and developing a learners knowledge structures (Novak, 2009). Collaborative concept mapping is also discussed as being a practical way of capturing and negotiating collective knowledge in a group or team, making it potentially helpful for doctoral candidates when discussing their work with peers and supervisors.

(Trochim, 1989) suggests that concept mapping may be useful both in the planning and evaluation of group projects. This is supported in a doctoral setting by Leshem's (2007) work on developing conceptual frameworks for the early planning of doctorial research, utilising both concept maps and group work. This potentially opens up the possibility of sharing a common interface across a range of different tasks throughout the research project from planning, writing and evaluation.

A number of existing concept-mapping tools exist such as C-map (http://cmap.ihmc.us/), Vue (http://vue.tufts.edu/) and KPE (http://www.kp-lab.org/tools/knowledge-practices-environment). KPE is of particular interest as it provides a range of web-based collaborative tools for knowledge work and has a sociocultural pedagogy at its foundation (Kosonen, Ilomäki, & Lakkala, 2008). Such collaborative technologies have become commonplace today.

2.3.3.3. Computer Supported Collaborative Learning/Work

As the pedagogical theories related to doctoral training generally call for a social view of the learning process, collaboration is an essential element of any design, whether it is for the support of supervisor-student relationship, peer writing/reading groups or collaboration on an academic paper or thesis. This implies that any technology developed to support the doctoral process would benefit from collaborative technologies that support these social practices. Even if they are not incorporated, it is important that the designer is aware and sensitive of the social-cultural learning environment that the design is part of.

Awareness of other users' location and perspectives is a recurring theme in work on shared workspaces in both Computer Supported Collaborative Learning and Computer Supported Collaborative Work (CSCL/W) (Buder & Bodemer, 2008; Cox & Greenberg, 2000; Suthers, 2001, 2006). This involves having cues for user's location and ownership markers, especially important if they are not collocated in both space and time.

Cox and Greenberg's (2000) work on supporting interpretation using groupware provides an insight into how users can collaborate critically on various pieces of information, an issue relevant to any design looking at supporting groups during idea generation and critique and the wider writing process. This is important when communities of practice are negotiating shared meaning, exploring common ground and negotiating intersubjectivity. In Cox and Greenberg's work there are elements not too different to the map and network nodes found in the Writers Assistant and iWeaver, yet it in this case the aim is collaboration. The additions suggested here include support for sketching, shared/similar workspace, free form annotation, creation and movement of data in the space. They also use multiple views to navigate the space and information, this again has similarities with concept mapping tools.

Burder and Bodermer's (2008) work about supporting controversial discussion explores augmenting the interface to display group awareness indicators. These indicators show at a glimpse the other users agreement with and perception of controversial ideas, not too dissimilar to feedback provided by peers on academic writing. These features may be combined with Ravenscroft & McAlister's (2008) work on supporting argumentation in order to create relevant prompts to further the conversation, argumentation being an essential skill in any scientific discipline, thus a skill all doctoral candidates should acquire. The skills necessary to effectively argue a point are discussed in the following section.

2.4. Synthesis

If we return to where we started this discussion, the Ph.D. has two main aims. The first and more traditional aim is to make a significant contribution to knowledge, and the second is for the novice researcher to acquire the research skills necessary to conduct "independent research". These skills are acquired through enculturation with a community of practice whether through cognitive apprenticeship or peer learning. The researcher uses tools to mediate the learning process. Through a computational process they develop abstract conceptual frameworks in the form of notes, sketches and other semiological outputs. How the novice researcher conducts this work depends on

their research skill level and ability. We can combine these elements using Activity Theory to create a holistic description of the Ph.D. Process (Figure 2-5). This Activity System will act as a guiding schema for this research. As a working schema it is important to note that it is not meant to be viewed as the one and only description of the Ph.D. process, but a pragmatic framework to position the design and construction of tools to support it. The red area in Figure 2-5 denotes the research focus within this project, although what lies outside this area is still of relevance and the influencing factors are expected, they lie outside the scope of this study. This study focuses on the individual work of novice researcher in the early stages of the Ph.D. process, while remaining open to any collaborative practices that may interface with the individuals work practice.

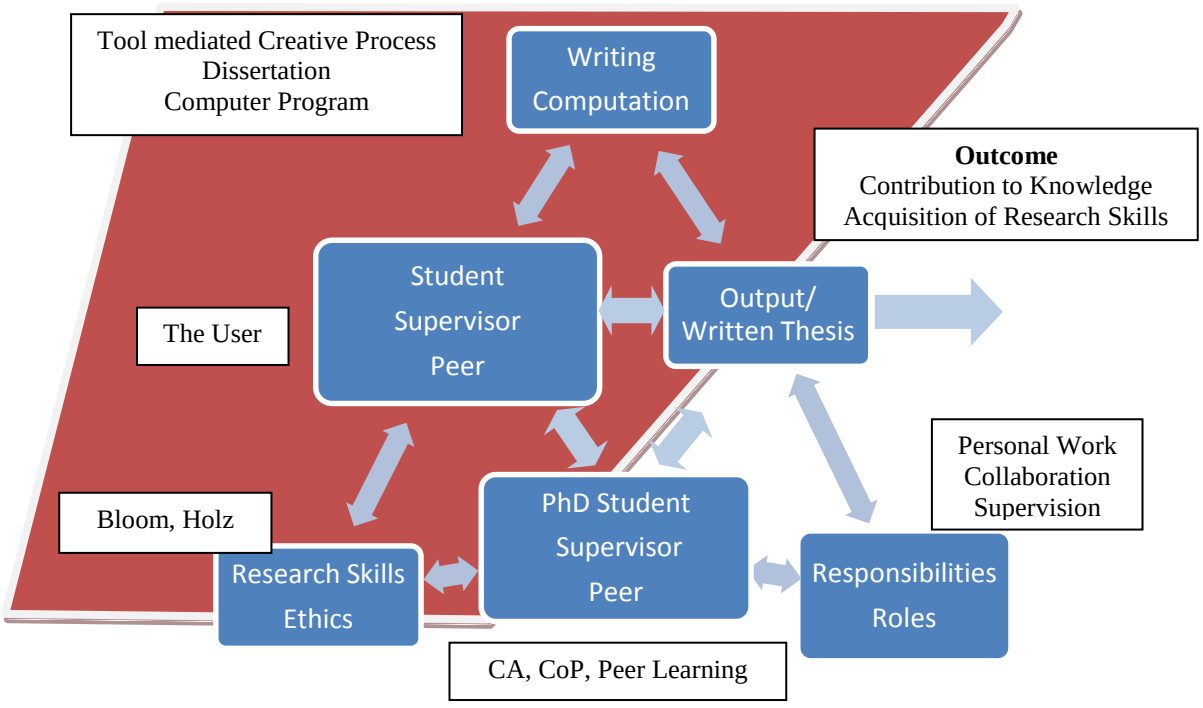


Figure 2-5 Activity Systems for Ph.D. Process (red: research focus)

The preceding sections have explored the research and writing skills needed by novice researchers across scientific disciplines and the pedagogical theories that underlie their acquisition. A number of existing tools and approaches were explored to provide a basis on which to build tools to support academic writing. HCI methods and theories, such as Cognitive Dimensions, were also introduced to provide guidelines and techniques with which to tackle the design of tools to support research and writing skills.

The "Single System" may be viewed as a creative process if aligned with the creative phases summarised by Warr and O'Neil (Figure 2-6). The interactive reading should be easily facilitated through intelligent interface design, supporting the user in analysis and evaluation as discussed by Holz et al. (2006). Interactive and citable notes may be facilitated through the provision of literature review protocols and argumentation prompts, to promote higher order cognitive processes such as, synthesis, analysis and evaluation. These processes also align with the early specific skills discussed by Holz et al. and involve activities such as search, scanning, selecting, analysing and critiquing the literature (Table 2-4).

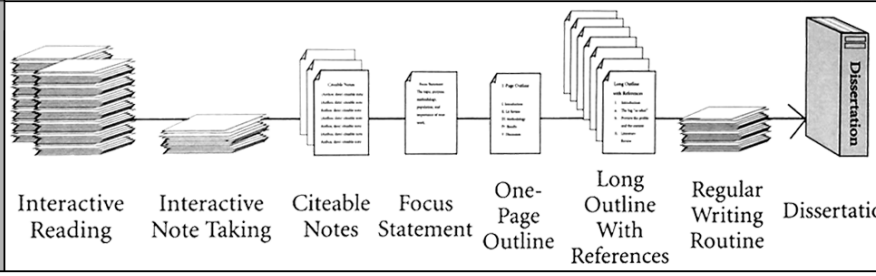
<table>
<tr><th>Models</th><th colspan="3">Analysis of Problem</th><th colspan="2">Generating Ideas</th><th>Evaluating Ideas</th><th>Donating</th></tr>
<tr><td>Wallas</td><td colspan="3">Preparation</td><td>Incubation</td><td>Illumination</td><td>Verification</td><td>X</td></tr>
<tr><td rowspan="2">Osborn</td><td colspan="5">Idea Generation</td><td rowspan="2">Idea Evaluation</td><td rowspan="2">X</td></tr>
<tr><td colspan="3">Fact-finding</td><td colspan="2">Idea-finding</td></tr>
<tr><td>Amabile</td><td colspan="2">Problem or task presentation</td><td>Preparation</td><td colspan="2">Response generation</td><td>Response Validation</td><td>X</td></tr>
<tr><td rowspan="2">Shneiderman</td><td colspan="3">Collect</td><td colspan="3">Create</td><td>Donate</td></tr>
<tr><td colspan="7">Relate</td></tr>
<tr><td>Single</td><td colspan="7"> 
</td></tr>
</table>

Figure 2-6 Creative Phases as they relate to the dissertation writing process

This focus on the early stage activities is considered essential as the target group for this research are early stage novice researchers, Ph.D. candidates. The outlining techniques found in the "Single System" could be supported by something similar to the outlining and concept mapping facilities found in Writer's Assistant and iWeaver, once altered to include a referencing system. Finally support for the regular writing routine may be facilitated by some feature that helps users self-regulate, a Holz et al. meta-cognitive skill. Single does suggest a word count graph as a possible approach for writers to gain insight into their writing activities. This project does not assume that a user will complete an entire thesis utilising the tools designed in this project, although the author will be both a user and developer of said tools.

Table 2-4 Specfic Skills Related to Novice Researchers from the Holz et al. (2006) Framework (green: primary concern, orange: secondary/emergent)

1 Search Literature	12 Collect Data
2 Scan Papers	13 Verify Data
3 Select Papers	14 Analyse Data
4 Analyse Literature	**15 Evaluate Results**
5 Critique Literature	**16 Draw Conclusions**
6 Analyse Research	17 Identify Limitations
7 Critique Research	**18 Link Research to Body of Knowledge**
8 Formulate Research Questions	**19 Connect Theory to Practice**
9 Identify Ethical Concerns	**20 Present Results: Oral**
10 Choose Methodology	**21 Present Results: Written**
11 Write Research Proposal	22 Present Results: Other

The "Single System" suggests similar community supports as those discussed in CoP, CA and Lee and Aitchison's (2009) references to reading and writing groups as it involves a significant amount of collaboration, in the form of group work and seminars. This suggests that any design should be able to facilitate collaboration, which will play a major role in the third creative phase, evaluating ideas. Peer and supervisor feedback offer an excellent method by which one can verify and validate ones approach and understanding. Although both Writer's Assistant and iWeaver provide novel approaches to the writing process, they are not widely used as word processors. However, the outlining views found in Writer's Assistant and iWeaver have been integrated into most modern word processors. The most commonly used word processors today, such as MSWord and Open Office, typically offer a linear view of documents and are not explicitly designed to support the free association of ideas, and thus promote thinking in a linear manner.

There are a number of online options emerging that allow for collaboration such as Google Docs (http://docs.google.com), Zoho (http://docs.zoho.com) or the open source alternative EtherPad (http://etherpad.org), but these again are limited by a linear focus. As for third party concept mapping tools, they facilitate a freer association of ideas, and even have collaborative features as in KPE, but the majority were not explicitly designed to support the writing process nor do they integrate multiple representations of the document as does Writer's Assistant and iWeaver.

Table 2-5 Design Heuristics

Context/Pedagogies	
Cognitive Apprenticeship Communities of Practice Peer Learning	Lave & Wegner, Boud & Lee, Leshem, Hopwood & McAlpine etc.
Tool Mediation	Vygotsky, Skagestad, Bereiter, Engeström
Core Research Skills Support	
Record Keeping	Holz et al.
Written	Holz et al.
Graphical	Holz et al.
Analysis	Holz et al., Bloom
Synthesis	Holz et al., Bloom
Evaluation	Holz et al., Bloom
Reflection	Holz et al.
Self-regulation	Holz et al.
Writing Related Activity Supports	
Analysis of Problem	Single, Sharples, Bloom, Holz et al., Warr, Amabile, et al.
Search Literature	Holz et al., Single
Scan Papers	Holz et al., Single
Select Papers	Holz et al., Single
Analyse Literature	Holz et al., Single
Critique Literature	Holz et al., Single
Outlining	iWeaver, Writer's Assistant, Single
Conceptual/Context	iWeaver, Writer's Assistant, Sharples, Novak, Leshem
Referencing system	Single
Interactive Reading	Single
Interactive Note taking	Single
Generating Ideas	Sharples, Bloom, Holz et al., Warr, Amabile, et al.
Citable Notes	Single
Long Outline	Single
Drafting/Revision/Regular Writing	iWeaver, Writer's Assistant, Single
Evaluating Ideas	Sharples, Bloom, Holz et al., Warr, Amabile, et al.
Collaboration	Sharples, Single, CA, CoP, Peer Learning
Self-Review Protocols	Boote, Brereton et al., Ravenscroft & Atchison
Cognitive Dimensions	
Delayed Gratification	Woods, Green
Terseness	Woods
Perceptual Cues	Woods
Accessibility	Woods
Premature Commitment	Woods, Green
Viscosity	Woods, Green
Formalness	Woods

The pedagogical theories of CoP and CA, the Holz et al. framework and the work on the acquisition of writing skills all suggest the benefits of an element of collaboration when it comes to training doctoral candidates; one-to-one meeting with their supervisor, reading or writing group etc. This paves the way for the introduction of CSCW/L tools.

The work on awareness of perspectives in the CSCW/L literature suggests that structured comments, drafts and notes shared amongst collaborators will help elicit a shared understanding, again echoing the work on CoPs. Elements found in the systematic literature process such as review protocols (Boote & Beile, 2005; Brereton, Kitchenham, Budgen, Turner, & Khalil, 2007) may also be included in order to scaffold the review process and aid collaborators in understanding what criteria and metrics are being looked for in the reviewed material. This may be further supported through shared argumentation rules similar to the prompts discussed by Ravenscroft and McAlister (2008). These features may also help with in evaluating ideas as per the creative phases.

Cognitive Dimensions of idea sketches (Woods, 1993) provide a way to assess the qualities of a design. Woods' dimensions in particular offer an excellent way to assess the concept mapping elements and note taking elements. The specification of guidelines from this approach makes it easier to use than the more broad conceptual approaches of Distributed Cognition and Activity theory. The Delayed gratification, Terseness and Perceptual Cues dimensions provide an excellent motivation for using a concept mapping space. Accessibility and Viscosity promote the idea of tight integration and easy access to notes, quotes and papers throughout the system. Cognitive Dimensions afford a lens through which we can view activities, before and after a prototype has been developed.

This synthesis of elements from the literature has been formulated into a set of design heuristics. These heuristics are displayed in a table (Table 2-5), documenting the four main areas of concern, tool context/pedagogies, and supports for core research skills, dissertation writing related activities and cognitive dimensions. The context and pedagogies provide the foundation of the tools context. The core research skills are not acquired directly by any designed system, but are simply facilitated. The creative phases act as the scaffold within which we place specific dissertation writing activities. Finally the cognitive dimensions for idea sketching provide useful heuristics with which we can design and evaluate tools designed to support the creative process within a knowledge working context.

In terms of design, emerging cloud-based approaches to the provision of tools are expected to become a central aspect of how we use technology over the next decade (Anderson & Rainie,

2010) and open up possibilities to provide more ubiquitous and pervasive tools. Cloud computing will allow the user to access their tools and resources through a variety of devices in a number of different locations, potentially opening up new forms of situated practice for researchers and Ph.D. students, while still facilitating traditional practices. The combination of the cloud-based approach and best practices from work on CSCW/L tools will inform the design of the tools developed in this research.

Finally it is important to acknowledge that there are a number of existing systems to support the research process that are referred to as Virtual Research Environments (VREs), unfortunately they are largely data repositories or places that aggregate social communications (Laterza, Carmichael et al. 2007). Although promising in their own right they are generally limited in pedagogical underpinning. Virtual Learning Environments (VLEs), such as Moodle and Blackboard (Dougiamas and Taylor 2003; Wilson, Liber et al. 2007), tend to have a stronger pedagogical underpinning but are largely aimed at traditional education systems such as undergraduate studies, again they tend to become repositories for course work, augmented with some communication functionality.

There is only one tool that makes an attempt to bring the mind map, word document and referencing system together through the use of coupling add-ons. This is Docear or as it was previously known as Sciplore (Docear, 2011), but by its creators own admission it is not very user friendly.

Neither VREs VLEs nor Docear focus on or scaffold the skills necessary and the activities involved in the work of a novice researcher, it is this issue and shortfall that the research hopes to tackle through the development of a cloud-based CSCW/L toolkit and embed it in practice in order to support Ph.D. candidates in their legitimate research activities.

2.5. Summary

The main novel concepts that the reader should take away from this chapter are the Activity System schema of the Ph.D. process and the design heuristics found in the synthesis section. Although the "Single System" provides a simple guide to dissertation writing, it lacks a rigorous theoretical underpinning. These schemas and heuristics provide a theoretical and technology orientated framework around the practice based approach found in the "Single System". The Activity System schema views the Ph.D. process as a rich dynamic interaction of tools, people, cultural rules and

artefacts and provides a novel theoretical perspective with which to view Ph.D. activities. The design heuristics provide a rich scaffold, highlighting and amalgamating the contextual elements and situated activities from across the reviewed literature and situates it within the context of the Ph.D. process described in the Activity System Schema. We can then use these heuristics to target specific activities and design tools to embed within and augment this dynamic and complex Ph.D. process.

Furthermore, these schemas and heuristics help guide the research agenda approach, which is to develop a useful tool capable of supporting legitimate activities related to early Ph.D. processes. The following chapter describes the research methodologies and design approaches that may be employed in order to realise the aforementioned theoretical frameworks in a practical design and implementation, that can be both used and evaluated by end-user

3. Research and Design Approaches

The following chapter explores both the research methodologies and design approaches used within this research. An important point to note about the transdisciplinary nature of this work is that a process akin to concept blending (Nagai, Taura, & Mukai, 2009) is at work and influences the approach to concept formulation. Theoretical approaches inform the research as they are synthesised into a schema that can be matched to the practicalities with which this research concerned. This may already be evident from the synthesised activity model for the Ph.D. process at the end of the last chapter. The same approach was used when deciding on research methodologies and design approaches. Although we have chosen Participatory Action Research as our research methodology and Participatory Design as our design process, they are not necessarily as defined by the literature but a synthesis of elements that act as a guiding approach within which to conduct the research.

This chapter sets out the philosophical argument for this approach building on the arguments about knowledge claims started in section 2.1.3. We will use these approaches to both help inform the design of tools that align with the design heuristics presented at the end of the last chapter. This tool will then be assessed as to its usefulness in legitimate learning activities related to the early Ph.D. process.

3.1. Research Questions

Can we develop a useful tool capable of supporting legitimate activities related to early Ph.D. processes?

1. How can we frame and describe the rich and dynamic the Ph.D. process, with the aim of designing tools to support that process?
2. What do the developed tools, as a technology probes, tell us about this class of application?
    a. Are the developed tools usable, did people use them, if so, how?
    b. What are the user's experiences, perspectives and observations on using the tool?
3. What can we learn from the developed tools, as an encapsulation of the framework and requirements gathered?
    a. What were the lessons learned from the prototype implementation?

These questions hope to shed light on how effective the designed prototype both supports Ph.D. processes, higher order thinking skills and related activities. Answering these questions will provide answers as to whether the tools developed provide supports for knowledge work and the essential skills needed to conduct 'independent' research.

The overarching questions relate the overall goal of this research: to contribute to the development of useful and usable tools to support the Ph.D. process. The initial secondary question, asking how to frame the Ph.D. process, is largely answered in the preceding literature review chapter through the creation of the Activity System Framework and design heuristics. In order to help answer this question a number sub-activity systems are created to inform the design, each highlighting a specific output and the associated research skills that they are designed to support.

The supplementary secondary questions look at both the use of the tools as a technology probe to explore this class of application, those designed to support aspects of the Ph.D. and what we can learn from the developed tools as an instance or encapsulation of the framework, heuristics and requirements.

This research must first establish what practical requirements, beyond those established in the literature review, and are needed when designing a system to support the Ph.D. process. How we aim to collect these requirements and answer these questions above relies heavily on our research methodologies and design approaches. As this work will focus on a single design implementation/interpretation of the design heuristics and Activity System, with a small number of users, it is qualitative in nature and more definitive answers are left to future, fine grained and controlled studies that lie beyond the scope of this work. The interpretivist and qualitative methodology is discussed in more detail in the following sections, before exploring our design approaches for requirement gathering in section 3.3.

3.2. Research Methodology

This work will be interpretivist and qualitative in nature:

"Qualitative research is a type of educational research in which the researchers relies on the views of participants, asks broad, general questions, collects data consisting largely of words (or text) from participants, describes and analyzes these words for themes, and conducts the inquiry in a subjective, biased manner." (Creswell, 2005)

Qualitative research by its very nature is a subjective and biased activity. Therefore it is imperative that any qualitative researcher acknowledges and incorporates these ideas. Biases should be limited or at least made explicit, particularly when interpreting data (Marshall & Rossman, 2006; Miles & Huberman, 1994). Gilovich (1991) states that people are adept at making ad-hoc explanations, but that they often make these assumptions based on misinterpreted or misperceived data, or put too much weight on ambiguous data, resulting in biased interpretations. Consequently when conducting qualitative research it is necessary for the researcher to make a "knowledge claim", meaning that they will state their approach to the subject and the assumptions that accompany this approach. Socially constructed knowledge, advocacy/participatory knowledge and more recently pragmatic knowledge are three major paradigms that qualitative researchers adhere to when conducting their research (Creswell, 2003), this provides a philosophical framework for their knowledge or ontology formation.

3.2.1. Transdisciplinary knowledge claims

'The keystone of Transdisciplinarity is the semantic and practical unification of the meanings that traverse and lie beyond different disciplines. It presupposes an open-minded rationality be re-examining the concepts of "definition" and "objectivity." An excess of formalism, rigidity of definitions and a claim to total objectivity, entailing the exclusion of the subject, can only have a life-negating effect.' (Nicolescu, 2002, p. 149)

As is discussed in the literature review, this thesis takes the unorthodox approach that knowledge is a system of artefacts that may be reinterpreted, assimilated, augmented and tested. Despite the pursuit of truly objective knowledge, concepts may only be falsified rather than proven true (Popper, 2002).

"The scientific community itself is obviously in some sense a vehicle or carrier of scientific knowledge... certain characteristics of the community, its structure and organization, may distort its product; and various correctives to that distortion may, in some circumstances, introduce further unintended distortions." (Bartley III, 1987, p. 446)

Knowledge and the concepts that constitute that knowledge are socially constructed artefacts that contain and engender the biases and beliefs of the culture that creates and maintains them. In order to acknowledge this influence, the following sections shall explore how beliefs influence bias and help in their formation (and vice versa), how this relation affects the formation of both individual, subjective knowledge and socially accepted, objective knowledge. The discussion will then explore

how reflection as an approach, can help researchers in making their biases explicit, therefore conducting a more valid and comprehensive investigation. This is relevant to the research context as it is argued that these biases if acknowledged and reflected upon can also act as motivation to direct and maintain momentum within the research project. Schemas used as a heuristic model provide a valid approach to framing and guiding a problem. Abstract conceptual systems, act as a method to both guide and evaluate research, but it is important to note that they are free to evolve and change in light of experience and observation, through a process of trial and error. Finally an argument is made for the use of a transdisciplinary approach, where schemas from a wide variety for domains may be combined to form new heuristic models with which to analyse and evaluate phenomena. This is especially important as this research combines perspectives from philosophical, educational and technological disciplines. This amalgam is not of any of these disciplines but lies between or across the disciplinary boundaries.

3.2.1.1. Belief, Biases and Understanding

"In developmental psychology there has been a clear distinction between cognitive, social and emotional development. Each has been studied separately. But the distinctions have been gradually eroding."(Jones & Issroff, 2005)

It is clear that a more holistic approach is needed to fully describe the effects on an individual researcher while participating in a reflective and collaborative learning environment and in turn, how they may influence that environment.

Here it is necessary to draw a distinction between what is meant by belief and understanding: belief may be taken to be the individual, subjective and affective aspects of knowledge, while understanding may be taken to be socially accepted and "objective" knowledge (Pehkonen, 2003). The distinction highlights the difference between beliefs as individually generated schemas and understanding as socially generated schemas. Although a distinction between meanings is made, these two ideas are mutually dependant and knowledge as a whole is a dynamic interaction between these sub-sets of knowledge.

As emotions may shape, awaken, and intrude into beliefs and thus create, alter and reinforce them (Frijida, Manstead, & Bem, 2000), they are important to take into account when people are encountering new or reflecting on past concepts and experiences. There have been studies (Chinn & Samarapungavan, 2001) that have shown that students frequently do not believe what they are learning in class, but may have a good understanding of the subject matter. It is suggested that the student tries to fit the concept to their belief systems before trying to fully understand the concept.

"One way in which affect influences beliefs is via mood-congruent biases: we are more likely to notice, encode, remember and make use of information that is congruent with a prevailing mood." (Frijida, Manstead, & Bem, 2000)

This shows that emotions inherently interact with biases in our thought processes, ultimately defining our goals and values. If beliefs are to be taken as a probability (Dewey, 1910), creditability or plausibility statements (Dewey, 1910; Frijida & Mesquita, 2000), belief formation may be motivated by the desire to be accurate (Harmon-Jones, 2000; Kunda, 1990), within a relevant socio-cultural context. An alternative perspective to that of the researcher may evoke dissonance (Harmon-Jones, 2000) and as there is a desire to be accurate the researcher will become motivated to understand and reduce this cognitive discrepancy. This is dependent on the whether the belief or new concept is more resistant to change. Learners will generally tend to avoid alterations to their belief structures and the associated discomfort, as they lack both the resources and motivation necessary to cause these changes.

As the aim would be to gain or approach the ideal of "objective" knowledge or understanding, a method is needed that helps the researcher encounter situations in which their beliefs and bias will be called into question. It is suggested that a reflective collaborative learning community may provide such a platform (Mehra, 2002). This leads on to the next sections where we shall first explore the interactions between the individual and social cognitions within an online collaborative research community and secondly the process of reflection.

3.2.1.2. Reflection

To utilise emotions as a tool to explore one's personal beliefs, it is necessary first to acknowledge and take cues from them, then to integrate them into a cognitive process that allows them to be assessed. Reflection is a process that if approached correctly allows this.

"Active, persistent, and careful consideration of any belief or supposed form of knowledge in the light of the grounds that support it, and the further conclusions to which it tends," (Dewey, 1910)

Here Dewey supports the idea that knowledge is formed from beliefs and that an act of reflection may help to reassess these beliefs and develop new beliefs from the conclusions of the reflective process.

"the reflective process is a complex one in which both feelings and cognition are closely interrelated and interactive. Negative feelings, especially about oneself, can form major barriers

towards learning. They can distort perceptions, lead to false interpretations of events, and can undermine the will to persist. Positive feelings and emotions can greatly enhance the learning process; they keep the learner on the task and can provide a stimulus for new learning."(David Boud, Keogh, & Walker, 1985)

In light of these observations the author would like to advocate the idea that if the anxiety perceived from not understanding a subject, if acknowledged and used to evolve or develop one's personal knowledge, it becomes a positive feeling. However if the individual is not able overcome the anxiety the feeling becomes negative.

Reflection usually is described as being composed of three different approaches: returning to experience, attending to feelings and re-evaluating experience (Boud, Keogh, & Walker, 1985). This process should allow the learner to adapt to the new information by creating new schemas and beliefs after re-evaluating their previous beliefs and emotions.

3.2.1.3. Schemas as Heuristics

'There is today a new kind of art that was born by transferring computer methods to the realm of art. The most spectacular example may be that of art that uses the incredible information circulating on the Internet as if it were new matter. Information rediscovers its original meaning of "in-formation": to create, ceaselessly changing new forms, arising out of the collective imagination of artists.' (Nicolescu, 2002, p. 98)

Nicolescu's quote is to emphasise the argument that knowledge is an ever evolving process. This thesis adopts the perspective that heuristic schemas offer a method with which we can explore and define the world around us. This is supported by the standard Oxford English Dictionary (OED) definition of heuristics: *"Serving to find out or discover."* OED

There is also an element of uncertainty associated with the term. It is never meant as the best or only solution, but used in an attempt to solve a particular problem.

"A heuristic process or method for attempting the solution of a problem; a rule or item of information used in such a process" OED

It is used in computing again to represent a 'good' solution that allows for the work to continue, without making claims that it is the only answer as some frameworks or models would have you believe.

"Under a 'heuristic' programming procedure the computer searches through a number of possible solutions at each stage of the programme, it evaluates a 'good' solution for this stage and then proceeds to the next stage. Essentially heuristic programming is similar to the problem solving techniques by trial and error methods which we use in everyday life." OED

Popper's theme that knowledge is achieved through a trial and error process is again echoed here. So if we take knowledge to be uncertain, what claims can we make and what use would our claims be? The following section hopes to position this work in a transdisciplinary perspective, where the heuristics used act as guiding principles, to use Popper's (1987) blind man analogy the heuristics offer a stick with which to probe the darkness. This allows for concepts and ideas from specific disciplines and approaches to be assimilated and combined to create new schemas that lie beyond those that they are based upon.

3.2.1.4. Transdisciplinary Knowledge

"Transdisciplinarity complements disciplinary approaches. It occasions the emergence of new data and new interaction from out of the encounter between disciplines. It offers us a new vision of nature and reality. Transdisciplinarity does not strive for mastery of several disciplines but aims to open all disciplines to that which they share and to that which lies beyond them." (Nicolescu, 2002, pp. 148-149)

An argument is made for the use of a transdisciplinary approach, where schemas from a wide variety for domains may be combined to form new heuristic models with which to analyse and evaluate phenomena. This is especially important as this research combines perspectives from philosophical, educational and technological disciplines. This amalgam is not of any of these disciplines but lies between, across and beyond the disciplinary boundaries.

This approach is further supported by Derry and Fischers (2005) work that aims to build a model for transdisciplinary graduate education. They argue that the transdisciplinary student should aim to solve *"complex and ill-defined real-world problems"* that require *"simultaneous problem framing and problem solving"* that *"cut across disciplinary boundaries"*. We argue that the Ph.D. process is such a *"complex and ill-defined real-world problem"*, that the heuristics developed act as the *"problem framing"* and the designed artefact is an attempt at*" problem solving"*.

"Our research focuses on the co-evolutionary interdependence of theory building and design as we investigate four interrelated themes: (a) distributed intelligence; (b) reflective communities; (c) lifelong learning; and (d) innovative media." (Derry & Fischer, 2005, p. 3)

Derry and Fischer emphasise *distributed intelligence*, this interpretation is aligned with the approach to knowledge as advocated in the literature review, and again influences from Engeström, Hollan and Hutchins are present. *Reflection* in action echoes the discussion in the preceding section. *Lifelong learning* has parallels with the focus on research skill acquisition of novice researchers, although Derry and Fischer here focus on transdisciplinary skills. Finally their emphasis on *innovative media* shall become apparent when we explore the designed tools in later chapters.

The reflexive approach is central and largely influences the research methodology chosen to frame this research. As the author is both a Ph.D. candidate and a novice researcher a Participatory Action Research approach has been adopted. The following section describes this approach and why it is a valid approach to use within the context of this research.

3.2.2. Participatory Action Research

An important aspect of this research is the methodology used. The Participatory Action Research (PAR) methodology (Kemmis & Wilkinson, 1998; Whyte, 1989) differs from research design approaches in that it is iterative and reflexive. It does not presume the best possible solution at the start of the process but starts with an informed perspective, based on reflection. A plan based on this perspective is then formulated and then implemented. Observations of the results then feed back into another iterative reflective cycle. This can be summarised as reflect, plan, act, observe and repeat/iterate (Figure 3-1). These PAR iterations or cycles can vary in size and scope, as will be evident in those discussed in the following sections.

The PAR methodology is appropriate as the lead researcher is himself a doctoral candidate who is using the tools being developed as they emerge. This methodology suggests that the researcher adapts their propositions as they cycle through the plan, act/observe and reflect stages of action research. The PAR methodology suggests the involvement of other members of the wider research community within our institution and outside becoming participants in the research. The action research aspect suggests we are not only looking to observe practice within the community but our research may even alter the practice it is exploring as suggested in the work on situated learning (Lave and Wenger, 1991), this is also an essential aspect of action research in general.

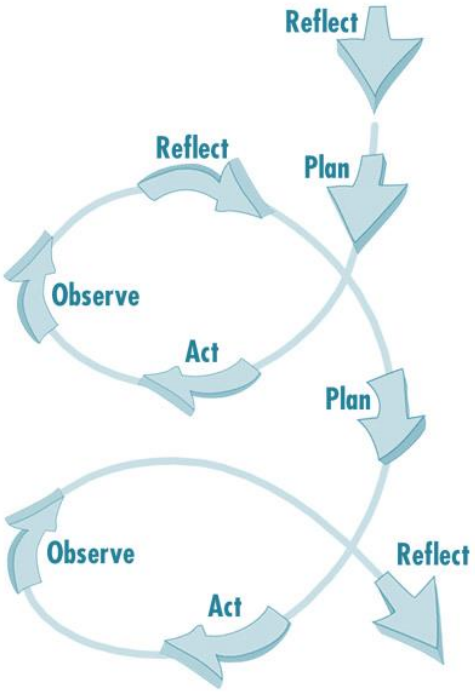


Figure 3-1 self-reflective spiral in action research (Whyte 1989; Kemmis and Wilkinson 1998)

The PAR approach must also be assessed as to its quality and validity (Creswell, 2005). The PAR method calls for the approach to clearly address a problem or issue in practice that needs to be solved; in this case technological supports for Ph.D. candidates writing related activities.

In order to help evaluate whether the action research project is effective, Creswell (2005) lists a number of questions that may be asked in order to ascertain the effectiveness of the intervention:

- Did the project build logically from the collected data?
- Was there legitimate collaboration?
- Has the work empowered the participants?
- Was there any change and did the solution make a difference?
- Was the research disseminated to appropriate audiences?

Here the author's logs, reviews of activities and interviews with participants will play a major role in assessing whether the project developed logically from the data, there was legitimate collaboration and the participants were empowered. The solutions to the central research questions will help to answer whether any change occurred and whether it made a difference.

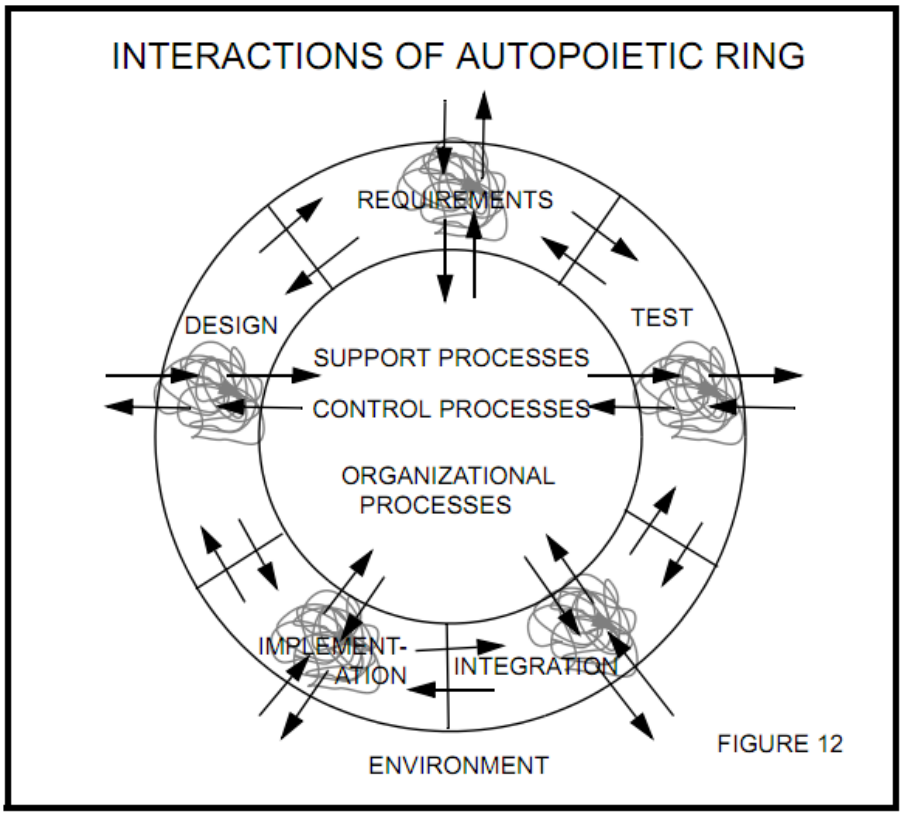


Figure 3-2 Autopoietic ring in Palmer's Wild System Design

3.3. Design Approach

3.3.1. Wild Software Systems

It is worth noting that there are a number of parallels between the PAR methodology and the Wild software development cycle, or Autopoietic ring as advocated by Palmer (1996), see Figure 3-2.

The Wild Software approach was developed by Palmer to compliment his Emergent Design philosophy. It accepts the sometimes volatile and unpredictable nature of design and allows for the designer to be more creative as they adapt to the environment and context. It is a practical and realistic interpretation of the design process and is a sensible approach considering that the software design and coding is being conducted by a single individual: this approach can become unwieldy with large teams of developers as standards need to be adhered to.

Here the *Requirement* gathering phase is equivalent to *Reflection*, *Design* is the *Planning* stage, *Implementation and Integration* is *Acting* and *Testing* is the *Observation*.

3.3.2. Participatory Design

Participatory Design (PD) (Muller, 2002) involves the user in the design process at a very early stage. As a side note this may be regarded as a form of cognitive apprenticeship (Farooq et al., 2005) where the designer is learning from the practitioner and vice versa.

A Participatory Design (PD) approach (Muller, 2002) complements the PAR approach. This approach is again appropriate as the lead researcher is both a designer and user of the system; this places the researcher in a privileged position with knowledge from both a practice and design perspective. While this position provides an advantage, it may also bias the design if others from the wider community were not involved. Therefore following the PD approach users from community will be asked to participate in the design process.

Meta-Design (Fischer 2003; Giaccardi 2005 Giaccardi and Fischer 2008; Fisher et al 2009) is an extension of PD, where the users become active designers themselves and there are a number of steps that are suggested in order to empower the users to get involved within design process. Seeding, evolutionary growth and reseeding are the processes about which meta-design is centred. A seed is an artefact about which work and discussions can take place. The evolutionary growth phase is where the participants focus on a particular issue to solve, using the seed as the resource for work. Reseeding is where the efforts from the evolutionary growth phase may radically alter the original seed.

Muller also suggests that the environment in which the users are engaged in the design process is important (Muller, 2002). He makes the distinction between the design environment and the work context and how the user may perform differently in either setting. Muller also discusses the idea of a third hybrid space that brings the users and the designer outside their usual working environment. This "third space" provides an environment for creative thinking and dialogue, allowing the participants and designers to tackle the issues outside the usual contexts.

Muller's work highlights workshops as an effective means by which PD may be conducted. Future Technology Workshops (FTW) (Vavoula & Sharples, 2007) provide potential end-users with the opportunity to envision future technologies to help support their current activities. This sort of workshop provides such a "third space" and creates a good basis for initiating dialogue with the novice researcher community. This following sections describes how these Future Technology Workshops and other data collection methods were used to gather requirements, design, implement and observe throughout the research project this thesis describes.

3.3.2.1. Future Technology Workshops

A number of workshops were run with doctoral students, their respective peers and supervisors where possible. Workshops are usually conducted in a third hybrid space that lies outside the usual work context of the participants. The location used is on campus and was purposely designed to encourage creative group work. A set of requirements for future technologies are an explicit output of these workshops and will are used to inform the design of the prototype. The participants are asked to develop a list of such requirements as part of the closing activity from the workshop. We also hope this engagement with the wider community will help establish a cohort of active participants in the design process.

3.3.2.2. User/People Centred design

Following on from the FTW sessions, Participatory Design (PD) sessions involving both past participants and opportunistically selected participants will explore both the use of technology in the Ph.D. process but will focus on day to day activities and prototype design.

The FTW and PD sessions provide a wider design environment in which to explore designs and prototypes to support the community. To evaluate the usability and practicalities of these designs, participants were invited to small User/People centred design sessions (Wakeford, 2004). This involved the users using the prototypes in legitimate activities and assess the usability of the design. This was achieved using Participatory Heuristic Evaluation, which will be explained in more detail below.

There are a number of reasons one would want to use evaluation methods in a HCI project. Assessing the user experience, the systems functionality and identifying problems with the system are highlighted as the main motivations (Dix, Finlay, & Abowd, 2004). A number of evaluation methods used throughout the design process are briefly described.

3.3.2.3. Expert Based Evaluation

Expert based evaluation comes in a variety of forms, here we will explore just two, cognitive walkthrough and heuristics (Dix, et al., 2004; Lazar, Feng, & Hochheiser, 2009).

A cognitive walkthrough involves a HCI expert “walking” through a list of set tasks that have been predefined. Using a specification of the system and an idea of what sort of users will be using the system, the expert will critique the system, highlighting their perceived usability issues.

Heuristics are a set of "rules of thumb" that provide a scheme against which to assess the system. Ideally the expert will be familiar with the heuristics, although there are two quite common heuristic sets, Shneiderman's golden rules (Shneiderman & Plaisant, 2009) and Nielsen's ten heuristics (Nielsen, 1994), this research uses a set of Participatory Heuristic evaluation criteria (Muller et al., 1998). This approach and other user based evaluation methods allow for the involvement of not only usability experts but also user process experts, in this case Ph.D. candidates and other academics. These user based evaluation methods are explored in more detail in the following section.

3.3.2.4. User Based Evaluation

Just as in the expert based evaluation methods there are a range of user based methods. These include empirical, observational and querying techniques. Although empirical methods are powerful for exploring very specific questions in controlled environments, they are difficult to implement when dealing with the complexities involved in groupware systems (Dix et al., 2004). Therefore the focus here will be mainly on observational and querying techniques.

Think aloud evaluation (Dix et al., 2004; Lazar et al., 2009) is a very simple approach whereby the user talks through what they believe is happening, why they take any particular action and what they wish to do. It can be used very early in the design process and is very cheap and easy to implement.

If resources are limited, Participatory Heuristic evaluation (Muller et al., 1998) may be used to balance out the need for experts and having a set of participants already. It can be the case in PD that the users are experts in their work context and that the designer has a good idea of usability issues. Together they use a set of heuristics to explore the systems for usability issues. One concern with this approach is experimental demand (Nichols & Maner, 2008), where the participants alter their behaviour to fit with their interpretation of the research purpose. Experimental demand will be largely unavoidable in the context of this research, but it must be factored in to all interpretations of the findings.

Querying techniques of evaluation such as interviews and questionnaires can elicit more detail about the user's experience than can be attained solely from any of the previously mentioned approaches. The power here is that you leave room for the users to present issues that the designer may not have thought of or that lie outside any set of heuristics or task list.

Any number of these evaluation methods may feed into the evolutionary growth phase of Meta-Design. Participatory Heuristics are probably the best solution if this approach is taken, as they involve the user and respect them as experts in their respective domains.

3.3.3. Participants

The participants were opportunistically selected from a range of relevant groups:

- Ph.D. students
- Supervisors
- Postdoctoral researchers

Although the research was open to a wide range of potential participants, it transpired that only one postdoctoral student participated in early prototype development. Three Future Technology Workshops were conducted, the first two recruited participants by word of mouth, while the third was held as part of a research methods course that Ph.D. students were obliged to attend. For participatory design sessions a Ph.D. student with a Human Computer Interaction background helped debug and test the system as it progressed, this resulted in the first participatory heuristic evaluation of the system. Again another design session involved a brief walkthrough by a professional web designer to help inform the look and general aesthetics of the tool. Following on from this five Ph.D. students from a wide range of disciplines were invited to a participatory design session that culminated in a heuristic evaluation of the developed prototype. This preceded the long-term testing phase. The first long-term participant was the only person to fully engage with the tool as part of another compulsory research methods course. The final three users were recruited by word of mouth and were known to the researcher before usage started. It should also be noted that the fourth long-term user was from the same research group and had the same supervisor as the author of this research.

Table 3-1 Number of Users

Heuristic Evaluations	Workshops	Long term Heuristic Evaluations
6	27	4

3.3.4. Ethics

Ethics approval from the Computer Science and Statistics Ethics Committee was pursued before each stage of the implementation; this involved adhering to the Data Protection Act and College regulations in relation to data storage procedures.

All data was made anonymous before being used within this study and any requests by participants to remove data from the findings will be respected.

Privacy is paramount and only the researcher shall view the original unaltered data, this does not apply to users passwords as these are encrypted so as they cannot be viewed by anybody. If it is necessary for any third party to view the data, it was made anonymous and permission to do so was sought from the relevant participants.

Data will be kept for a period of five years, after this time it will be disposed of in a manner that will guarantee the anonymity of the participants.

Where participants were engaged in testing or workshops as part of their course work, as occurred twice, participation was completely voluntary and any refusal was guaranteed not to affect their grade.

3.3.5. Data Sets and Analysis

Following the PAR approach a number of data sets will be collected:

- Observations – video/audio/notes
- Theoretical Frameworks
- Artefacts/Prototypes
- Participatory Heuristics Evaluations
- Interviews
- Prototype usage statistics
- Usability Studies

This study was mainly one of qualitative research, where a mixed methods approach was employed to allow a thorough investigation of the system implementation and usage. Thus concurrent and transformative strategies of inquiry (Creswell, 2003) were employed when collecting and analysing the data. To conduct the data analysis it was necessary to compile all the data from the datasets into

coherent spans of text. The design heuristics developed in the last chapter were used to locate pertinent information across all the datasets. A coding and theming methodology was used to iterate over the datasets with the aim to sensitize with the data. As part of the iterative nature of PAR, the initial data collected helped inform the future direction of the research and what steps needed to be adapted in reflexive manner.

There are two main quantitative data sets used to complement and inform the analysis; these are usage statistics of the prototype and heuristic evaluations of the usability of the final system.

In the final stage all data was collated and analysed, the design heuristics were used to create interview questions to help explore whether the tools effectively facilitated and supported the skills and activities set out in the design principles.

Evaluations were conducted in an iterative fashion, using an array of datasets. Initially FTWs and participatory design sessions explored the community's perceived requirements for future tools in order to inform the initial design. This initial design acts as a "seed" for an evolutionary growth iteration of the prototype, with the aim of "reseeding" again later in the process. The early prototypes are being evaluated using participatory heuristic evaluation (Muller, et al., 1998), talk aloud protocols, interviews and observations. A brief report is made on the findings from these initial heuristic evaluations and design process, involving 6 Ph.D. candidates as participants. This is supplemented by an initial test of the system by 4 users in legitimate contexts, highlighting a number of issues that need to be addressed before the tool may be deployed more widely.

3.4. Summary

The preceding chapter has followed on from the evolutionary epistemological perspective we started with in chapter 2. It emphasises the transdisciplinary nature of the work and the consequence of this on both the research methodologies and design approaches used within this research. This transdisciplinary approach informs the research as both the design and research approaches are synthesised to fit their domain application. A similar approach was taken to synthesise the activity schema for the Ph.D. process at the literature review. Although we have chosen Participatory Action Research as our research methodology and Participatory Design as our design approach, they are not necessarily as defined by the literature but a synthesis of elements that act as a guide within which to conduct the research.

4. CAWriter Tool

This chapter discusses the CAWriter tool, which is an extension of previous prototype iterations of the CAWriter tool whose development is charted in chapter 5. This chapter takes a conceptual activity theory based approach to analysing the CAWriter tool. This abstract layer is added to both inspire those who would like to use a similar approach in their own work and to bridge the gap from tool design to tool evaluation. The activity systems developed throughout this chapter are an amalgamation of the activities and research skills defined in the design heuristics from the literature review chapter.

"Thinking is an activity in which the brain participates along with the eyes and the hands and a multitude of external devices, ranging in complexity from the pencil or the straight edge and compass to today's interactive computer systems." (Skagestad, 1993)

The literature suggests that doctoral candidates often receive little support with their academic writing beyond the one-to-one meetings with their supervisor. This chapter describes CAWrier a tool that aims to address this shortfall of support by scaffolding a number of activities related to the early dissertation writing process. This section describes the rationale and approaches used in the design of a computer supported collaborative writing tool, CAWriter (Cognitive Apprenticeship/Assistant Writer)(Byrne & Tangney, 2010, 2012).

The Holz et al. framework and the “Single System” act as a theoretical framework for the current iteration of the CAWriter tool, which aims to develop a computer supported collaborative prototype to support writing activities relevant to doctoral candidates.

4.1. Design Context

The social context (Figure 4-1) within which any design resides is crucial when deciding specification and features. This research acknowledges that the Ph.D. process can involve travel and multiple computer usage; therefore any implementation must be flexible and allow the user access as and when it suits them. The candidate is also embedded within a community of academics, which the literature has labelled using a variety of terms; Community of Practice, Cognitive Apprenticeship and Peer Learning.

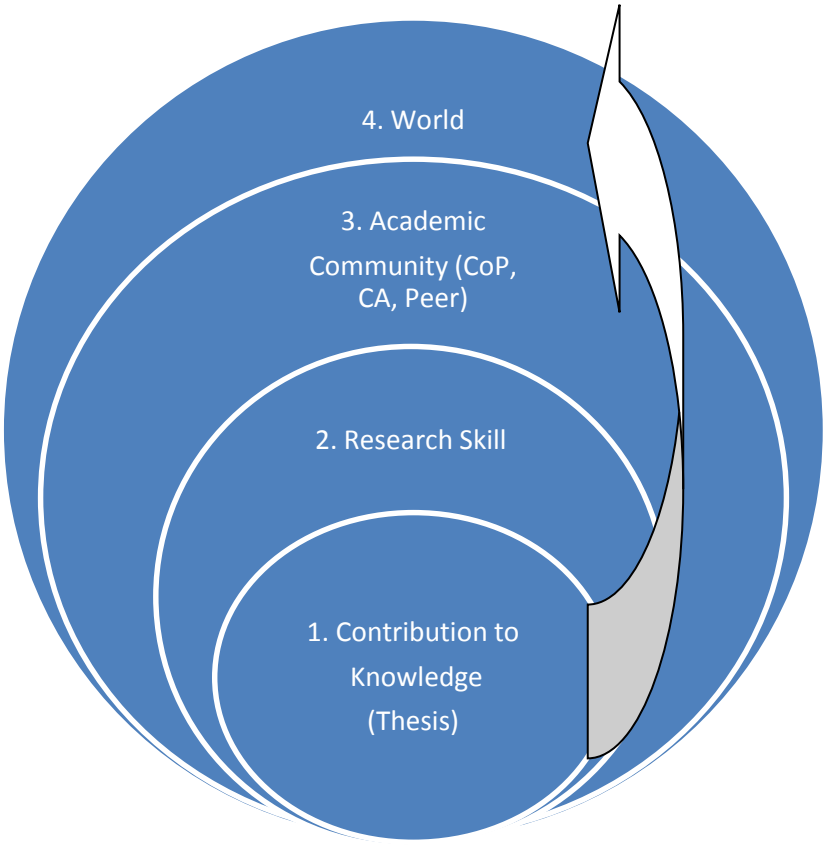


Figure 4-1 Design context for Doctoral Candidates

Doctoral candidates acquire their research skills through their interactions and participation with this community, therefore the design must appreciate this resource, aiming not to replace, but augment this relationship, leveraging off of it where possible. If there is a successful synergy among these elements it is fair to say that the candidate will make a significant contribution to knowledge, via a written thesis, not only to the academic community, but hopefully to the world at large.

The acquisition of research skills is more than often transferred as tacit knowledge through legitimate practices. Doctoral candidates learn these research skills from their academic community through a variety of different interactions (Figure 4-2).

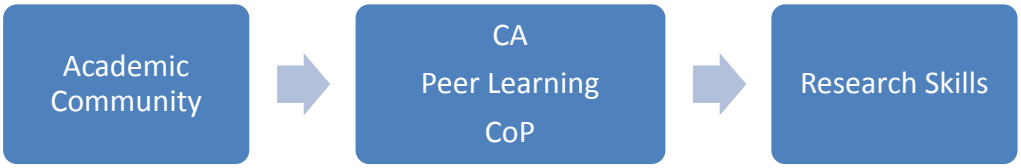


Figure 4-2 Pedagogical context for Doctoral Candidates acquiring research skills

Cognitive Apprenticeship is usually used to describe the Student-Supervisor relationship, the central relationship in any doctoral candidate's studies. This relationship is largely comprised of progress meetings assessing the state and direction of research. Here they may explore topics such as theoretical frameworks, experimental design, and data analysis, involving activities such as brainstorming, critical thinking and oral presentation. Another scenario is meetings discussing or providing feedback on their academic writing, whether this is for conferences, journals or the final Ph.D. thesis.

Peer learning can be used to describe a wide range of activities ranging from informal conversations with academics and fellow candidates to formal reading or writing groups. The term peer learning can also be extended to include peer-review feedback on submitted material at conferences, journals or for book chapters.

Community of Practice may incorporate the above with the addition of wider supports such as dedicated postgraduate courses or seminars that deal with research skills, academic writing and other relevant topics. Although these are usually of great benefit they are often short, in high demand and do not cater for individual needs, as may be the case in the Student-Supervisor scenario. The community of practice can also incorporate the more informal learning and other activities that lie outside the central research process, such as teaching, attending and presenting at seminars.

Figure 4-3 Knowledge Work context for Doctoral Candidates

Now that we have an idea of the social context within which the Ph.D. process resides, we can see that these processes are essential for the acquisition of research skills. Building on multiple perspectives from the literature we can describe how it is through the combination of social engendered skills and the use of tools that knowledge evolves, and significant contributions are made (Figure 4-3).

4.2. CAWriter – Design Rationale

This section discusses the design rationale for the prototype, CAWriter. The section that follows does not describe the design process in a chronological manner; as is described in chapter 5. The

section that follows reports the higher level concepts that inform the final design evaluated in Chapter 6.

4.2.1. Activity Systems

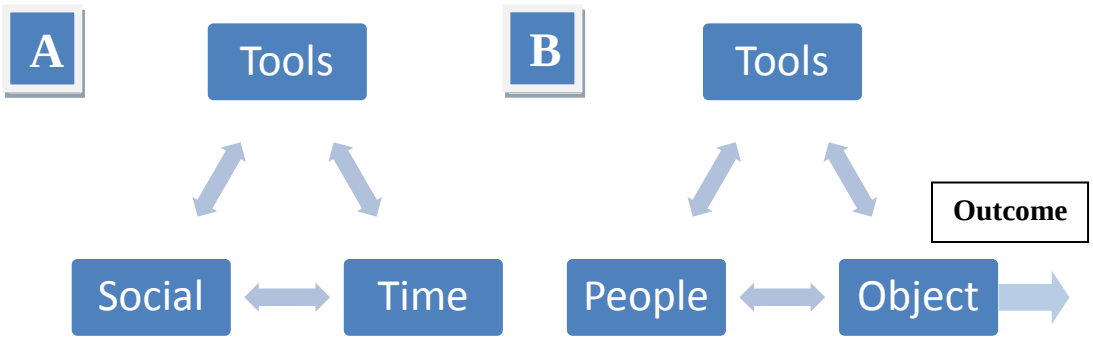


Figure 4-4 A) Distributed Cognition and B) Activity System

The Human-Computer Interaction theories of Distributed Cognition (DC) and Activity Theory (AT) give a basic framework to start looking at processes and how to design for them. Both theories are similar in nature in that they have a social and technological dimension. Distributed cognition focuses, as the name suggests, on the distribution of activities, whereas Activity Theory focuses on the mediation of the activity and the roles, rules and tools involved. The temporal dimension of DC and the output/task/goal dimension of AT may seem different at first, but if the temporal dimension is viewed as the ability to plan ahead, utilise forethought or developing meta-cognitive practices such as reflection, this temporal element can be simply interpreted as the ability to plan and set tasks or goals. This allows us to use the basic Activity System described in Figure 4-4 to the CAWriter system as a whole (Figure 4-5), providing an overview of the constituent tools and the tasks they facilitate.

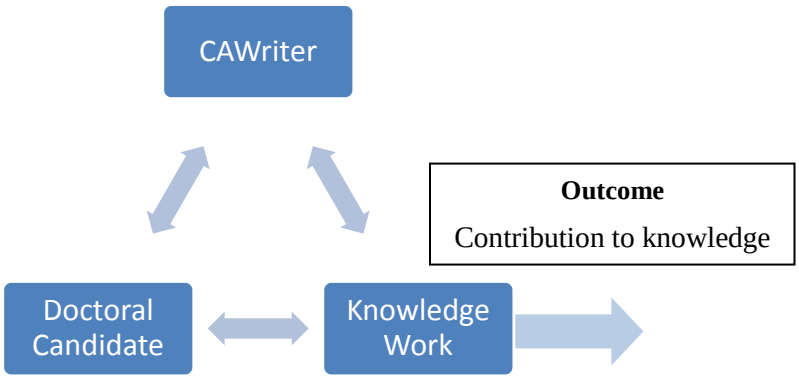


Figure 4-5 Activity System describing the CAWriter system as a whole

4.2.2. Technical Design Themes

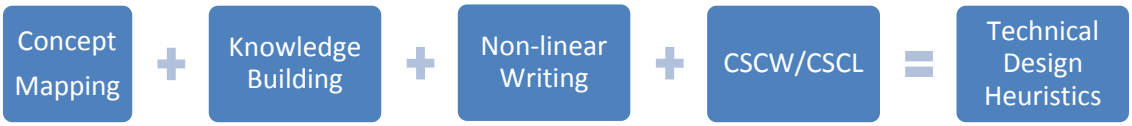


Figure 4-6 State of the Art Technical Design Themes

Taking the basic premise that tools will help mediate "knowledge work" and lead to contributions of knowledge, the design uses a number of state of the art systems in order to create a set of technical design themes to inform the design (Figure 4-6). Existing concept mapping and knowledge building environments are similar in nature, both are becoming networked and collaborative (Figure 4-7). Each system utilises linked nodes, which may have further resources or attributes attached. For example annotating links or attaching documents in CmapTools or threaded conversations and notes in Knowledge Forum.

Non-linear writing environments like iWeaver (Figure 4-8) are not common. The main distinction these non-linear approaches have to the more common word processors, such as Microsoft Word, is the "MapView", this provides a free space to organise ideas conceptually rather than the linear fashion found in most standard word processors. This "MapView" is similar in nature to the concept mapping and knowledge building applications mentioned above, suggesting that the synthesis of these technologies may help augment word processing environments with supports for higher order thinking and creative thinking.

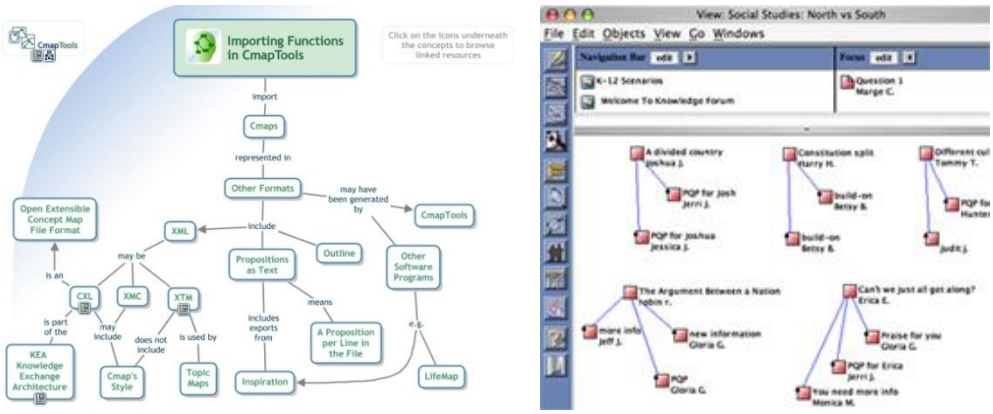


Figure 4-7 CmapTools (left) and Knowledge Forum (right) are examples of Concept mapping and Knowledge Building applications

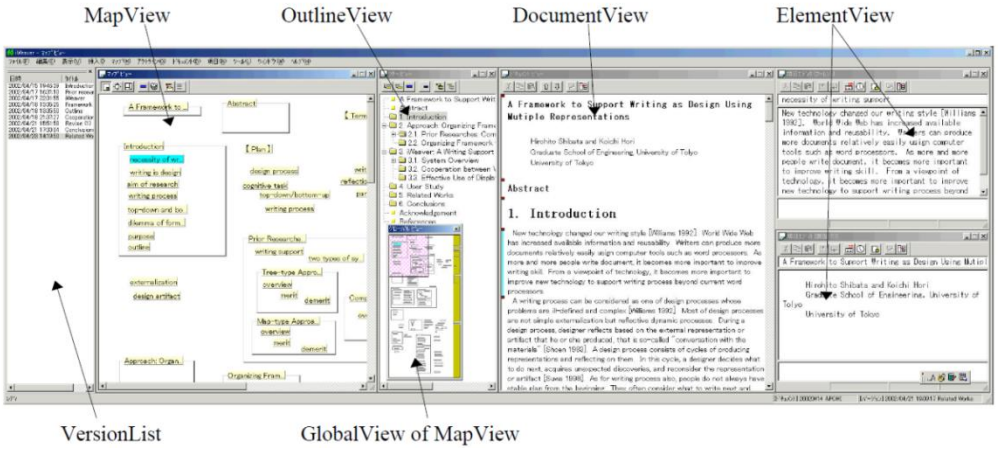


Figure 4-8 iWeaver non-linear writing environment, based on Writer's Assitant

The other views found in iWeaver, such as the "OutlineView" or "DocumentView" have corresponding or similar views to those found in MSWord. The terminology can become a little confusing as in MSWord it is not called the "Outline View", which shows a different structure, but is called the "Document Map". This "Document Map" view is accessible through the menus, but is not an obvious feature in the recent versions. This view shows the tree structure of the document, providing an alternative navigation mode, but does not offer any editing capabilities.

The "DocumentView" from iWeaver is practically the same as the main view in MSWord, although the contents are edited via the "ElementView" in iWeaver. The "Outline View" in MSWord allows for both editing and restricting in the single view, but images are not displayed and navigation is limited to collapsing or expanding heading tree structures and scrolling up or down.

The concept of multiple views of the writing process is supported by Bereiter and Scardamalia in their book, "The psychology of writing", where they distinguish between what they refer to as the "Content" and the "Rhetorical" spaces. The "Content" space is where writers are free to loosely connect ideas, take notes and generally collect or create informal artefacts; this aspect is not explicitly supported by linear writing solutions in general. The "Rhetorical" space is that of formal writing, the contents of this space are closer to the finished written document and would largely be the focus of linear writing solutions. This perspective aligns itself well with the view of Writing as Creative design as advocated by Sharples, where the 'final' text is the result of a large variety of inputs that range from informal ambiguous notes to usable paragraphs of text and quotations.

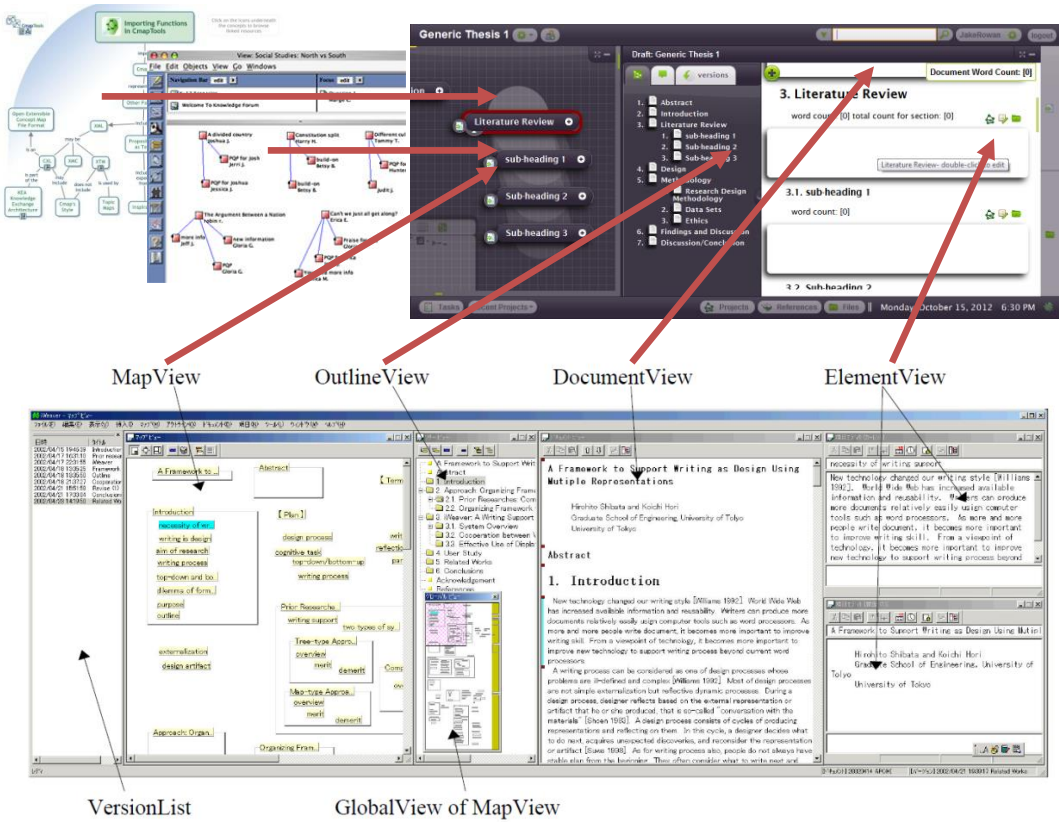


Figure 4-9 State of the Art influences on CAWriter

CAWriter is an amalgamation of elements of all these systems (Figure 4-9). The concept mapping tools, knowledge building tools and MapView inform CAWriter's CMap view, an informal space that is free to change and semi-formal notes can be attached to relevant nodes. The OutlineView of iWeaver and Document Map view of MSWord is instantiated in the TreeView feature of CAWriter. The DocView is a synthesis of both the DocumentView and ElementView from iWeaver, the DocView displays the whole document, to edit any section the user simply double clicks that section, and this also orientates the CMap view on the corresponding CMap element. The rest of this section deals with how each of these views, plus the LitView are used in practice, each time illustrated by an Activity System representation describing how the tools augmented by research skills results in an output that feeds into the Ph.D. thesis process.

4.3. Analysing the Problem

In order to help the user get started, upon first log in they are presented with an option to select from a list of pre-set project templates (Figure 4-11). This helps them start to frame their research problem.

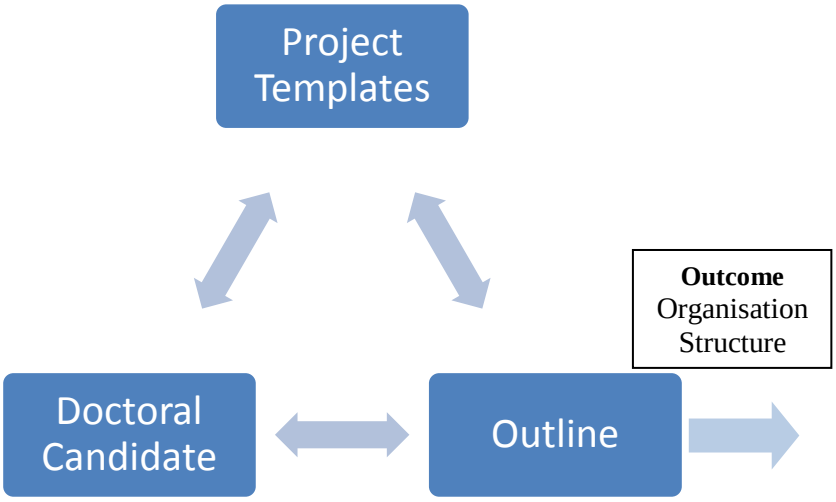


Figure 4-10 Activity System for Project Templates outputting Project Outline

Two of these templates are generic thesis structures common in scientific disciplines (one is shown in Figure 4-12, left), there is a Ph.D. notes project (Figure 4-12, right) and finally the outline of a scientific paper is also provided. A blank project is provided so that the user can choose to create their own. These personalised templates can also be shared if desired. This ability to share and create templates provides the potential functionality for custom templates for specific disciplines and scenarios, not something that was leveraged within the scope of this research, but could help customise the tool to individual students.

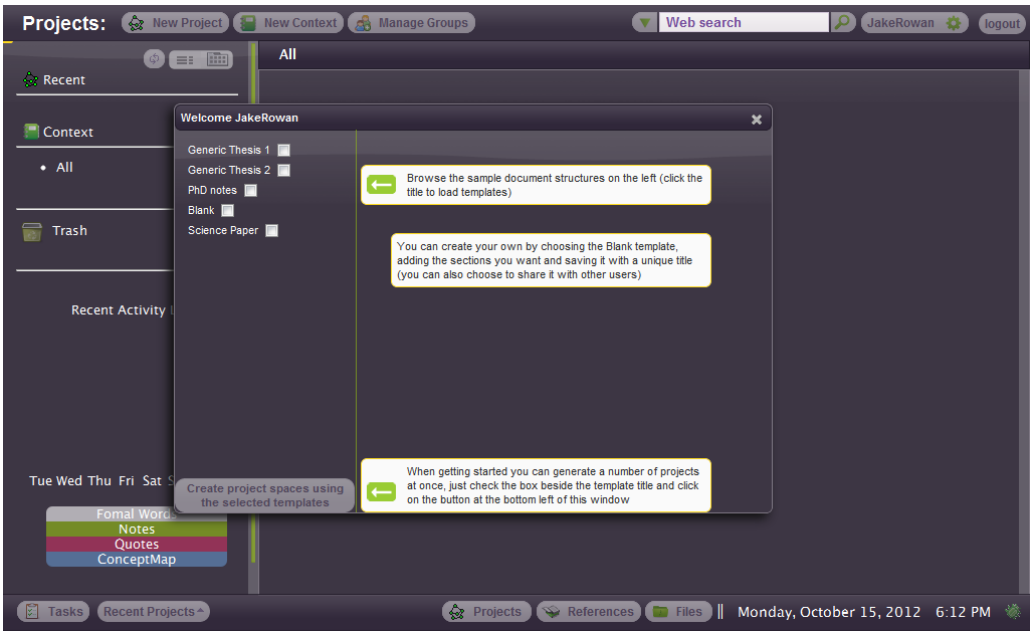


Figure 4-11 CAWriter on first login, prompts for project templates

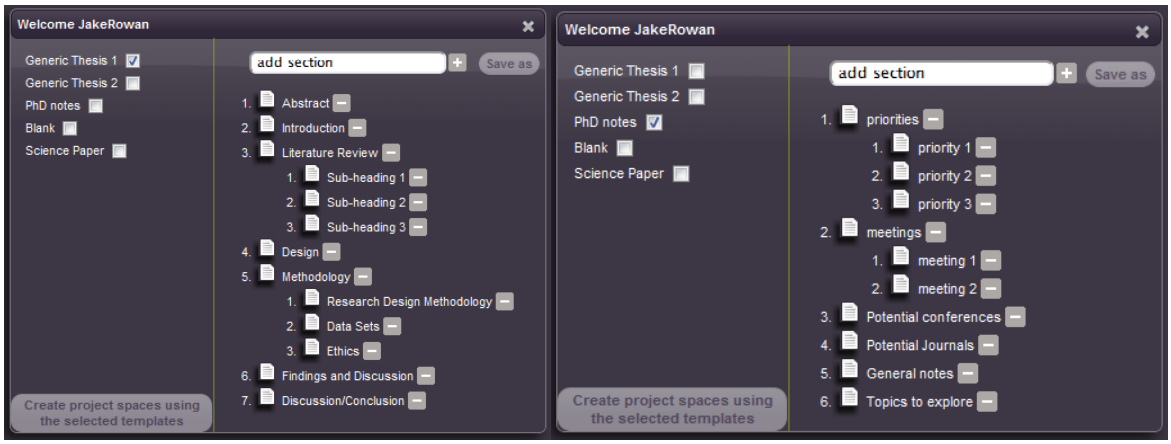


Figure 4-12 Sample project templates, generic thesis template (left) Ph.D. notes (right)

The reasoning behind this feature is to provide an easy way to get started, so rather than facing a blank screen, they can easily populate the system with an outline of the project, which can act as a thinking aid. If for example the user chooses the first generic thesis template it provides the outline as seen in Figure 4-13. Users were advised to replace the three sub-heading elements with three key words relating to their research area. These words may then act as the basis for conceptual framework creation and the literature review search. Although the conceptual framework features are described here before the literature review supports, it is a dynamic and iterative process with each activity informing and influencing the others.

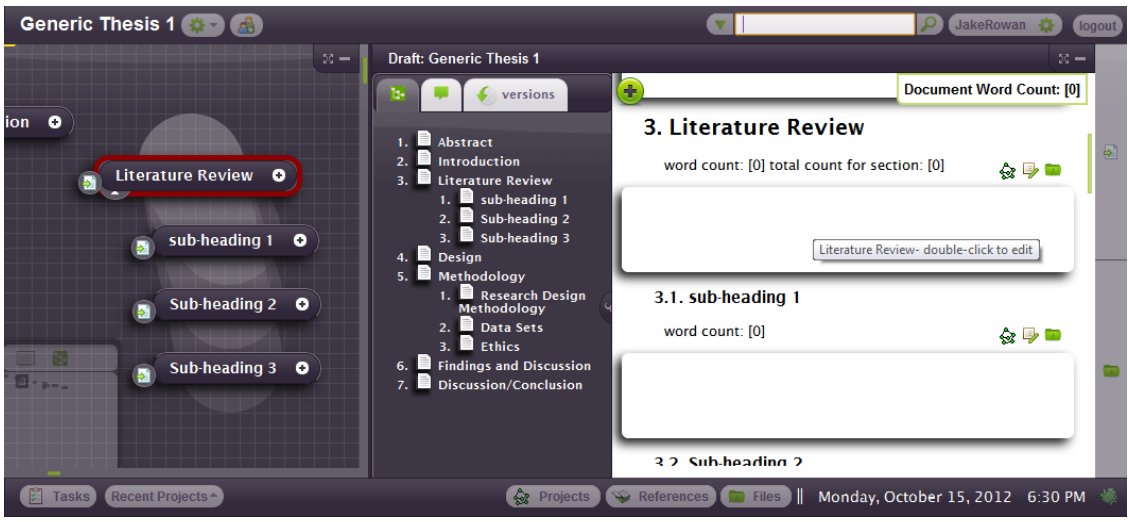


Figure 4-13 Automatically generated structure and elements from generic thesis template

4.3.1. Conceptual Framework

"A conceptual framework explains, either graphically or in narrative form, the main things to be studied — the key factors, constructs or variables — and the presumed relationships among them. Frameworks can be rudimentary or elaborate, theory-driven or commonsensical, descriptive or casual." (Miles & Huberman, 1994, p. 18)

Conceptual frameworks have been advocated as method to get novice researchers thinking about their research topic and area. There is no definitive approach, but they are similar in nature to both concept mapping and the creative approaches to writing discussed in the literature review. CAWriter utilises the CMap space for this task, if the user has or has not pre-populated the space from an existing template they are free to create and edit contents to create a structure that fits their research. Figure 4-15 shows a conceptual framework that relates various theoretical elements together as they are reflected in this research.

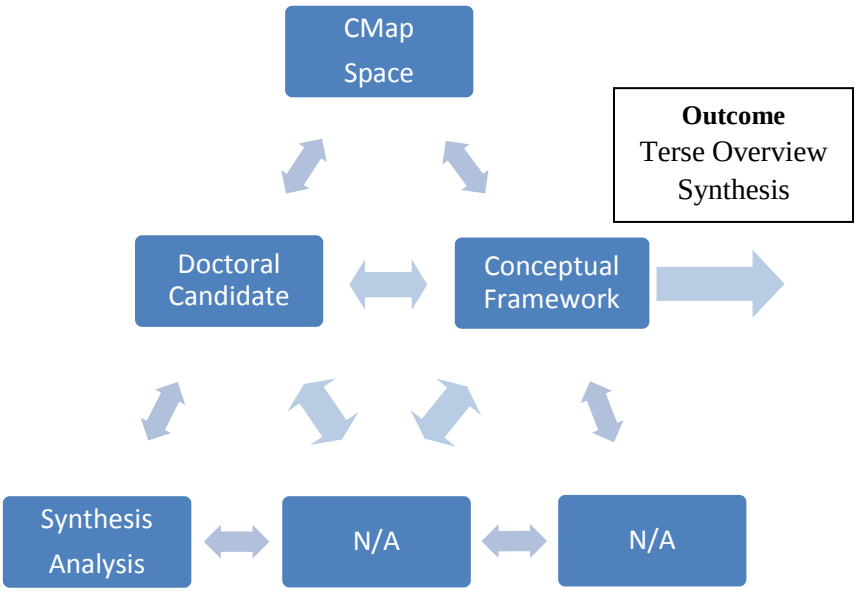


Figure 4-14 Activity System for Concept Mapping outputting Conceptual Frameworks.

Adhering to Wood's Cognitive Dimensions for idea sketching as the basis of the design, considerations were made so that the system has reduced viscosity, terseness, perceptual clues, reduced premature commitment, enhanced accessible and reduced formalness. Reduced viscosity was achieved by making it as easy as possible to get the ideas down, using a clean and simple user

interface. Terseness provides a simple to read overview of the topic, an inherent quality of concept mapping style representations. Perceptual cues are realised through the linking of elements within the CMap space as well as the ability to relate elements based on proximity. Reduced premature commitment and reduced formalness are facilitated by the informal nature of the space and the ease with which the contents may be changed and edited.

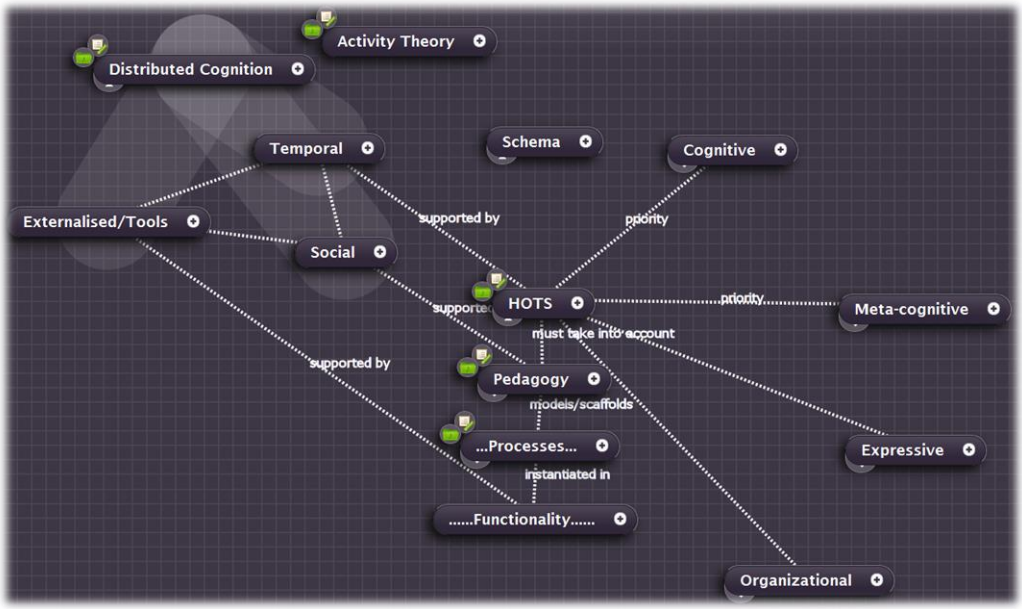


Figure 4-15 Example Conceptual Framework using CAWriter

This process involves a number of research skills. In order to bring ideas together from a number of areas and create a coherent conceptual framework, the user must bring a number of elements together from a range of different areas; this is by definition the process of synthesis. Although the user may only have limited knowledge of each element, it is a researcher's prerogative to analyse the contents of this conceptual framework and update it accordingly. This highlights both synthesis and analysis as the main skills found in this stage.

4.3.2. Literature Review

The literature review is a central activity of any Ph.D.. Holz et al. dedicate the first 5 specific research skills to this activity: Search Literature, Scan Papers, Select Papers, Analyse Literature and Critique Literature. CAWriter associates these activities with the first phase of the creative process, analysis of problem (Figure 4-16). This phase calls for collecting, fact-finding, idea generation and preparation, similar to at least the first 3 literature related skills from Holz et al.,

search, scan and select. This activity is not meant to happen in isolation and the user is encouraged to use the CMap space and update their conceptual framework as they work. Analysis and Critique of the literature are discussed in more detail in the section dedicated to the "Single System" for dissertation writing.

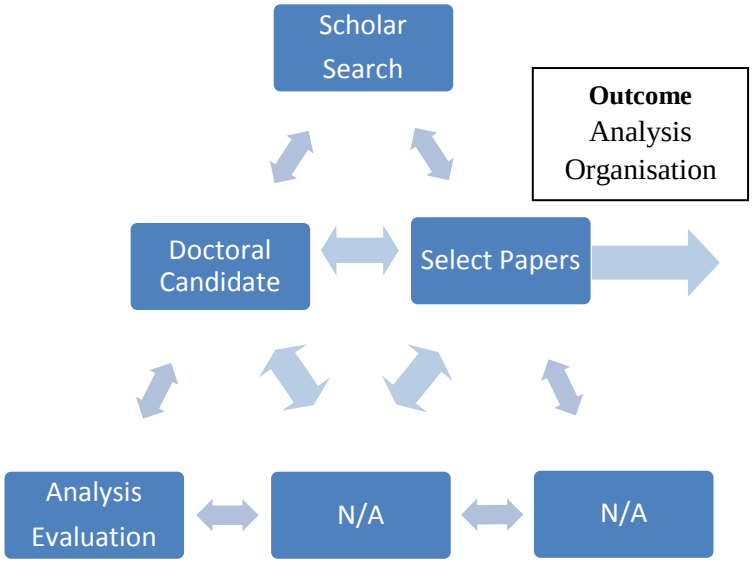


Figure 4-16 Activity System for Scholar Search outputting Relevant Papers

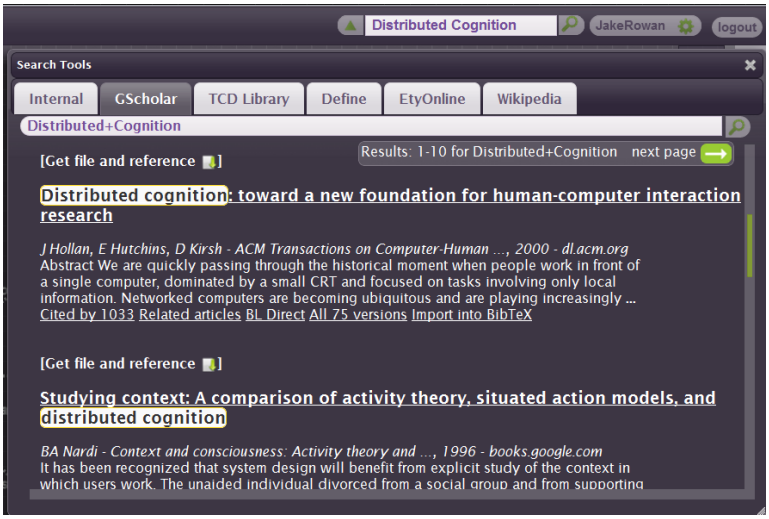


Figure 4-17 Google Scholar Search, with quick file and reference retrieval

CAWriter provides a literature search facility based on Google Scholar, it also provides search results from Trinity College Dublin's Library as this is the host institution. As CAWriter is based within the Trinity's infrastructure it can avail of the library subscriptions. This allows for a single click download of the file and reference, shown as the "Get file and reference" option in Figure 4-17. Users can click on the link to the paper to look over the abstract or preview the document before adding it to their profile. Once the "Get file and reference" is selected the file and reference are added to the file and referencing system within CAWriter and are automatically linked together, these features are discussed in more detail in the following section.

4.3.3. Organisation

Organisation is mentioned as a basic skill in the Holz et al. framework. CAWriter focuses on the record keeping skill as it ties in well with the writing process. CAWriter provides two main functional elements that make record keeping easier. There is both a file management system and a basic referencing system (Figure 4-19). These provide the functions to record and store a range of file types in the file system and BibTex formatted references in the referencing system. If the file has a reference attached both clicking on the file name in either the reference window or file list will open the file within CAWriter, this highlights the tight integration of data on the server side of the CAWriter application.

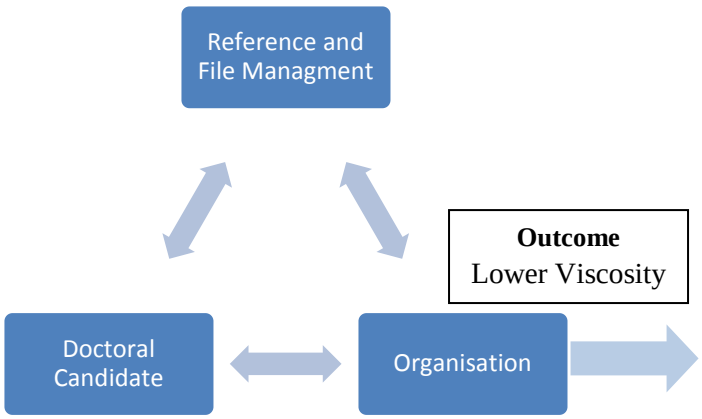


Figure 4-18 Activity System for Reference and File Management Features outputting Organisation

There are many more record keeping facilities with CAWriter beyond the file and referencing system, which will become evident in the following sections. Files can be associated with CMap elements, notes can be attached to CMap elements and notes and quotes can be collected and automatically associated with files.

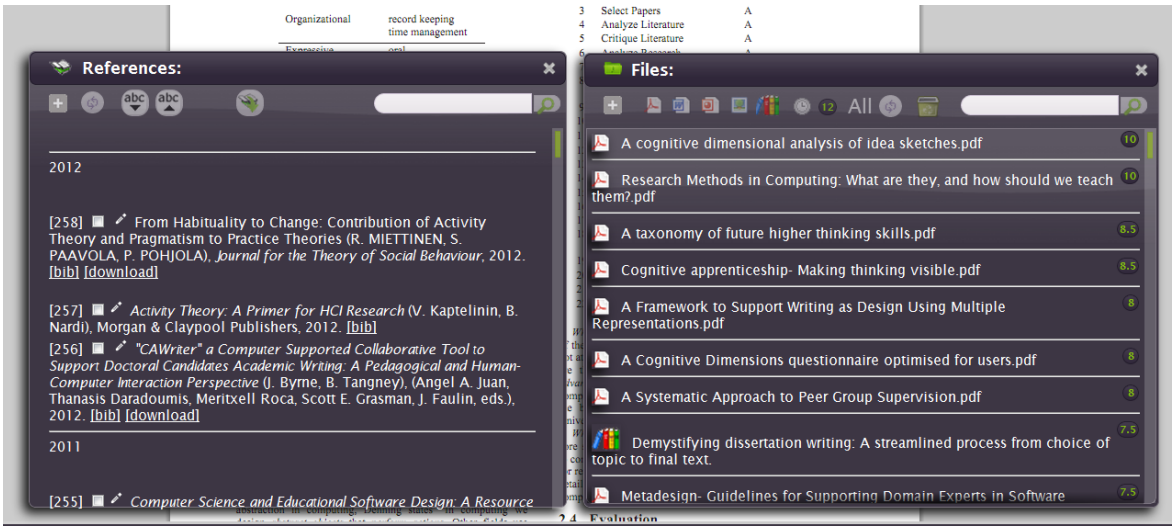


Figure 4-19 Reference (left) and File Management (right) Features

4.3.4. The "Single System" for Academic Writing

The "Single System" was chosen as a template for the design of CAWriter as it provides explicit activities that can be supported. It is also a process that looks at the whole dissertation writing process rather than only a subsection. This allows us to place the activities in a legitimately situated process whose aim is to output a Ph.D. dissertation. Although it is not expected that this will occur with users during the course of this research, the pedagogical approaches that inform this work suggest that all learning activities should be embedded within a legitimate activity situated within their work practice.

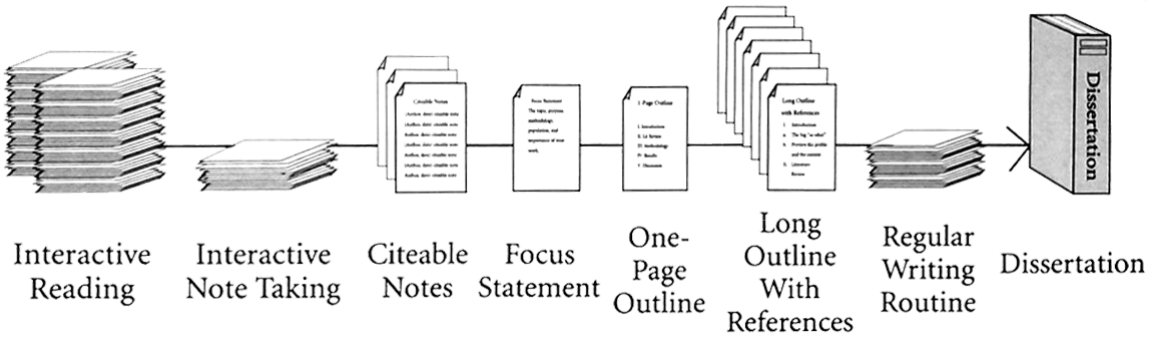


Figure 4-20 The "Single System" for Academic Writing

4.3.5. Interactive Reading

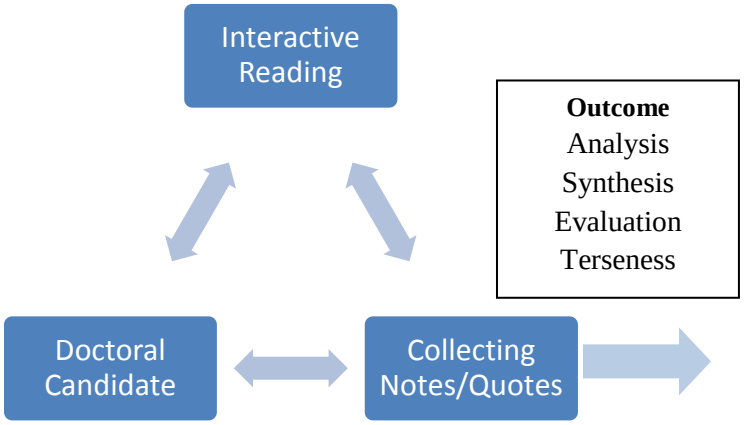


Figure 4-21 Activity System for Interactive Reading outputting Comments/Notes and Quotes

Interactive Reading is the first phase in the Single System, it occurs after papers have been selected and downloaded to the CAWriter file storage facility. This phase goes beyond the collection of material described in the creative phases and the selection of papers described in the Holz et al. specific skills. The aim is to support cognitive skills such as analysis and evaluation.

Analysis is supported by the interactive reading phase that Single promotes. In the original description of this phase by Single it largely consists of reading while collecting quotations or jotting notes in the margin on printed medium. As CAWriter is a digital tool efforts were made to digitise this process. Most documents are in .PDF format, a proprietary format that can be embedded within most modern browsers through plug-ins, but the website code cannot access the contents due to security restrictions. In order circumvent this issue the .PDF files were converted to HTML, the code that websites are built with, on first load. This process was achieved using the 'pdftohtml' command found in most Debian Linux operating systems, allowing the creation of dynamic and interactive note taking and quote collecting as seen in Figure 4-22. The user simply highlights the text of interest and a small toolbar appears, with 4 options: get selected quote, add comment/note, tag document with this phrase or search for this phrase.

Quotes and page numbers are automatically attached and linked to the document and are accessible through a side panel (Figure 4-23). This side panel contains a range of information about the document that largely based on scaffolded user input. As well as quotes the user can attach their own notes through either of two routes. The first is a quick note by clicking the small plus in the upper left hand corner of the document view, a small pop-up text input appears. The other is

through the tabs in the side panel, here they can access a rich text editor to create more detailed and formatted notes, quick notes are automatically added to this side panel. The side panel also features tabs to add or edit the reference information (this can be automatically retrieved from Google Scholar), see what CMap objects are linked to the file, attached tags and other peoples shared notes on the same file.

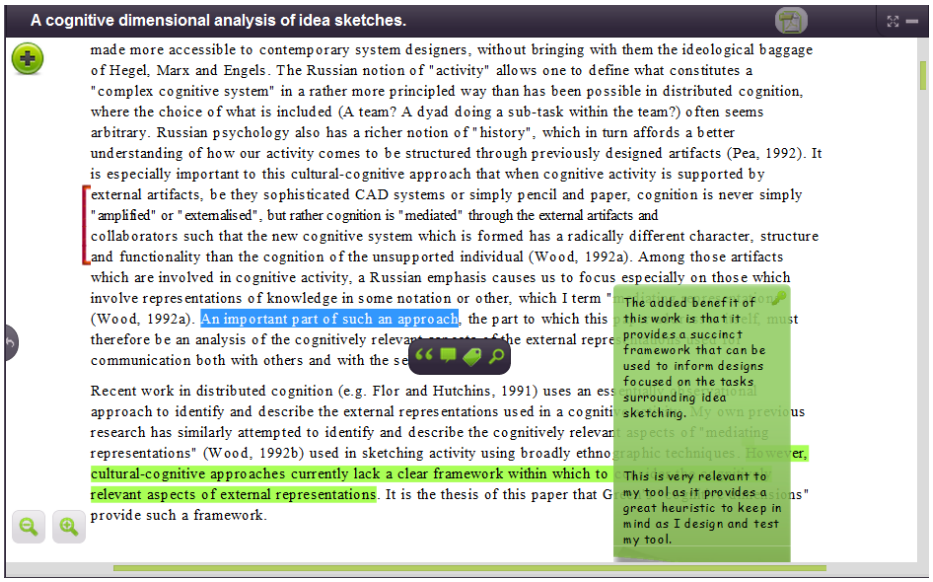


Figure 4-22 Interactive Reading: Comments (green highlight and post-it) and Quotes (red highlight)

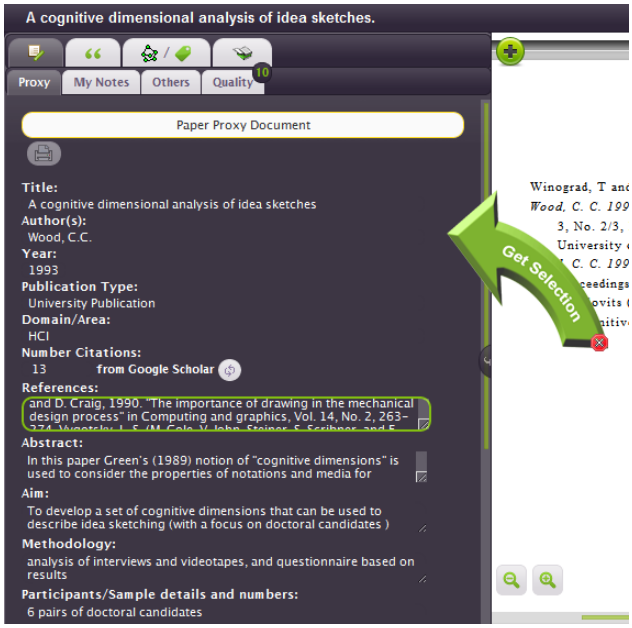


Figure 4-23 Interactive Reading collecting Proxy Document information to side bar

CAWriter also provides what is referred to as a "proxy document" in the side panel (Figure 4-23). This is a template that the user can populate with relevant information from the paper, book or report in question. The title, author, year, publication type and Google Scholar citations number are automatically inserted once the reference information is attached. The following sections include abstract, references, aim, methodology, participant/sample numbers and details, context, data analysis techniques, findings, future work and conclusion. The user can highlight a portion of text with the side panel open, a large arrow appears asking if they would like to input the selection into the proxy document. The user simply selects the section they wish to populate and clicks the arrow.

The proxy document serves a number of purposes; firstly it supports analysis of the literature as it makes explicit the salient points from the document under review, as the user becomes familiar with this process they will be able to pick out this information upon their first read of any paper. Secondly the proxy document also helps with data overload and locating relevant information, if the user has filled out the proxy document they will not need to refer to the whole document but can look at the proxy document for a synopsis of the salient information. This quick access to information may suggest that the cognitive dimension, terseness, is being supported. Having such an overview of the document may help in the evaluation and critique, a matter we go into more detail in the interactive note taking phase.

4.3.6. Interactive Note Taking

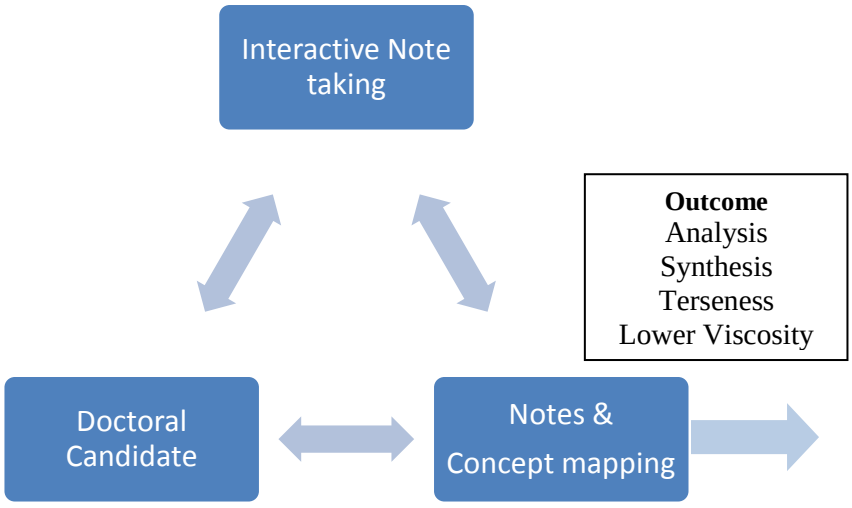


Figure 4-24 Activity System for Interactive note taking outputting Refined Notes and updating Concept Maps

Interactive note taking is a more in depth analysis of the quality and relevance of the document under review. CAWriter utilises the same features used to support the interactive reading phase along with a few additional extras. The “Quality Assessment” form is a questionnaire template adapted from an approach to systematic literature review (Major, Kyriacou, & Brereton, 2012). This form has 12 questions, with three options: yes, no and partially Figure 4-25. These answers are weighted as 1, 0 and 0.5 respectively. The first three questions are broad questions that make sure that the document is research orientated, is clear and relevant. If the user answers no to any of these questions they may not continue as the paper is not of a high standard or relevant. Answering the form will give the document a rating from 0-12, the file system view can order the files using this parameter, placing the highest rated documents first. This form provides supports for both analysis and evaluation of the literature. As the user becomes acquainted with these questions they can quickly asses the relevancy and quality of the documents while conducting interactive reading. They may also use this questionnaire to assess their own work in future as it provides probing questions that are beneficial for a researcher to have in mind when reflecting on their own work. This opportunity to reflect provides the user with chance to assess their own biases as to how they view other research writing. As this is a template questionnaire, it is possible that it may be adapted to suit specific disciplines or working contexts, although this customisability was never tested with users.

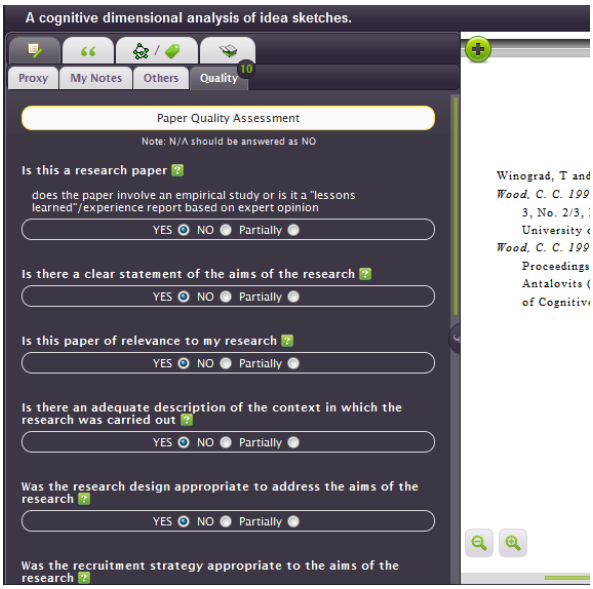


Figure 4-25 Quality Assessment form

Further supports for analysis are provided through the rich set of options for the collection of notes. This can be achieved through three main options, notes attached to the document under review, notes attached to CMap elements or CMap elements themselves. When moving the note creation away from the document review view, there is more of a chance for synthesis to occur as contents from other reviewed documents may be present in the CMap element and note views (Figure 4-26). This provides the user with opportunities to evaluate the contents in relation to each other and update the notes or CMap elements accordingly. When these amalgamations of notes become more formal, they become citable notes.

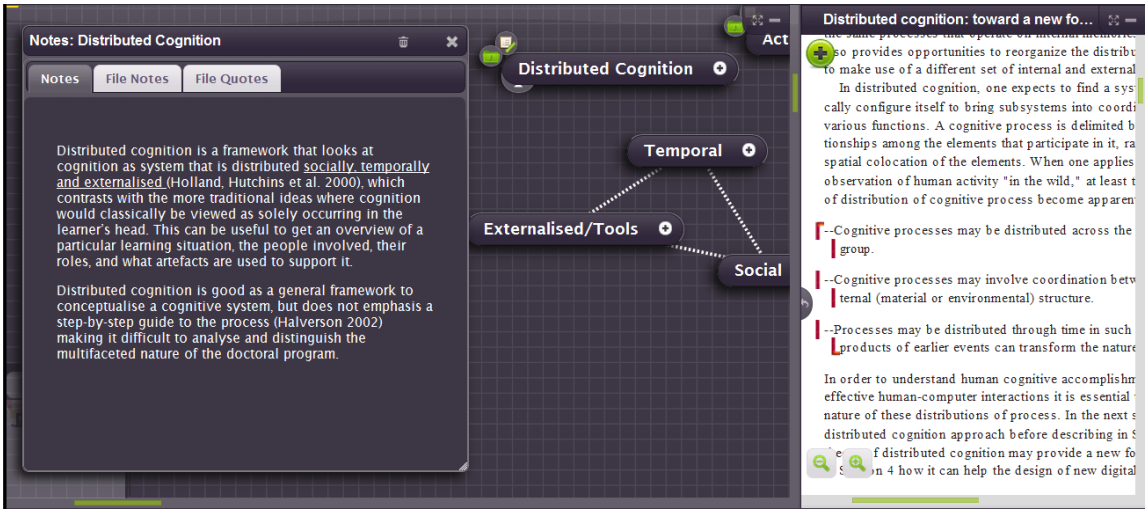


Figure 4-26 Interactive note taking, refining Concept Maps and attached notes

4.4. Generating Ideas

We now look at the skills and activities used to support the generating ideas phase of the creative process. These range from creating citable notes to work on the long outline of the draft document.

4.4.1. Citable Notes

Citable notes develop from the literature review process, once ideas and notes are collected on a particular subject, they can be summarised into short paragraphs. These may then be inserted into the formal document window.

This step requires synthesis, analysis and evaluation of ideas, bringing an assortment of different concepts or approaches together in an appropriate and coherent manner. Although not implemented

a feature where one can auto import suggested citable notes into the document may be worth exploring in the future.

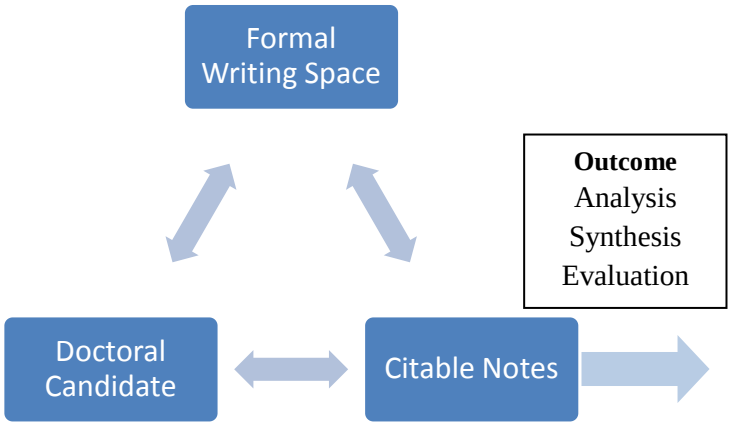


Figure 4-27 Activity System for Formal Writing Space outputting citable notes

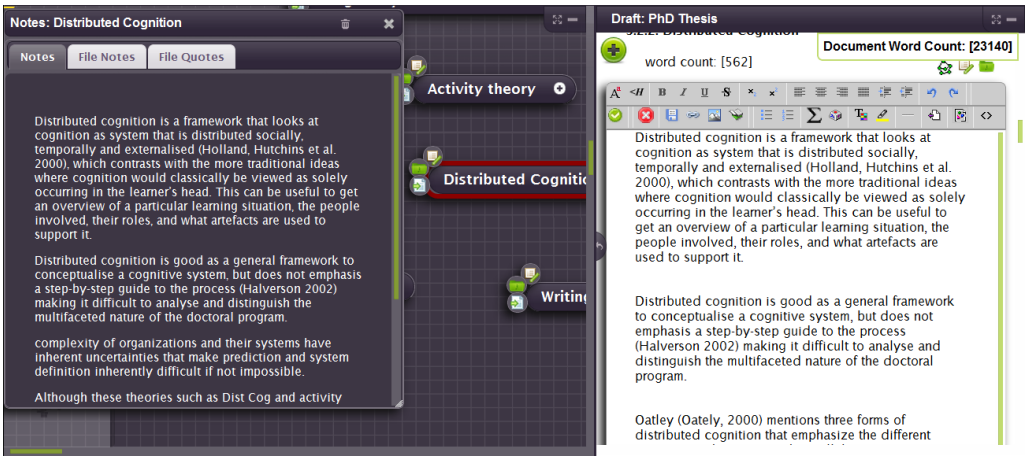


Figure 4-28 Transferring citable notes to Formal Writing Space

4.4.2. Focus Statement

The focus statement was not explicitly supported by CAWriter, although the automated template structure does create an 'Abstract' element, which may be populated with a focus statement. There is also the option to add a description to the project, again another design option for entering the focus statement.

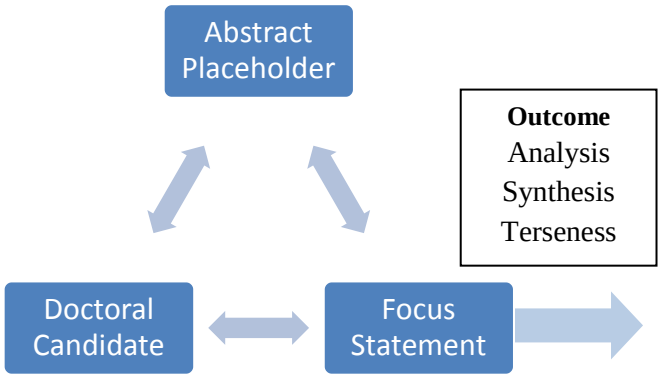


Figure 4-29 Activity System for Abstract placeholder outputting Focus Statement

4.4.3. One-Page Outline

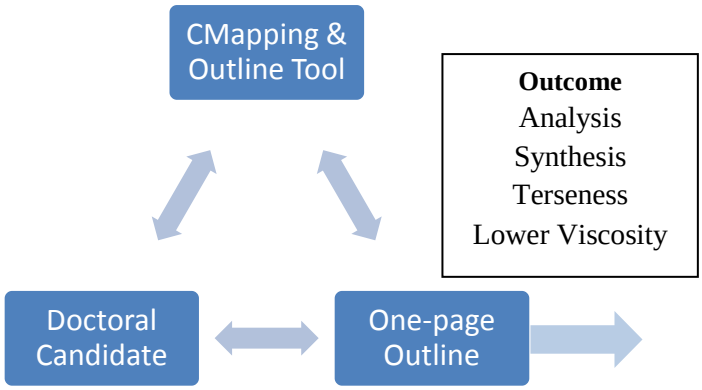


Figure 4-30 Activity System for Concept Mapping and Outline Tool outputting One-Page outline

The one Page outline is supported from the outset in CAWriter. As has been described in the 'Analysing the Problem' (5.3) upon first log in the user has the option to create the outline of their thesis or paper. If they bypassed this option and created their own conceptual framework using the CMap space, they can easily add a CMap element to the document structure, using a small pie/radial menu that is accessed via the plus sign on the element. Once added to the document structure it appears in the tree structure and formal document views (Figure 4-31). Using the tree structure view the ordering can be changed and updated easily by simply dragging and dropping the element in question. The structure relationships are shown as the wide shaded regions in the CMap space. All five cognitive processes are present here as the user threads their ideas together into a coherent document outline.

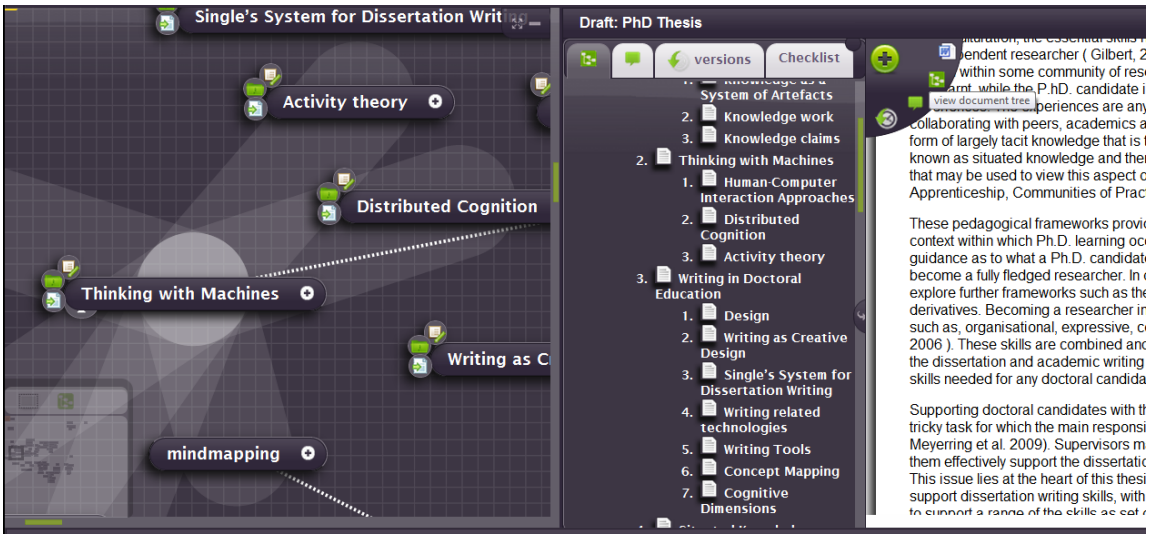


Figure 4-31 One-Page outline using Concept Map and Document Tree view

4.4.4. Long Outline

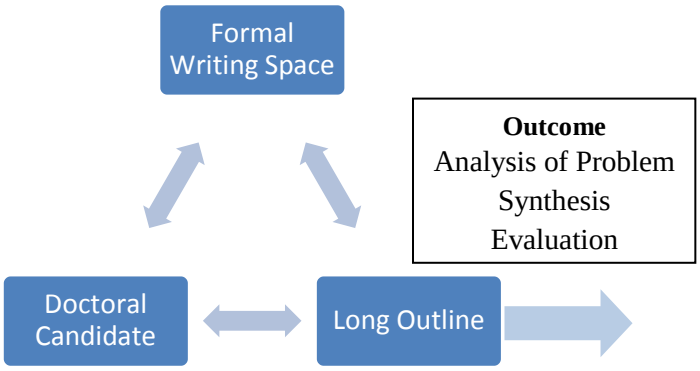


Figure 4-32 Activity System for Formal Writing space outputting Long Outline

The long-outline is essentially a combination of citable notes and the one page outline. As the user populates the formal document with their citable notes the long outline takes shape (Figure 4-33). Although these steps are distinct in Single's approach they are unified and interrelated in CAWriter. This is achieved through the tight integration of supports and functionality.

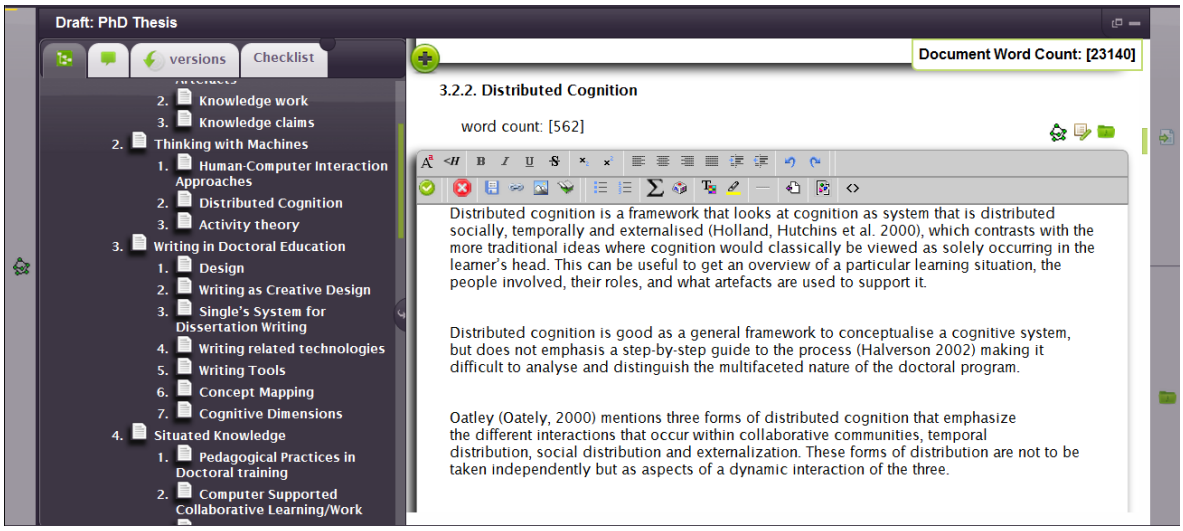


Figure 4-33 Using the Formal Writing space for completing Long Outline

4.5. Evaluating Ideas

This is the final phase of the creative process that CAWriter is designed to facilitate. The system is orientated towards the earlier stages of the writing process so that it can support novice researchers. It therefore does not cater well for the final formatting and completion of the finished document. CAWriter cannot hope to compete with existing word processors in this regard; therefore it is not a finishing tool, but a space for "knowledge work".

4.5.1. Regular Writing Routine

A regular writing routine is important to develop writing skills. Although Single suggests recording word counts as an indicator of activity, CAWriter goes a step further and attempts to give a broader overview of the knowledge work that the user is engaged in. CAWriter provides an activity log chart (Figure 4-35) that shows activity across a variety of tasks, from Concept mapping work, quotes collected, notes written or word count of formal words written. This provides the user with feedback with which they can self-monitor, a meta-cognitive skill advocated by Holz et al.

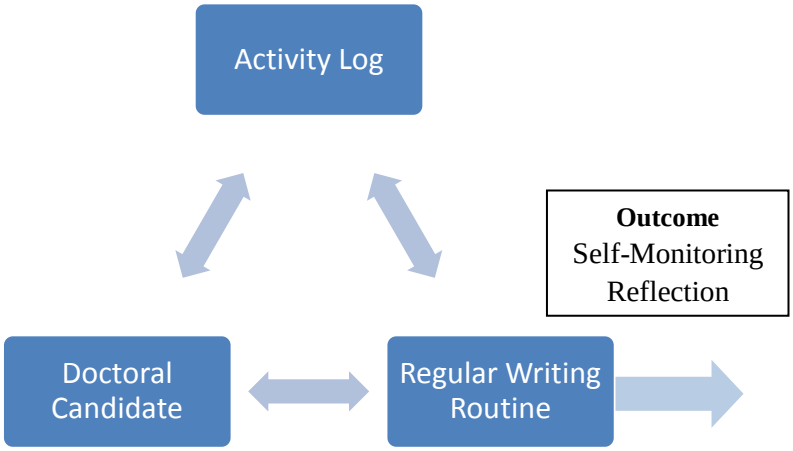


Figure 4-34 Activity System for Recent Activity Log outputting a Regular Writing Routine

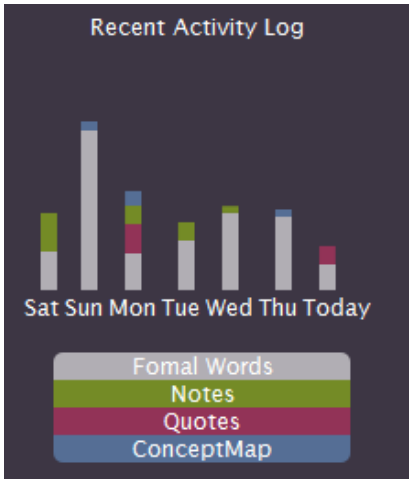


Figure 4-35 Regular Writing Routine and self-monitoring is supported by a Recent Activity Log

4.5.2. Collaboration

Collaborative features are integrated into CAWriter on the basis that the Ph.D. process involves a number of social dynamics, whether through cognitive apprenticeships or peer learning. Utilising the suggestions for group work systems, based on CSCW and CSCL, a number of features were implemented (Figure 4-37). Each project may be shared with either individuals or predetermined groups (Figure 4-37, A).

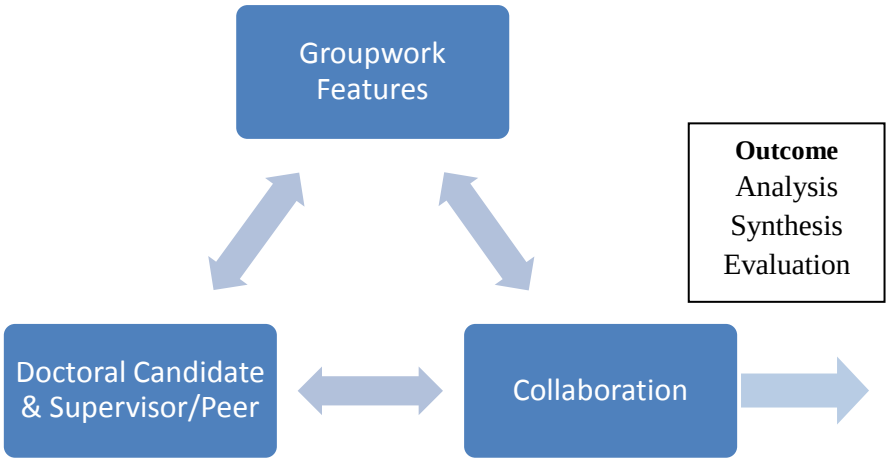


Figure 4-36 Activity System for Groupwork Features outputting Collaboration

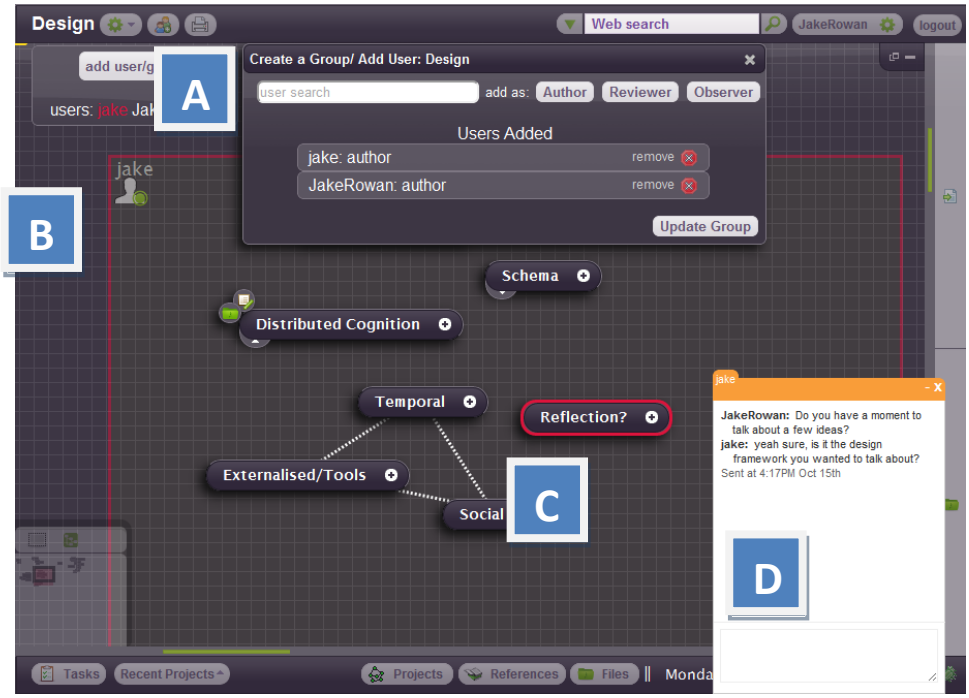


Figure 4-37 Groupwork Features A) add users or group to project, B) other user view portal, C) other user's concept map objects, D) chat window

There are three access levels that the owner of the project can allow: Author, Reviewer and Observer. An author has the same privileges to edit all content that the owner has. The reviewer can add content, but they cannot edit or remove existing content. The observer can simply view the content, but they have no editing or creation privileges. Once a user is present within the CMap

view their presence and view portal is represented by a coloured rectangle with a small icon with their user name attached (Figure 4-37, B). This updates the user's location as they pan/scroll around the CMap space, providing the other users with some awareness of their activity and what they can see on their screen. When an author or reviewer adds contents to the CMap space, the added content will be highlighted with a unique colour specific to that same user (Figure 4-37, C). Finally a basic chat function was added to allow remote users to converse either synchronously or leave message asynchronously (Figure 4-37, D). This chat window is accessed by either the user list that drops down from the top panel or by clicking on the user's icon in the CMap space. Although these features were integrated, they were not tested in collaborative settings, so their usability and usefulness remains an unknown.

These features provide the user with the opportunity to share, discuss and evaluate their ideas with others. This might be utilised across all the creative process phases, from analysis of the problem to final donation of a finished body of work. In order to support the evaluation of ideas in more detail, CAWriter also provides a number of supports for community feedback on written content through comments and notes.

4.5.3. Community Feedback

For more in depth community feedback on written content, CAWriter provides a basic commenting system for the formal document view (Figure 4-39). When a user wants their work reviewed, they create a new revision of the document and share it (Figure 4-39, A). When the reviewer selects the revision in question they are presented with two options, to leave comments (Figure 4-39, C) or to edit the contents of the text (Figure 4-39, B).

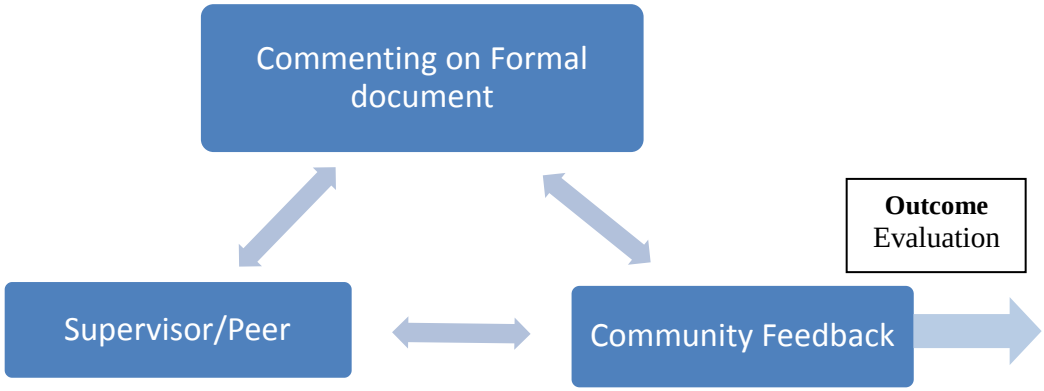


Figure 4-38 Activity System for Commenting Features in the Formal Writing space outputting Community Feedback

When leaving a comment it is very similar to the literature review features, simply select the text and either choose a sample comment or write a custom one. To edit the text they open up the text portion of interest edit it and save. These edits result in a view that displays the added content highlighted in green and the removed content highlighted in red. These features are again aimed at facilitating the evaluation of ideas, concept and writing skills. These were not tested extensively within this research but are viewed as essential if the aim is to support the writing process from beginning to end.

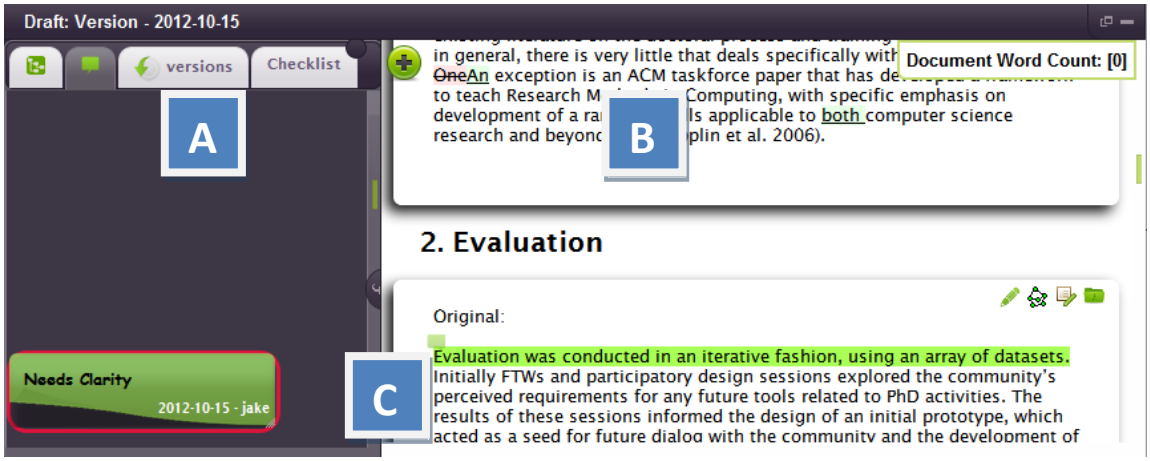


Figure 4-39 Collaborative Writing Features A) Version control, user can choose if shared or not, B) See suggested edits inline (underlined is added, stroke out is removed), C) see collaborators comments inline

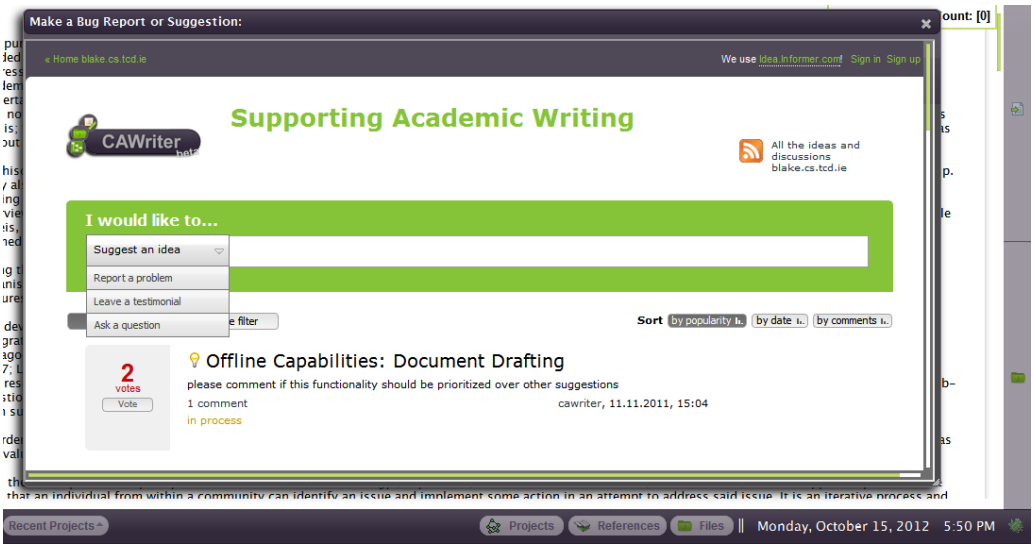


Figure 4-40 Community feedback and bug reporting

For more general community feedback and help, CAWriter provides a feedback system that is accessible via a small bug in the bottom right hand corner of the screen (Figure 4-40). This was used for bug reporting, asking for help and asking for new functionality. This is an essential element if a project was to scale up to many users and still maintain the participatory nature of the design process.

4.5.4. Self -Review Protocols

These activities are designed again to help the user evaluate ideas. Here there are a set of prompts the user can use to do a self-assessment of their own ideas, biases and/or work. The first such support replicates the structure of the quality assessment form but takes a protocol from the literature (Boote & Beile, 2005). This allows the user to self-assess their literature review using a list of predefined questions, again the score is made explicit so that the user can evaluate the state of their literature review (Figure 4-42).

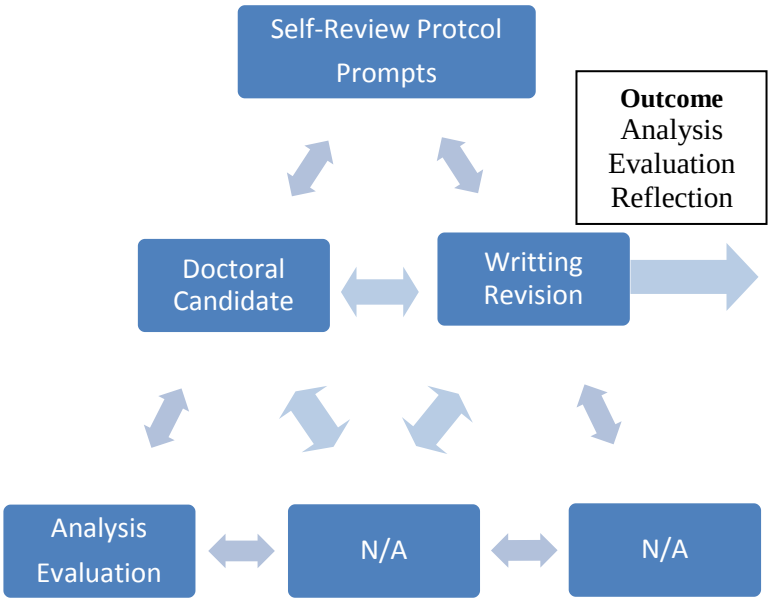


Figure 4-41 Activity System for Self-Review Protocol and Reflection Prompts

Building on Ravenscroft's idea to prompt users with questions to help them reflect on various aspects of their work, whether this is to come up with new ideas, improve on existing ones or set

goal, a set of prompts were integrated into the notes window to help prompt users if they could not think of how to advance (Figure 4-43). The importance of reflection is highlighted in the sections 3.2.1.1 and 3.2.1.2, where bias shapes our worldview and reflection is an opportunity to reassess these prejudices.

Figure 4-42 Literature Review Protocol

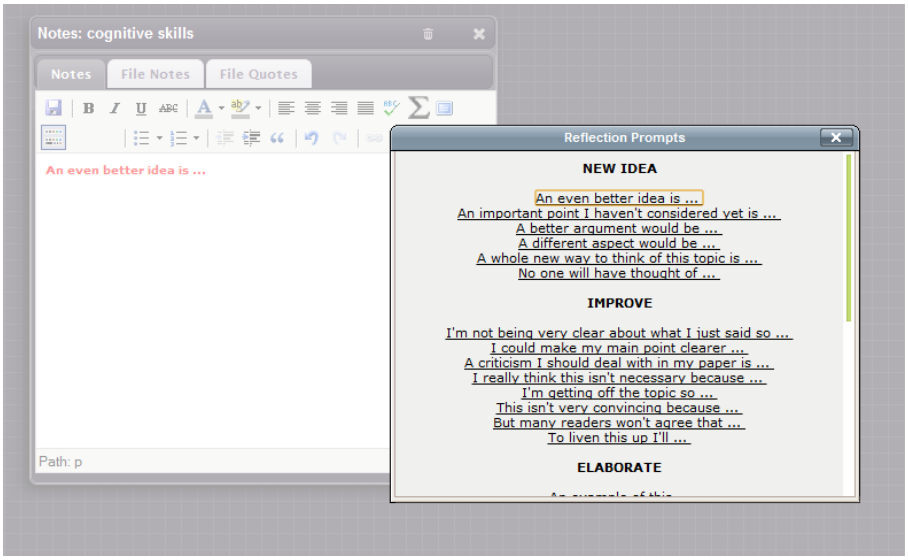


Figure 4-43 Reflection prompts

4.6. Summary

This chapter has seen the development of the latest version of CAWriter. CAWriter is a realisation of the Activity System, Design Heuristics and user requirements. There has been particular emphasis on the "sub" activity systems that can be used to describe how the various research skills and dissertation writing activities interact and relate to the designed artefact. The findings from a set of user studies and participatory heuristic evaluations are presented and discussed in chapter 6.

The following chapter outlines how the methodologies and approaches discussed in chapter 3 were implemented over the course of this research in order to develop a tool which meets the design heuristic criteria recommended at the end of the literature review. This process builds on both personal and community insights, culminating in the tool, CAWriter that was described in detail above. CAWriter is then evaluated in chapter 6 where the findings are discussed.

5. System Design Narrative

"The system element in each case is like a probe into the system that can produce a specific response to the environment. So, we create representations, and we set those in motion to produce simulated behaviours. We then view those simulated behaviours in different perspectives (such as those named for real-time systems). We then attempt to understand the content of those systems, given the behaviour of the representations of the various perspectives. This is the basic operation of system design." (Palmer, 2009, p282)

This chapter aims to describe the process by which the tools were developed to support the Ph.D. process. Using Palmer's description of a system view as a probe to help further inform our understanding of the system and provide us with a mechanism with which to augment and incorporate the new findings into our new system view. This is an abstract way of viewing the action research cycles or wild design model. This chapter outlines the main stages of the design process (Figure 5-1), the assumptions made and the lessons learned. It can be chaotic and impulsive at times, but this is the nature of the beast that is real world systems development.

For those interested specifically in user feedback and requirements rather than the design process and timeline, section 5.6 reports the findings of a number of Future Technology Workshops used to gather requirements and user insights.

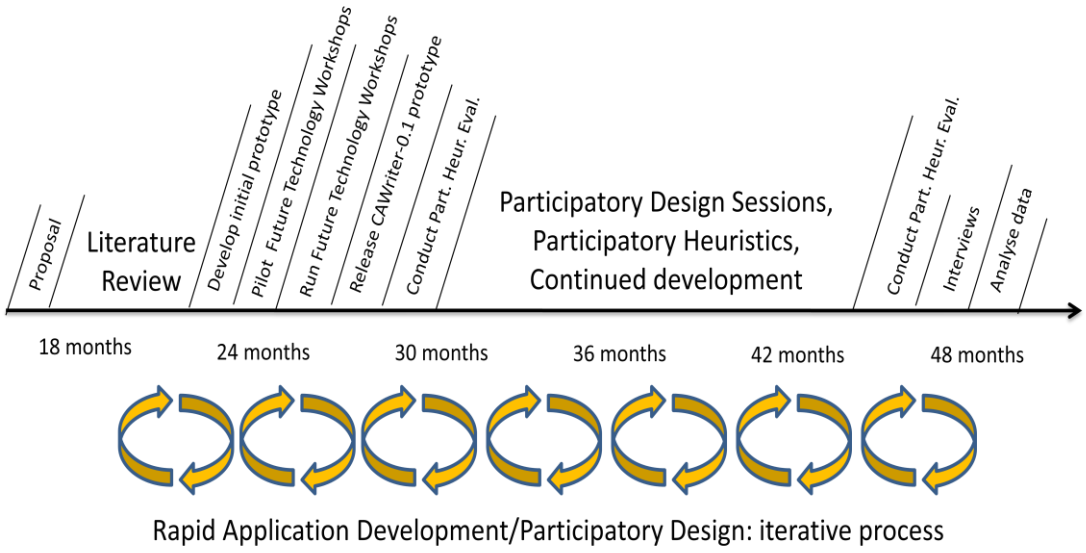


Figure 5-1 Development timeline

5.1. Proposal

The initial proposal for the Ph.D. looked at creative collaboration. This was a very general starting point that could deal with a huge range of activities ranging from music creation to architectural design. It was quickly decided that the Ph.D. would be the domain to focus on as a single test case for creative collaboration. This focused the initial literature reviews on three main areas, Ph.D. education, creativity and collaboration. As this work was being conducted in a computer science context, and the author's background in technology and learning, the use of tool mediated learning was implied.

5.2. Initial literature review

The initial part of this research explored the literature discussing pedagogical issues as they related to supporting Ph.D. candidates. This highlighted aspects such as CoP, CA, peer learning and the Holz et al. framework as broad theories within which to target tool support structures, but they did not however provide a basis for legitimate practices within the community.

Further reading explored creative processes and working with ideas. This explored a variety of works relating to creativity in science and scientific breakthroughs. This in part motivated a deeper exploration of truth claims and the limitations of truth in knowledge formation. This introduced the work of Bereiter and his ideas about "knowledge work" and "abstract conceptual artefacts". The exploration of creativity also revealed the Warr and O'Neil synthesis of creative practice that offered an excellent structure about which a basic tool to support creativity could be built.

Furthermore an extensive review of CSCW and CSCL technologies was conducted to explore potential implementations that may help inform any future design implementations. Here HCI elements related to designing sociotechnical tools were explored. Distributed Cognition and Activity Theory were identified as central theories used to guide the design of such tools. This matched with the pedagogical literature discussing PhD education as a social process.

5.3. Initial Prototype- MobileCog-0.1

The initial prototype, MobileCog-0.1, was developed with a number of purposes in mind. Firstly it was developed in order to explore what was possible within the modern browser: Web 2.0 technologies, APIs, JavaScript, PHP and MySQL (Figure 5-2). This approach was taken to allow

for collaborative technologies to be developed, as a web based tool is inherently networked and would be easier to adapt to facilitate collaboration. Secondly that the exploration of technologies and development of a dynamic prototype would allow the author to significantly enhance their skills in this area. Thirdly the prototype acts as an externalised representation of the amalgam of both technical ability of the designer and generic tool functionality found within current ad-hoc academic work, and would act as a design seed for thought and discussion with the community.

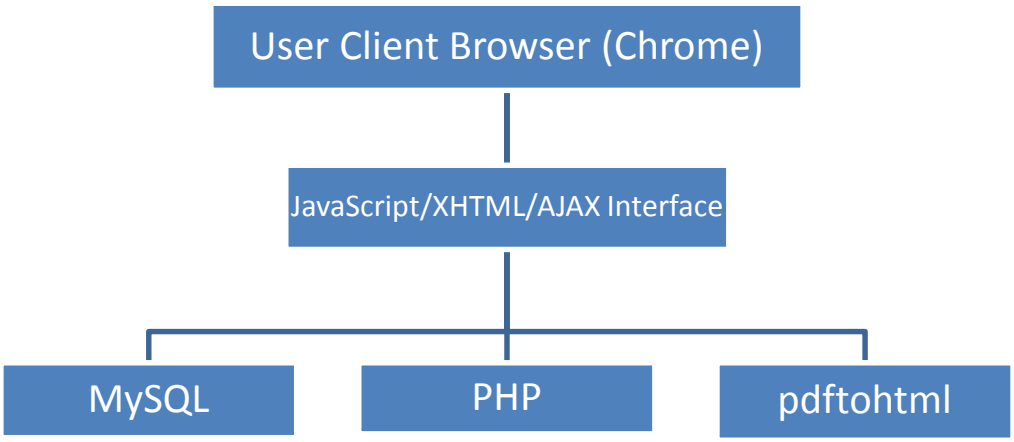


Figure 5-2 System Overview

Projection: Web 2.0 tool for ad-hoc creative collaboration

Context: Academic research (general)

Research Focus: Creative technologies, CSCW/CSCL, Productivity, Web 2.0, Distributed Cognition, Activity Theory and Reflection

Theoretical Heuristic Schemas: Knowledge Work, Distributed Cognition, Creative Processes

Technical Heuristic Schemas: Knowledge Building, Ubiquitous/Nomadic Computing, CSCW/L, Web 2.0, Creative Technologies

Design:

The focus of this prototype was upon what Holz et al refer to as organisational tools and included calendar functionality, task lists, project note spaces, file storage, bibliography management and meeting audio recording. These tools formed a “mash-up” using existing open software and the

latest in dynamic AJAX technology, thus allowing the user to load everything into one page, moving away from the traditional web approach of loading a new page for each new resource/tool.

This prototype was largely inspired by distributed cognition. The central elements of distributed cognition as discussed above are social, temporal and externalised. This prototype iteration was focused on the externalisation of ideas for future reflection. As the name, MobileCog, implied the idea was to support the users with cognitive processes in a mobile and distributed fashion, a theme that remained throughout the design process,

This prototype was built on web based technologies so that in the future social elements could be easily integrated. This prototype had rudimentary ability to share projects and integrated Google Wave access, which is now redundant.

From a temporal perspective the design had an integrated calendar function that linked up with Google Calendar via the provided API. This calendar function was intended for future planning and scheduling of tasks as discussed in the CSCW literature. The backend tracked changes with the intention that this log could be used by the user to review past revisions and potentially have a view that would let the user cycle through the changes as they happened. This ability to review past work and processes, although never fully completed, was intended as a tool to support reflection and self-monitoring, two of the meta-cognitive skills discussed by Holz et al.

Finally the whole UI was viewed as a means to externalise the user's concepts in a Distributed Cognition fashion. The central work are was a conceptual work area inspired by creative technologies such as Mind-Maps, Concept-Maps and knowledge building environments, that would allow the user to integrate with the rudimentary referencing and file management systems.

Some further experimental features were included such as embedded email access, task list, web search and meeting recording. These were integrated based on the tools used day to day in the research community within which the research was taking place, with the exception of a meeting recorder. This recorder was an experiment to see if it was possible to create a recording tool embedded with a browser The idea being that during a meeting you leave it running and it records only the last 3 minute in order to catch those "how did you just phrase that" moments. It was found that currently the only way that this is possible is either through Java applets or Adobe Flash, the implementation developed for this prototype used Java, building on a freely available software plugin. A screenshot of this prototype can be seen in Figure 5-3. This prototype focused on layout, possible navigation options and a variety of tools.

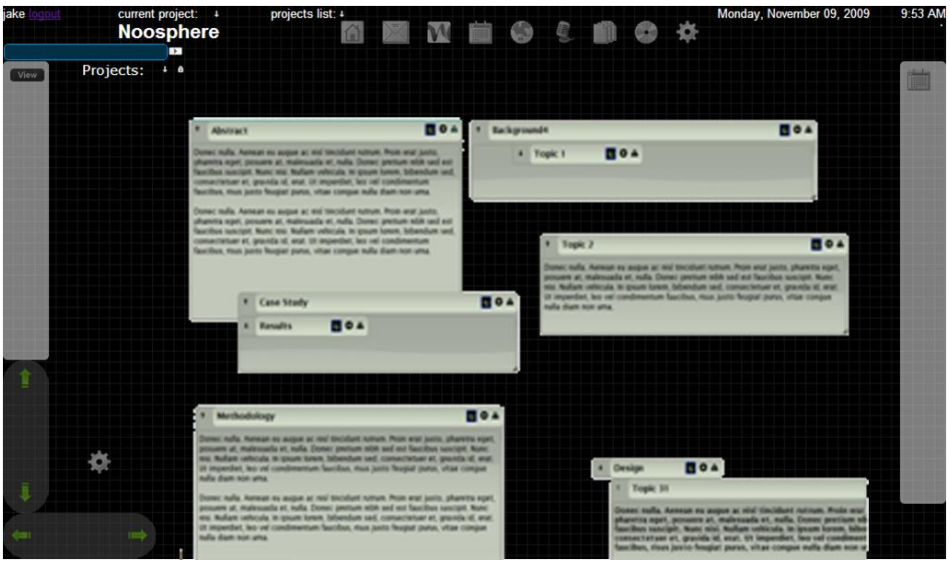


Figure 5-3 MobileCog-0.1

Lessons Learned:

The development of this tool provided an insight into the flexibility of the modern browser and the potential for the development of desktop like applications within the browser. There were issues relating to usability, and there was no specific task or activities facilitated beyond the concept mapping features and integrated technical functions. This created a lack of flow in the task orientated activities, suggesting that a more rigorous framework and scaffold was needed to structure the activity within the system.

5.4. post-it.MobileCog

Projection: adapt MobileCog-0.1 to emulate post-it like workflow

Context: Academic Writing (based on observation)

Research Focus: Creative technologies, Productivity, Web 2.0

Practical Heuristic Schemas: Knowledge Worker Observations

Technical Heuristic Schemas: Knowledge Building, CSCW/L, Web 2.0, Creative Technologies

Design:

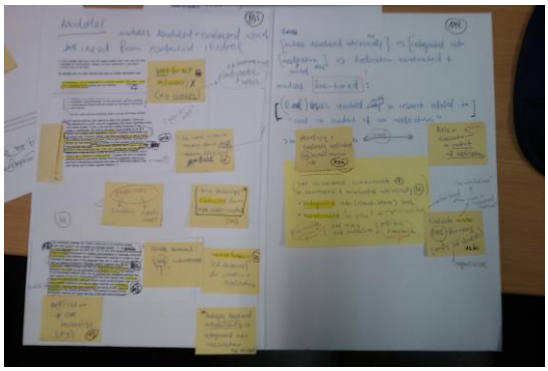


Figure 5-4 example of post-graduates work practice

In line with the PAR approach of look, think and act, an initial outreach to the community highlighted a post-doctoral researcher, looking to digitize his approach to writing academic papers. The researcher in question uses conventional media such as sheets of A4 paper and applies printed and "post-it" notes to these sheets and arrange them on their desk or walls (Figure 5-4). This resembles both Sharple's work on writing as creative design and the notes network of Writer's Assistant. It also reflects similarities to the practice Woods' discusses in his work on Cognitive Dimensions of idea sketches, exemplifying terseness and perceptual cues.

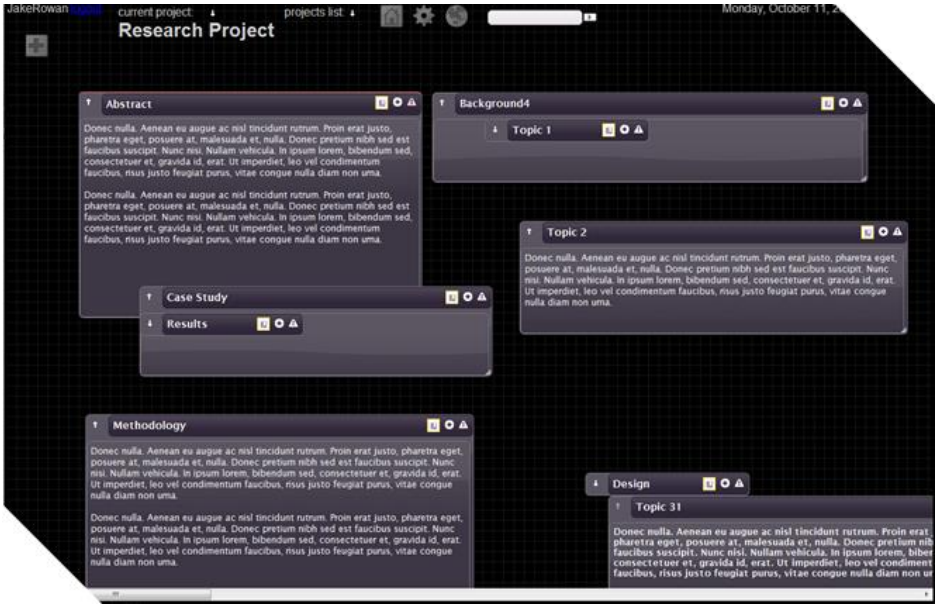


Figure 5-5 screenshot of first iteration post-it.mobilecog

The approach looked quite close to what was achievable in the project space in MobileCog-0.1, therefore it was adapted and stripped down to focus on this task alone (Figure 5-5). A number of informal meetings worked on the usability of the tool, where a list of issues was collected and fixed before each meeting.

Lessons Learned:

This prototype focused mainly on note taking and was the digital equivalent to a pin board where one could pin notes, highlight the points of major interest and organise them spatially. Although it showed promise and was of use to the post-doctoral researcher in question, it lacked the structure and facilities for more novice researchers. It was not clear how and when the novice researcher could best use and integrate the features into their workflow.

5.5. CAWriter-0.01

Projection: adapt post-it.MobileCog to support the writing process in a more explicit manner

Context: Ph.D. Academic Writing (based on literature)

Research Focus: Writing Tools, Writing Approaches

Theoretical Heuristic Schemas: Writing as Creative Design

Technical Heuristic Schemas: Non-Linear Writing Tools

Design:

CAWriter-0.01 was developed from the need for a more structured interface as noted in the work on MobileCog-0.1 and to support academic writing, in a more explicit manner than the facilities found in the post-it.MobileCog prototype. The aim of the initial CAWriter series of prototypes was to help novice academic writers collect notes and resources from the literature, construct a draft document and collaborate as they do so. It went beyond the anecdotal evidence used to design post-it.MobileCog, and instead drew from the literature on experimental writing tools. A non-linear approach to writing was developed from suggestions from the literature (Shibata, H & Hori, K., 2008; Sharples, M. 1999; Sharples, M. et al, 1989) and backed by community practices and experiences; this saw the creation of multiple views that allow the user to move from a brainstorming conceptual mapping view through to an outline and draft document view (Figure

5-6). In supporting the socio-cultural perspective, primitive collaborative features were added that allowed multiple users to work on a single project.

The work on iWeaver and Writer's Assistant influenced this and future prototype iterations considerably. It was at this point that the multiple views of a single data source were formulated. There would be three main views associated with the writing process. The main project view is almost identical to the post-it.MobileCog prototype, a conceptual space to organise notes and ideas (Figure 5-6, 1). The second view was an outline view (Figure 5-6, 2) that was populated by nodes from the conceptual space, functionality was provided so that the user could drag and drop these section headings into an order and tree structure that suited their work, this structure in turn affected the document view. The document view (Figure 5-6, 3) essentially used the contents from the elements in conceptual space that had been added to the outline view and displayed it as a unified document. These three views essentially replicate the functionality found in iWeaver (Figure 5-7).

Figure 5-6 CAWriter-0.01 1) Concept Map/Note Network 2) Outline view 3) Document view

Lessons Learned:

This development was promising as it showed that the prototyping environment was easily adapted and altered to accommodate insights from both practice and the literature. But there were issues with the conceptual space as there was confusion as to what content was placed here. In this iteration both notes and formal content are mixed in a single view, with the document view filtering out all but the formal content. This made for a cluttered and cumbersome user interface. There were also questions as to how this is tool is any better than using a word processor for notes and formal

writing. This raised question as to what contributions this research was bringing to the table and how it differentiated itself from standard practices and tools.

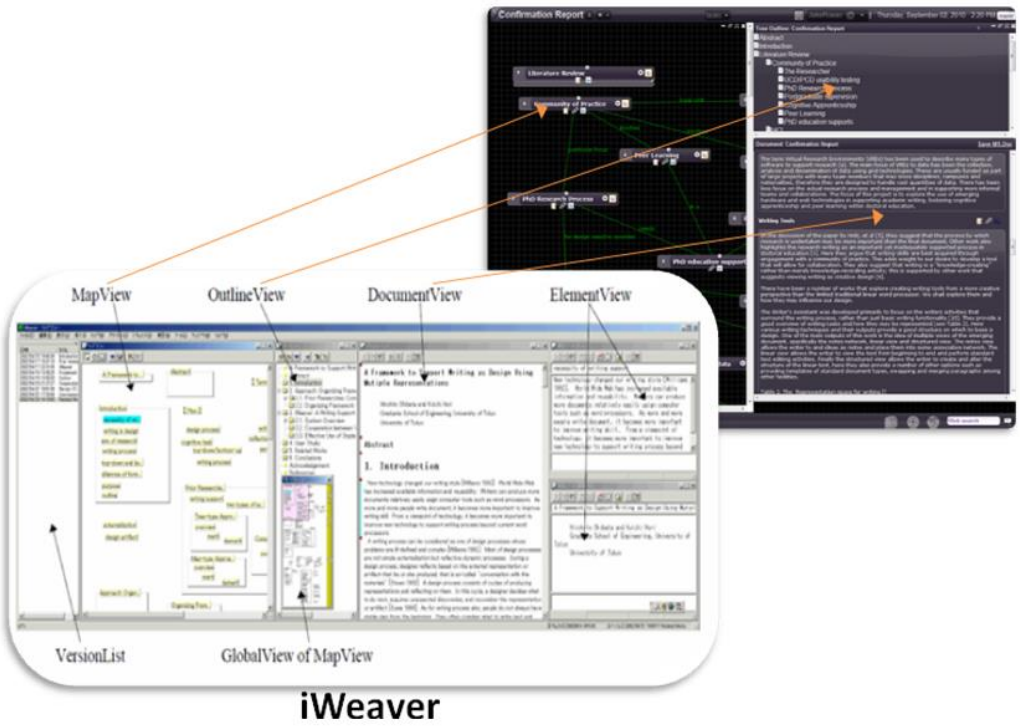


Figure 5-7 Example of mapping iWeaver functionality to later version CAWriter prototype

5.6. Future Technology Workshops

The scope was widened to look at the needs of the Ph.D. candidates specifically. An initial FTW was organised and attended by 12 Ph.D. candidates, the focus was on future supports for the Ph.D. process. During the FTWs participants were asked to produce rough prototypes of their desired technologies to support them with their doctoral work. A number of common themes emerged: communication/collaboration, privacy controls, planning, different views of information and integrated referencing management. One prototype in particular reflected the desire for a system that centres on concept-mapping spaces, with auxiliary functionality built around them (Figure 5-8). Further requirements that emerged from the workshops ranged across a number of themes that are reflected in the literature, these included support for document drafting, advanced referencing, organisation, visualisations, ubiquitous access and collaboration.

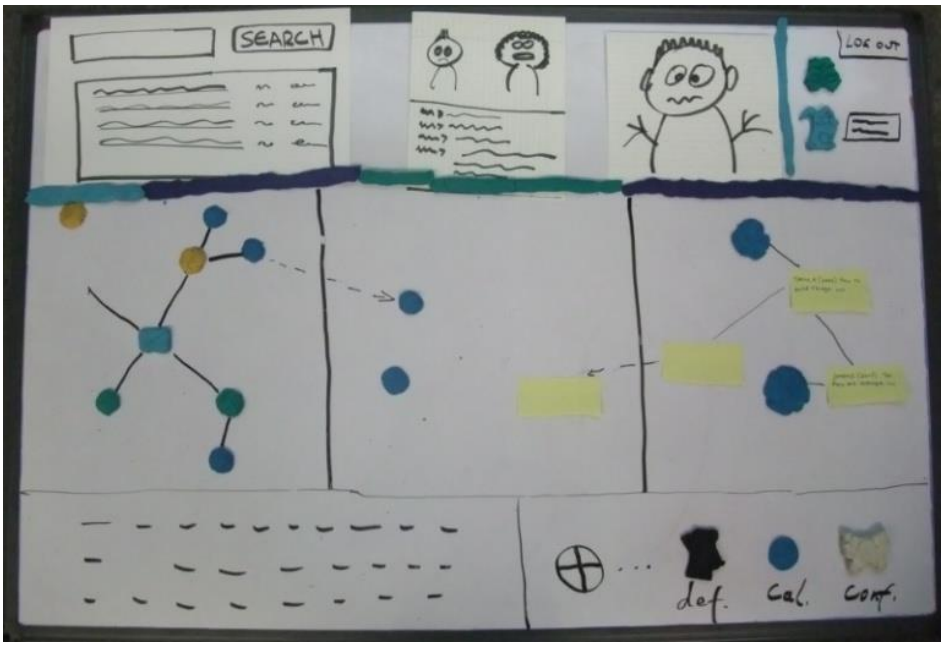


Figure 5-8 Future Technology Workshopp Concept Mapping prtotoype

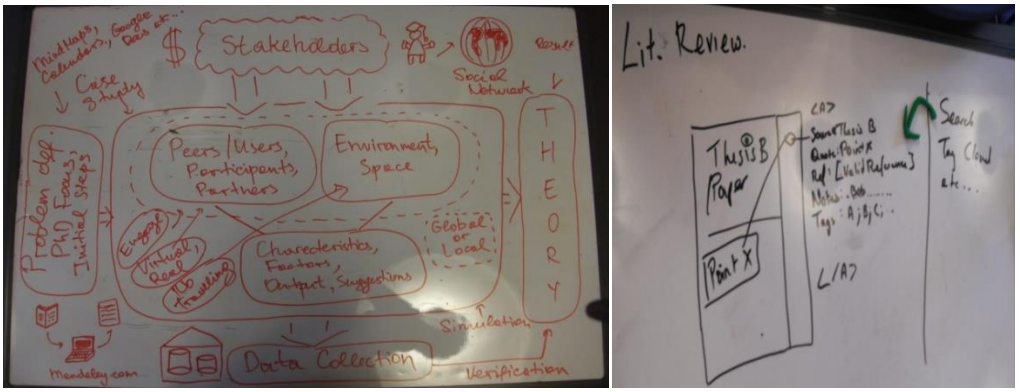


Figure 5-9 Holistic support (left) and Literature Review support (right) prototypes

This perceived support for writing related activities such as literature review is supported by a literature review based prototype developed in the last workshop (Figure 5-9, right). Another noticeable prototype was a very holistic one that involved many parameters from stakeholder, data collection and theory (Figure 5-9, left). This prototype also emphasises the perceived complexity of the Ph.D. as a process. This diverse nature is represented in the list of brainstorming of activities and requirements for future tools to support Ph.D. activities as seen in Table 5-1 and Table 5-2. These tables were filled out in the workshops on a PowerPoint slide, with the whole group was asked to help complete the table and confirmed the entry reflected what they were suggesting.

Table 5-1 Future Technology Workshop Brainstorming Results

Getting feedback – as many people as possible	Mind Mapping
More collaboration	Notes
Managing bibliographies easily	Going to conferences
Writing/rewriting	Visualisation of document relationships
Diary/journals	Literature collecting
Publishing	Summer schools
Structuring /assimilation ideas – better capture tools	Tight integration of data/literature elements
Brainstorming	References + bibliography
Running/designing experiments	Networking
Data collection analysis	Integrated communication
Literature review in every expanding knowledge base	Writing
Linking between activities	Publishing
Better facilitation of collaboration	Reference network
Maximising attendance workshops/conferences	Writing review (feedback)
Structuring/organizing work/deadlines	Case studies / data collection
Presenting	Editing
Reading + notes	Modelling/ experimentation
Reading + writing group	

Table 5-2 Future Technology Workshop Requirement Results

Artificial Intelligence	organise facilitate writing groups
The cloud	privacy controls
Structure ideas	models templates for workflows
Multiple views (with comparisons)	planning workflows
Context awareness	optionally remote attendance of conferences
Avoid data overload	Auto-summarising
Intuitive capture	Linguistic readability
easily integrated pervasive	Mind mapping
pdf files with metadata	Social network
Seamless integration- from consumption to production (standards)	Automated reference system
Ubiquitous network access	reference network
different views of information	categorisation
reference management - including "auto" linking	crowd sourcing metadata
communication collaboration	ubiquitous
advanced search	document network
community directed development	data network
customisable tools	peer comments
automated quote "grabbing"	graphing tools
community knowledge base	data visualisation

5.7. Initial Participatory Heuristic Evaluation

A participatory heuristics evaluation session with a Ph.D. candidate showed that there was still a lack of flow within the tasks and that the features did not explicitly support the higher order skills form the Holz et al framework, suggesting that more scaffolds were necessary. Here the "Single System", argumentation prompts and structured literature review protocols, were reviewed as a solution to these issues.

The similarities between the features suggested in Writer's Assistant and iWeaver and the activities found in the "Single System" made it an obvious choice as a scaffold. It also fitted well with the creative phases of Warr and O'Neil. The project underwent a reseeding phase with the integration of a number of elements of the "Single System" into CAWriter. This required relatively minor alterations as most of the components are present; interactive note/quote taking, citable notes collection, referencing, outlining and basic revision features.

5.8. CAWriter-0.1

Projection: Refinement of CAWriter-0.01, more explicit supports for Thesis Writing Activities

Context: Ph.D. Dissertation Writing (based on literature)

Research Focus: Writing Theory, Thesis Writing Activities

Theoretical Heuristic Schemas: Writing Theory, Writing Activities (Single System)

Technical Heuristic Schemas: CSCW/L awareness and communication

Design:

This iteration focused on more explicit supports for thesis or dissertation writing in general. Scardamalia and Bereiter's (1987) work in their book, The Psychology of Writing, talk of two distinct spaces, the content space and the rhetorical space. This distinction motivated a change in perspective to split the conceptual view from the document view, making the conceptual view equivalent to the content space and the document view equivalent to the rhetorical space. This meant that the conceptual view was reserved for the more informal notes and returned to a more concept-map type view found in the first prototype, MobileCog-0.1. Functionality was added to

facilitate this emphasis on concept-mapping through the addition of connecting lines and connection labelling, as found in the concept-mapping literature (Novak & Cañas, 2006).

In order to distinguish the rhetorical space, functionality was added to the document view to allow the editing of sections within that view, and this was the only view in which formal text could be added to the document. It was hypothesised that this distinction would promote more free-form thought in the conceptual space, alleviating some of the mental blocks that are sometimes encountered when writers are over-critical of their own work early in the writing process.

In order to bring the design more in line with thesis and dissertation writing the "Single System" (Figure 5-10). As we have seen, the "Single System" provides a simple but explicit tasks that are to be completed as part of the journey to a complete dissertation. As the system already had components such as a conceptual space for notes, outline view and a long outline view in the document view, it was considered a good match.

As the focus is to support novice academics, the literature review became an important focus. Starting with interactive reading, an essential part of the literature review as set out by Single, a basic system that allowed the user to upload files and link to Google Books was added. This enabled the user to view and read documents within the tool, using Google Documents viewer for .pdf and .doc file formats, the most commonly used for academic papers.

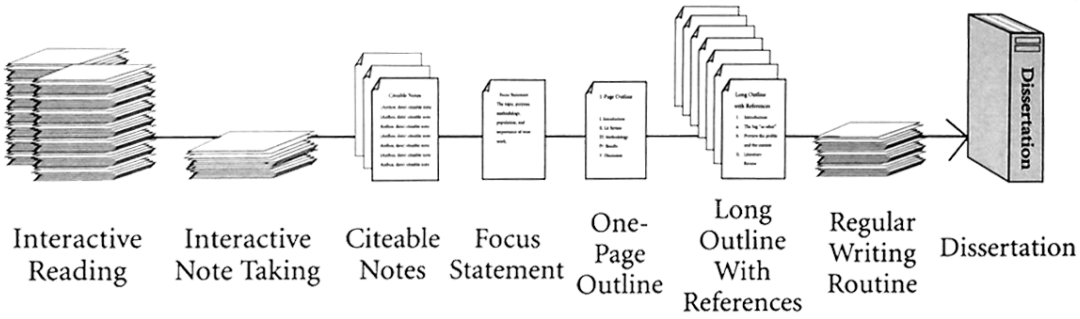


Figure 5-10 The “Single System” for dissertation writing

It did not however enable the central elements of Interactive Reading, such as highlighting and in-line notes within these documents as they are read, as is suggested in the "Single System". This was due to technical limitations with the current implementation, which was rectified in later iterations. Interactive note taking was facilitated through the addition of note and quote inputs that were attached to the file browser (Figure 5-11). Further dedicated note tools were added to the elements

in the concept mapping view, so that each node could have its own notes visible through a small pop-up window. If a file was associated with a node in the concept mapping view, those notes and quotes would also be visible in the notes pop-up. The aim here was to provide an integrated interface that unites all data and provides an easy to navigate knowledge space. The file and referencing systems were also made more robust with a cleaner interface (Figure 5-12).

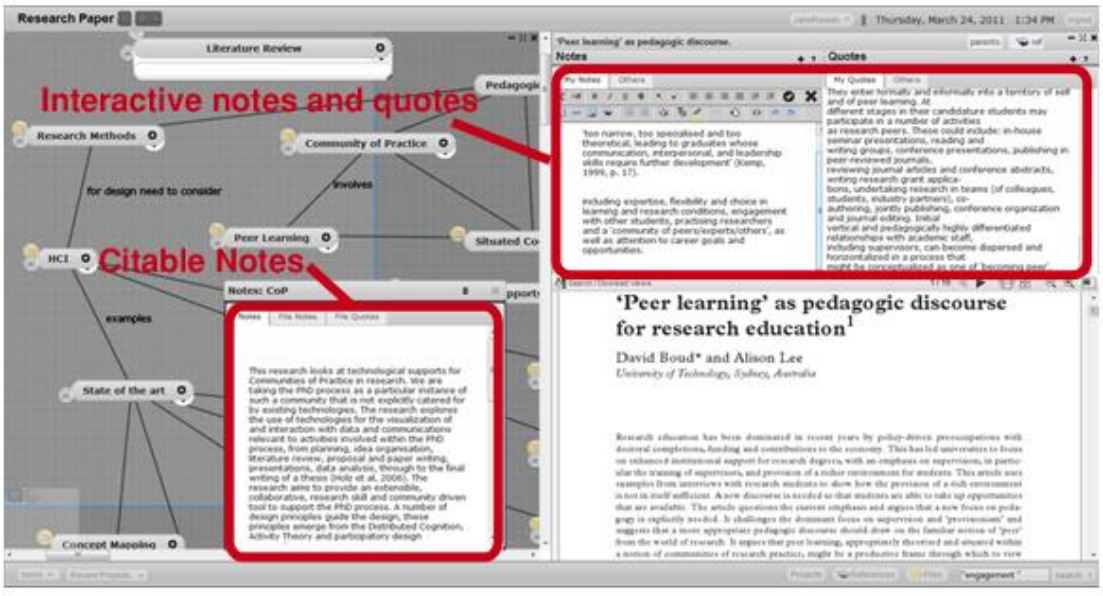


Figure 5-11 Interactive note taking features in CAWriter 0.2

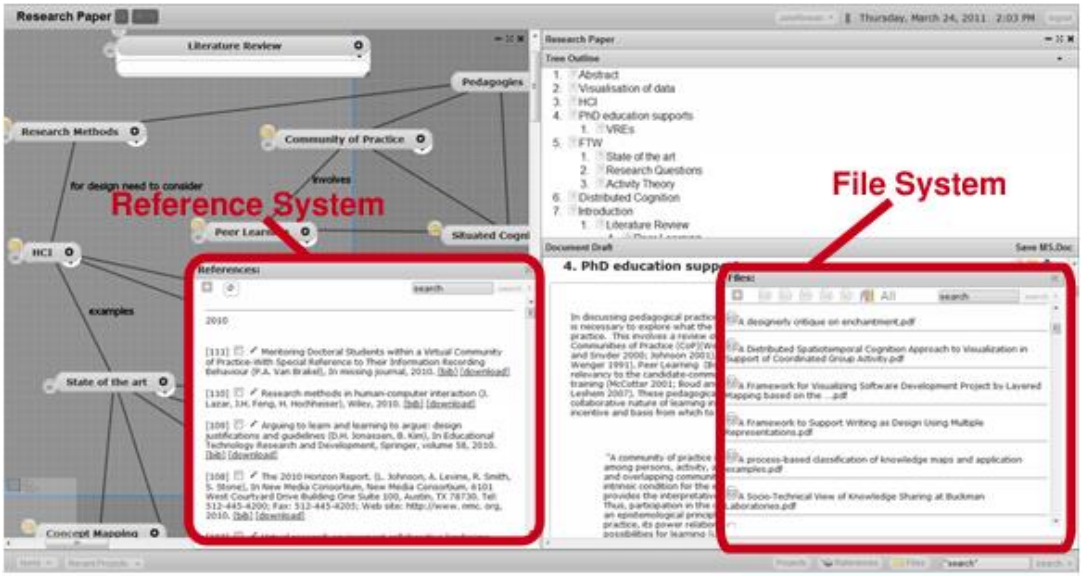


Figure 5-12 file and referencing system features in CAWriter 0.2

In supporting the socio-cultural nature of tools, basic collaborative features were added that allowed multiple users to work on a single project. These include basic chat, location awareness in the concept mapping spaces and the ability to co-edit shared content; these were heavily influenced by the CSCW literature (Buder & Bodemer, 2008; Cox & Greenberg, 2000; Suthers, 2001, 2006).

Lessons Learned:

Although considerable improvements had been made, the system still felt clunky and difficult to use. There was limited consistency between views and there was a need to clean up the interface and focus on Wood's cognitive dimensions.

5.9. CAWriter-0.2

Projection: Refinement of CAWriter-0.1, User Interface overhaul

Context: User Centred Design

Research Focus: UI, Usability, Heuristics

Theoretical Heuristic Schemas: PD, UCD, Usability

Practical Heuristic Schemas: Heuristic Evaluations, FTW Feedback, Web Designer input

Design:

CAWriter-0.2 was an effort to clean up the interface. A number of Participatory Heuristic evaluation sessions were conducted, along with a consultation with a professional web designer. These sessions indicated inconsistencies in the interface that influenced both the user experience and usability. This called for a number of superficial yet usability altering changes. Although the changes made in this iteration were generally minor, a significant number were made. A lot of effort was made to make the interface consistent, this meant making sure that symbols were used to represent a single function, connected windows were obviously distinguishable and that ample and equal space was provided for buttons and headings throughout the interface.

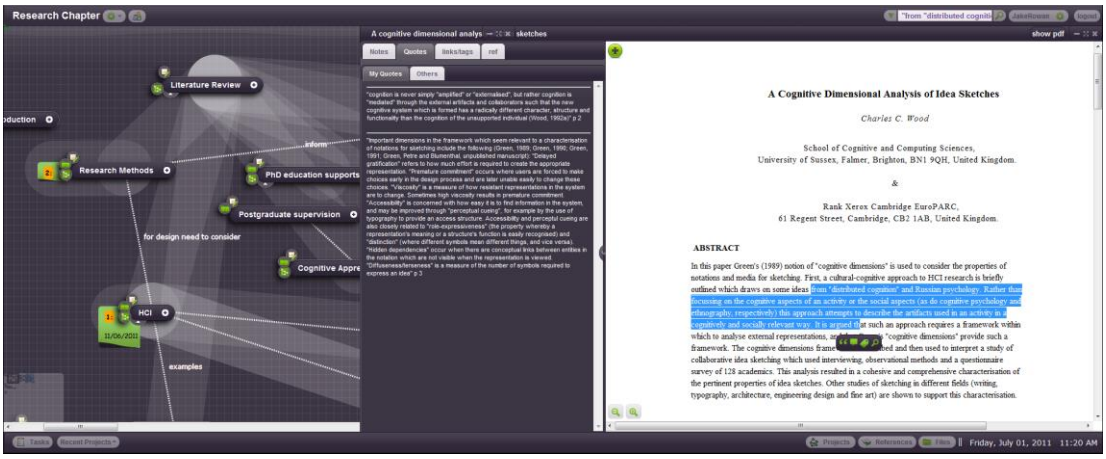


Figure 5-13 Side panel and interctive reading support

Features were also added to facilitate the interactive reading process; this involved moving away from the Google Document viewer to a customised HTML rendering of PDF documents. This allowed for richer in-browser interaction. The user could now highlight text to annotate, collect quotes, tag or search for the selected phrase. The addition of these new features required a redesign of this view, a side panel was added rather than the drop down notes and quotes inputs found in the previous iterations (Figure 5-13).

5.10. CAWrite-0.3

Projection: Refinement of CAWriter-0.2, more explicit supports for Research Skills with particular focus on Literature Review supports.

Context: Academic Writing (based on literature and feedback)

Research Focus: Research Skills, Literature Review

Theoretical Heuristic Schemas: Research Skills, Literature Review

Practical Heuristic Schemas: Observations, User Feedback, FTW Feedback

Design:

CAWriter-0.3 aimed to develop more explicit supports for research skills. Although previous iterations had been developed with the generic and specific skills in the Holz et al. framework in mind, there were no explicit supports for skills such as evaluation and analysis.

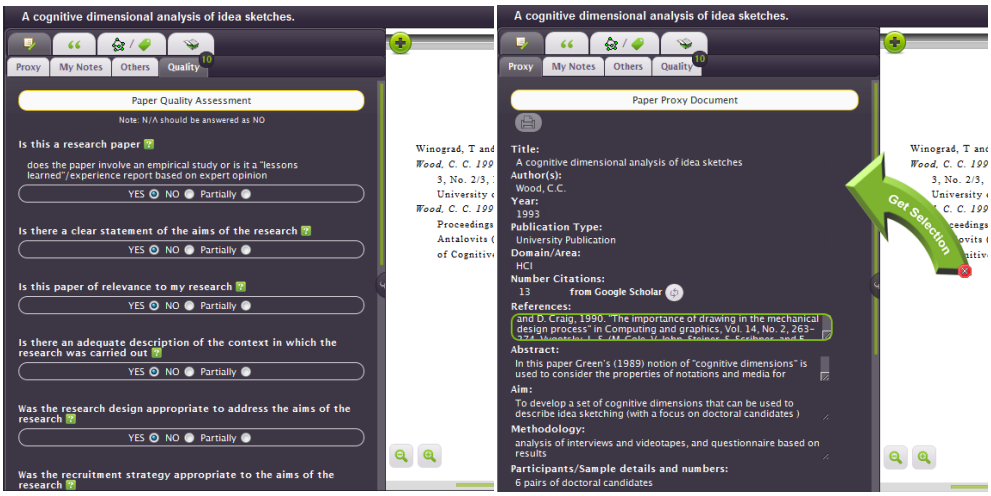


Figure 5-14 Quality Assessment form (left) and Proxy document (right)

In order to address this shortfall in supports a number of new functions were added to the interactive reading view. These functions were added to the new side panel created in the last iteration. Two features in particular were added to focus on evaluation and analysis skills. A "proxy document" section was added which highlighted central aspects of the paper being read. The user would enter the obvious elements such as author, title and abstract, but also more detailed information such as number of participants/samples used, methodology etc. To supplement this "proxy document" a "Quality Evaluation" (QE) (Major, et al., 2012) form was created adapted from one found in the literature (Figure 5-14). This QE form is composed of 12 questions that help the user reflect, evaluate and analysis the quality of the paper under review. The user answers yes, no or partially to each question, these answers are weighted with yes receiving a 1, no receiving 0 and partially receiving 0.5. If the question is not applicable, the user is to answer no. This creates a number that gives an indication of quality of the paper. This number is displayed in the interactive reading view side panel and the in the file-system view, in this view the papers can ordered based on the Quality indicator.

The web search feature was improved to provide the ability to search and retrieve documents from Google Scholar results. To do this the Google Scholar result was retrieved, parsed and additional code injected to create a download button. When clicked that paper is added to the file-system and the reference added to the referencing system. The number of search options was limited to internal, Google Scholar, Trinity College Library, Etymology, Definitions and Wikipedia. These options were provided to cover a wide range of uses from looking up definitions or concept to retrieving literature for review.

6. Implementation and Discussion

This chapter discusses the implementation and findings of this research. The findings are comprised of four separate user studies conducted over a period of a year involving Ph.D. candidates and a set of heuristic evaluations from both the user studies and separate usability testing sessions, with 10 heuristic evaluations in total.

Two of the user studies were between one and two months in length, while the remaining two were approximately 5 months each. In total the usage period for all the studies combined was 397 days with distinct usage on 134 days (Table 6-1). This represents considerable system usage in legitimate contexts as the participants were never pressured to use the system and engaged in these activities as part of their legitimate Ph.D. activities. Furthermore each participant was introduced to the system through a single introductory session that walked the users through the various features of the tool.

Table 6-1 User Studies Login Statistics

User Study	**1**	**2**	**3**	**4**	**Totals**
Usage Dates (2012)	Oct-Dec	Mar-Apr	Mar-Jul	May-Sep	
Usage Period (months)	2	1.5	5	5	13.5
Usage Period (days)	58	43	145	151	397
Logins (distinct days)	23	21	25	65	134
					Averages
Logins per week	2.78	3.42	1.21	3.01	2.61
Logins per month	11.9	14.65	5.17	12.91	11.16

Within each user study there are three main data sources. These sources will be used to answer the research questions within the limitations of the evidence available. In order to answer questions related to the activity systems and the accompanying research skills there are activity logs, usage data, user generated content and interviews. To answer questions of usability there are heuristic evaluations from both the user studies and usability test sessions, and further perceptions will be gleaned from interview data.

6.1. Implementation findings

The following section provides an overview of the user experiences during the user studies. These findings are further discussed in section 6.2.

6.1.1. User Centred Design - Case 1

User 1 was a male part-time computer science Ph.D. candidate in his first month of the Ph.D. program. As he is part-time he is still engaged in industry work, where he works for a large multinational as a user experience expert. This background makes this candidate an expert usability evaluator. User 1 was recruited as part of a research methods module that is a requirement for early stage Ph.D. candidates. Although a number of other students showed interests in CAWriter, User 1 was the only user who used the system extensively over the module. This research methods module required the students to critique a seminal paper in their research area, making it an excellent opportunity to test the features found in CAWriter.

6.1.1.1. User 1 Activity

Figure 6-1 User 1 login and interactions activity

User 1 used CAWriter over a 58 day period, with an average of 2.78 visits per week, this activity ramped up as he approached assignment deadline (Figure 6-1). Over this period he logged in on 23 distinct days. Interactions indicate where there was input from the author to help the user with an issue or explain functionality in more depth.

User 1's feature usage was limited, there was no use of the file attachments, notes or proxy documents. There was some testing of the Quality assessment and quotation collection features on the first day, but this occurred only during a demonstration of the features. The CMap did see

repeated activity over the two month period (Figure 6-2), but analysis of the CMap content suggests this was feature testing rather than legitimate Ph.D. work. There was no formulation of a conceptual framework and most elements were unedited template elements.

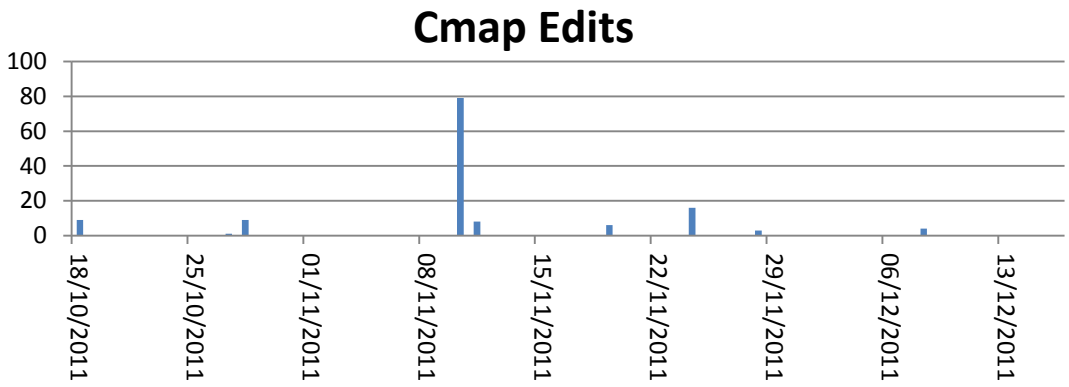


Figure 6-2 User 1 CMap activity

The central activity that user 1 focused on was file and reference acquisition using the search features and document editing. There were a total of 20 files added (a number of duplicates), 13 distinct files had references attached, with a further 2 manually added references without the file attached. User 1 created a 4524 word document over the two month period. Analysis of this written content shows that although a number of the headings leveraged off those that were created using the automated system template, this user did not create new headings using the CMap space. User 1 instead used the rich text editing window to create enlarged bold headings within the existing headings.

A number of interactions were needed to correct bugs or demonstrate features to this user (Figure 6-1). These were largely carried out through Twitter communications or email, and tended to coincide with activity within the system.

6.1.1.2. User 1 Heuristics

Looking at the heuristic evaluation carried out by user 1, the results are poor (Table 6-2). Two questions on the heuristic evaluation form were not answered as they were not deemed relevant (blue highlight in table). Out of the remaining 13 questions only 7 were marked as positive.

Table 6-2 Heuritic Evaluation by User 1

(blue: answered N/A, orange are heuristics not met)

Heuristic	User 1
System Status	yes
Task Sequencing	yes
Emergency exits	yes
Flexibility and efficiency of use	no
Match between system and real world	no
Consistency and standards	yes
Recognition rather than recall	no
Aesthetic and minimalist design	yes
Help and Documentation	no
Error recognition: diagnose and recover	yes
Error Prevention	N/A
Skills	N/A
Pleasurable and respectful interaction	no
Quality work	no
Privacy	yes

6.1.1.3. User 1 Interview

User 1 was interviewed after the course had ended and the course work had been submitted. The interview was semi-structured in nature and the guiding questions looked at perceptions of using the tool, suggestions, single system supports and research skill support. The interview findings have been summarised into four main topics, user perceptions and observations, suggestions for features or changes, skills and activities.

6.1.1.4. User 1 suggestions

As this user used the system a number of months before the others there was time to make some simple changes to implement his suggestions. An attempt was made to address the following suggestions with a single interface adjustment:

- Thought the design was good but finicky at times, over engineered
- Thinks CAWriter has possibilities but the interface could be simplified
- Better natural dialogue might lead to "faster adoption" and "more satisfied user".
- Going straight into the document would be his natural dialogue
- Probably want a way for hiding CMap view [refers to it as structure thing off] for novices
- Beginners might want to get in and edit like they would do with word.
- Main obstacle was not seeing his progress: "where's my stuff as Amazon would say"

When this user was using the system, each project would open up to the CMap view. This was altered so that the project opened the CMap and document draft side by side. This focused the attention on the document editing task and I think this was a crucial change to help focus the task and help workflow. As this issue was not raised by subsequent users it might be dubbed a successful alteration.

Two more suggestions were familiar to both the self-regulating skills and regular writing activity discussed in the literature:

- An issue with Ph.D. completion and non-completion is that the candidates don't feel like they are making progress. Some "indication that you are making progress" that is highly visible might help combat this.
- Thinks what you need to see is getting messages that you are actually creating something, whether "using a progress bar", or the "point of entry immediately is the editing screen".

The activity log was added to address this and seems to have been appreciated by both users 3 and 4. Again this seems to be a good motivational tool for users to track their work and get feedback on what they are spending their time on.

The other suggestions were things like offline mode, MSWord import/export, MSWord templates, customised quality assessment forms, quality assessment, *"visual map"*, new literature alerts, and scheduling tasks. The most interesting suggestion was to use it with undergraduates or even in

second level education. The prospect of designing supports for what is considered the pinnacle of education and bringing those supports to younger learners could make for a very interesting future direction.

6.1.1.5. User 1 Perceptions and observations

This user was very positive overall about the concept of CAWriter, seeing the need for more structure for novice researchers. CAWriter offered a process that structures the Ph.D. process which this user thought was *"great"*. Favourite features included the search and referencing features as *"doing the bibliography is painful"*. While travelling around Europe he *"used* [CAWriter] *all the time"*, utilising multiple devices to access the tool, suggesting that the web based nature of the tool suited this users work practices. The web based nature was also praised as there was no need to install a dedicated tool and all one needed to access it was a browser and an internet connection. The ability to add other users was viewed as a positive, with one caveat that this user was sceptical of peer review as he does not take criticism well.

Despite these positive remarks this user had issues with usability and workflow. There did not seem to be a natural flow with his work practices. There were however suggestions of misconceptions and lack of knowledge of some essential features. These misconceptions were about the CMap and TreeView. It seems that this user did not know there was a tree structure view and even suggested that the CMap be redesigned to be more like a hierarchy. This suggested that perhaps more time was needed to explain the function in more detail on an individual basis so that all features were realised and their purposes understood. This user also showed an aversion to concept mapping in general dismissing it as for *"professional academics or some kind of hipster"*. This may have influenced their lack of use of this feature.

At the time this user was using CAWriter the interface only showed the CMap when you opened up a project, the fact that you had to click on a CMap element to open the working document did not seem natural to this user. This suggestion was acted upon and changed for subsequent users, the new interface opened the CMap and document together when opening a project to focus the attention on the writing process and create a more natural dialogue. This was the most important observation made during this user study as this issue did not arise thereafter. Further suggestions for minor changes or new features are collated and presented in section 6.4.2.

6.1.2. User Centred Design - Case 2

User 2 was a female neuroscience Ph.D. candidate in her first six months of the Ph.D. program. User 2 was recruited after being introduced to CAWriter at a talk given to a multi-disciplinary group of Ph.D. candidates at a course promoting innovation and creativity.

6.1.2.1. User 2 Activity

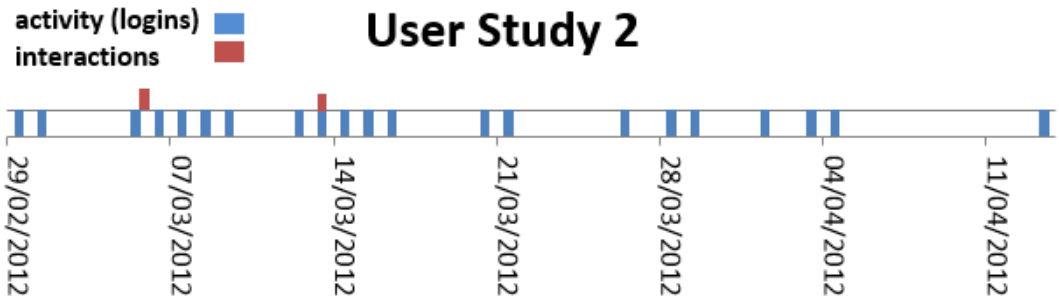


Figure 6-3 User 2 login and interaction activity

User 2 used CAWriter over a 43 day period, with an average of 3.42 visits per week, this activity trailed off as she entered into a lab rotation that limited her time and access to computers (Figure 6-3). Over this period she logged in on 21 distinct days.

User 2's activity was again rather limited as she made no use of the file attachments, quality assessment forms or proxy documents. There were 3 files uploaded, each with a reference attached. A total of 2 notes were attached to elements in the CMap space. The CMap did see repeated activity over the one and half month period (Figure 6-4), and analysis of the CMap contents suggests that extensive use was made to relate, structure and order concepts.

The central activity focused on by user 2 was CMap editing and construction, although this activity slowly declined. User 2 created a 2870 word document over the 21 sessions. Analysis of this written content suggests that this writing space was used to collect notes rather than for writing a linear document, which may suggest why there were so few notes added. This is backed up as the two notes that were added were added in the first two weeks of usage, whereas the formal document space was used consistently throughout the usage period. This user did also demonstrate a single use of the automated referencing system.

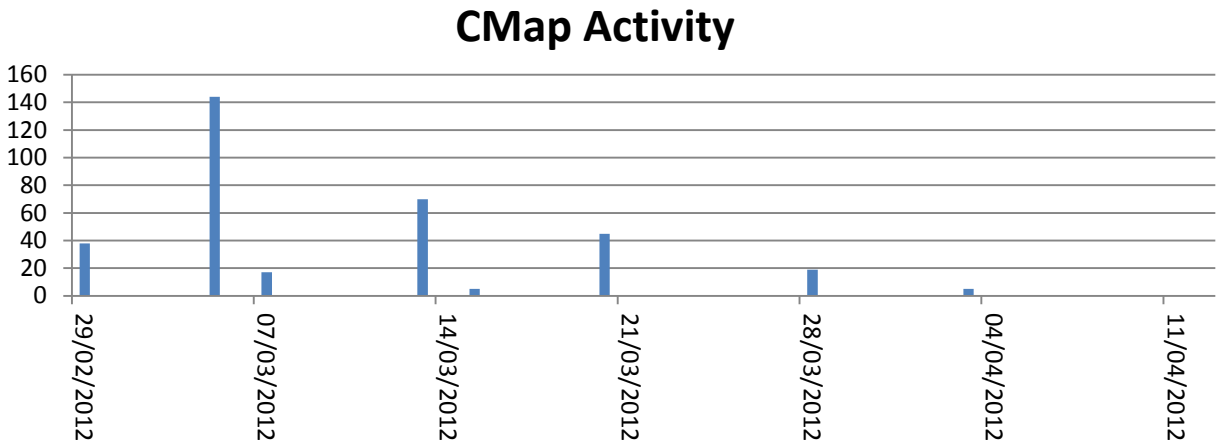


Figure 6-4 User 2 CMap activity

Only two interactions occurred with this user (Figure 6-3). The first of these was a one on one session that walked the user through the various features of the system, a reiteration of the initial demonstration, but this time with more dialogue. The second was a request for the ability to add Greek symbols to the text, a feature that existed, but was not easily accessed.

6.1.2.2. User 2 Heuristics

User 2's heuristic evaluation is much more positive than the User 1's rating (Table 6-3). All questions on the heuristic evaluation were answered. Out of the 15 questions 14 were marked as positive. Although one should be concerned about experimental demand here (Nichols & Maner, 2008), as the user may be answering what they think the researcher wants to hear.

6.1.2.3. User 2 Interview

User 2 was interviewed a few months after their activity stopped, this delay in interviewing may affect freshness and introduce retrospective recall, thus limiting the reliability of this users responses. Despite these concerns this user did have quite explicit responses and offered an opportunity to evaluate why she stopped using the tool. The interview was semi-structured in nature and the guiding questions were similar in nature to the first interview which looked at perceptions of using the tool, suggestions, the single system supports and research skill support. A discussion on cognitive dimensions was added to this interview to explore the usability of the tool in more detail, as the results from the first interview were too broad. The interview findings have been summarised into five main topics, user perceptions and observations, suggestions for features or changes, skills, activities and cognitive dimensions.

Table 6-3 Heuritic Evaluation by User 2 (orange are heuristics not met)

Heuristic	User 2
System Status	yes
Task Sequencing	yes
Emergency exits	yes
Flexibility and efficiency of use	yes
Match between system and real world	yes
Consistency and standards	yes
Recognition rather than recall	yes
Aesthetic and minimalist design	yes
Help and Documentation	no
Error recognition: diagnose and recover	yes
Error Prevention	yes
Skills	yes
Pleasurable and respectful interaction	yes
Quality work	yes
Privacy	yes

6.1.2.4. User 2 Suggestions

This user had one major issue and that was the referencing system, which as discussed before does need more work. A help function was also requested, but as was discussed above, the evolutionary nature of the design process meant the help documentation would quickly become obsolete. When a stable release of the system is deployed, help functionality will be essential. Other suggestions were improved formatting of exported word document and PDF export function. This user also made suggestions towards using CAWriter collaboratively *"I could see myself sharing with*

someone I was trying to impress". She even used it at a conference, this may open up alternative collaborative activities in the future. This shows the perceived collaborative potential of the tool.

6.1.2.5. User 2 Perceptions and observations

This user was again largely positive about their use of CAWriter, *"it was good... it worked well"*. They didn't view it as a necessity but thought it was *"really beneficial"*. They considered it a *"great way to start when it came to writing"* and *"definitely helped bring it all together"*. There were a number of remarks contrasting it with conventional media such as paper and pen. *"You weren't carrying around folder with you or anything like that"* and *"signing into the system and setting yourself up and everything was there already"*. This user also seemed to naturally work on paper creating *"mind maps"*, this practice however changed when they were introduced to CAWriter. When pressure to write did develop, she did revert back to Microsoft Word, however she still maintained using CAWriter to create concept maps and structure her document flow, a process she originally would have done using conventional media. This change in practice does suggest that CAWriter is able to compete with conventional media in the concept mapping sphere, at least for some users.

This user did not make extensive use of the file uploading, referencing or literature review supports. This lack of use was related to issues this user had with uploading files and adding references. The search functionality in CAWriter and the associated file and reference acquisition was not fully utilised by this user, this may have alleviated some of the trouble this user had. The user did see the benefit of these features but argued they need to be streamlined and made easier. This does however suggest that basic functionality is very important to get right if one is to support higher level processes. If the user cannot effectively organise and maintain their information it interrupts their work flow and this in turn affects their willingness or ability to focus on higher level tasks. This user did have an individual run through of the system, but this largely focused on the CMap and document editing features, this suggested that a more rigorous and structured training program may need to be developed.

A further point to note is that this user did comment that support for writing was last on the list in terms of her relationship with her supervisor. This agrees with the literature suggesting that support for writing is limited in Ph.D. education. This user did make further suggestions for minor changes or new features; these are collated and presented in section 6.4.2.

6.1.3. User Centred Design - Case 3

User 3 was a female mechanical engineering Ph.D. candidate in her second year of the Ph.D. program. User 3 was recruited the same way that User 2 was, after being introduced to CAWriter at a talk given to a multi-disciplinary group of Ph.D. candidates at a course promoting innovation and creativity.

6.1.3.1. User 3 Activity

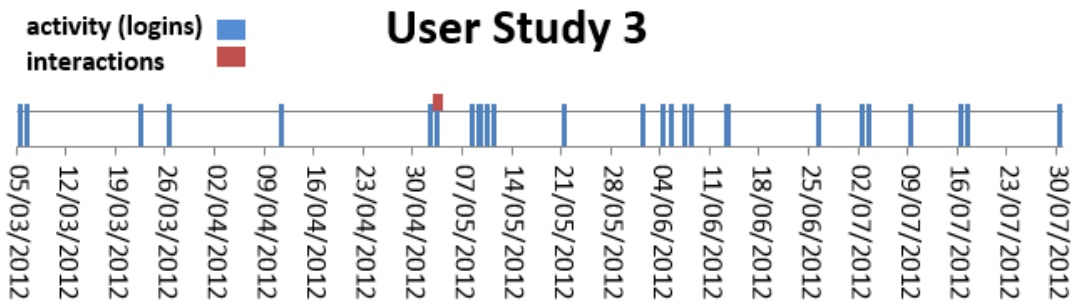


Figure 6-5 User 3 login and interaction activity

User 3 used CAWriter over a 145 day period, with an average of 1.21 visits per week, although this activity tended to be in localised bursts with larger gaps of time in between (Figure 6-5). Over this period she logged in on 25 distinct days.

User 3's activity was again limited as she made no use of the file attachments, quality assessment forms, proxy documents or quotation collection facilities. There were 69 files uploaded, although only 30 distinct files, suggesting a number of duplicates. 12 of these distinct files had references attached, suggesting that duplicates are the result of the file upload facility. There was also one instance of a reference added without a file present. Only a single note and file attachment notes were attached to elements in the CMap space. This was just after a support interaction to explain the features in more depth.

The CMap space did see repeated activity over the entire period (Figure 6-6), although it did see a decline in the last few months. Analysis of the CMap contents suggests that extensive use was made to relate, structure and order concepts. There seemed to be a change from concept mapping activities to formal document editing about half way through, this seems to have coincided with a flurry of concept mapping edits.

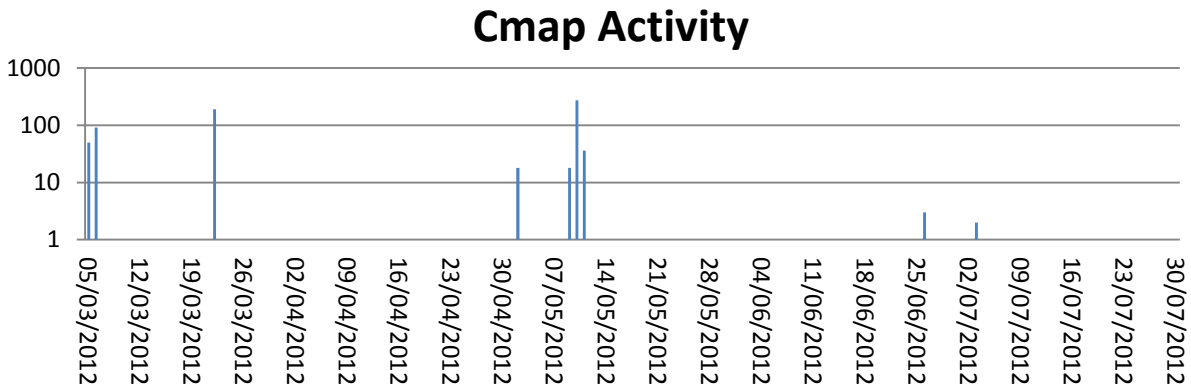


Figure 6-6 User 3 CMap activity (note logrithmic scale)

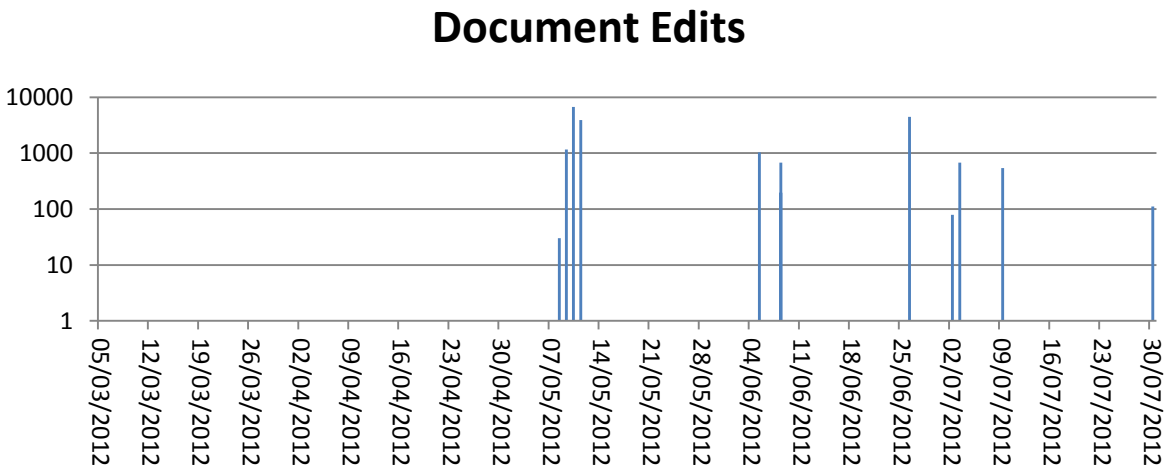


Figure 6-7 Document Edits (note logrithmic scale of word count)

The formal document editing space seems to have been used as both a note collection and formal writing space. There are portions of well-constructed text with the occasional truncated note or set of bullet points. There was also an extensive use of highlighting to denote certain sections. This use of the formal writing space to store informal notes may explain the limited use of dedicated notes attached to the CMap elements. This combined notes and formal word document became a rather large document of 21,175 words.

Only a single interaction was conducted with this user (Figure 6-5). It involved a one on one session that walked the user through the various features of the system, again a reiteration of the initial demonstration. This was followed by more regular and condensed activity.

6.1.3.2. User 3 Heuristics

User 3's heuristic evaluation (Table 6-4) is again more positive than the User 1's rating and reflects that of User 2. All questions on the heuristic evaluation were answered. Out of the 15 questions 14 were marked as positive.

Table 6-4 Heuritic Evaluation by User 3 (orange are heuristics not met)

Heuristic	User 3
System Status	yes
Task Sequencing	yes
Emergency exits	yes
Flexibility and efficiency of use	yes
Match between system and real world	yes
Consistency and standards	yes
Recognition rather than recall	yes
Aesthetic and minimalist design	yes
Help and Documentation	no
Error recognition: diagnose and recover	yes
Error Prevention	yes
Skills	yes
Pleasurable and respectful interaction	yes
Quality work	yes
Privacy	yes

6.1.3.3. User 3 Interview

User 3 was interviewed a few months after their activity died down. The interview was semi-structured in nature and the guiding questions the same as the interview with user 2. The interview

findings have been summarised into five main topics, user perceptions and observations, suggestions for features or changes, skills, activities and cognitive dimensions.

6.1.3.4. User 3 Suggestions

User 3 had only two main suggestions, an auto-save function to reduce worry over data loss and a data analysis tool. The data analysis tool did appear a number of times throughout the project in different forms such as the post-doctoral researcher suggesting that it could be used as for Affinity diagrams a method used in HCI research to analyse and categorise data. This aligns well with the third creative phase of evaluating ideas, an aspect that is poorly supported in the current revision. This would move the tool towards full support for the Ph.D. process.

6.1.3.5. User 3 Perceptions and observations

This was another generally positive user, *"brilliant idea, writing space with files attached, visually very good, you can see everything"*. They suggest that it's *"useful if you are a student who is left to their own devices a lot, it gets you another support mechanism then as well"*. There was no issue with usability of the tool except on smaller laptop screens. This user, like user 2 alluded to a sense of CAWriter as a Ph.D. space, *"feels like you have a whiteboard in front of you plus all your files, plus your actual document... So it is a real workspace... it does actually feel like that when you're on your computer"*. There was also a perception of freedom, a sense that they could *"mess"* with ideas without fear and that trying to do the same thing in Microsoft Word would be *"painful"*. There was also an appreciation for the fact that information is all in the one place as with a *"refill pad you could lose pages"*.

The recurring issue of support for academic writing is evident here again with this user having a *"laid back"* supervisor and workshops on the topic oversubscribed. This agrees with the literature suggesting that support for writing is limited in Ph.D. education. Despite this, the user did see potential for the system to be used to explore concepts with their supervisor: *"will they understand my logic?"* Further suggestions for minor changes or new features that this user made are collated and presented in section 6.4.2.

6.1.4. User Centred Design - Case 4

User 4 was a female computer science Ph.D. candidate in her first months of the Ph.D. program. User 4 joined as a member of the same research group that the author is part of. She was recruited

after being introduced to the tool as part of a lab demonstration. After showing an interest in the tool she decided to sign up to use it as part of her Ph.D. process.

6.1.4.1. User 4 Activity

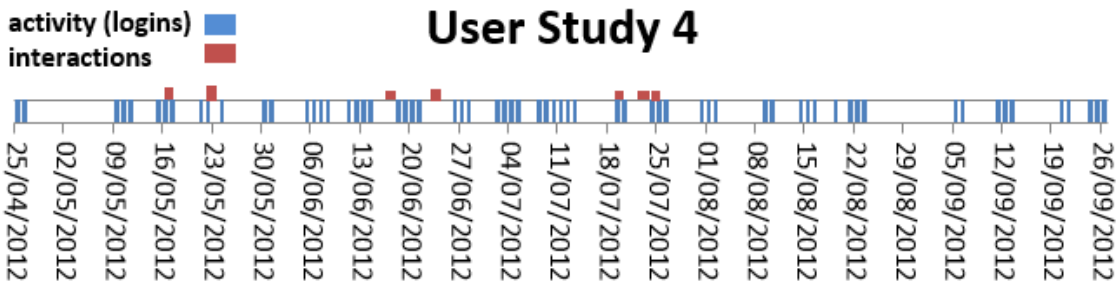


Figure 6-8 User 4 login and interaction activity

User 4 used CAWriter over a 151 day period, with an average of 3.01 visits per week, although this activity tended to be in localised burst with larger gaps of time in between usage, similar to user 3 (Figure 6-8). Over this period she logged in on 65 distinct days.

User 2's activity was the most extensive and comprehensive usage of all the users to date. A total of 93 files were uploaded, 79 of these had references attached, suggesting heavy usage of the automatic reference and file download. There were 4 references added using reference manager; these did not have files associated with them. Approximately 30 additional files were uploaded, but these were duplicates and were deleted. This was the result of a technical issue with this system, this was fixed swiftly. Extensive use of the literature review features were made, with 66 edits of proxy documents and 15 quality assessment forms filled out. A total of 5 notes were attached to files, with 119 inline comments and 747 quotes collected from the literature.

The CMap saw extensive usage over the entire 5 month period (Figure 6-9). Analysis of the CMap contents suggests that extensive use was made to relate, structure and order concepts. Even more so over eight projects were created in total, three focused on formal writing projects, four were used for notes and one was used to prepare a presentation. A total of 17,072 words in the formal writing spaces across all 8 projects. 12,039 of these words were in the formal writing projects. Over 144 CMap elements were created, of which 92 related to headings in the formal document view. Within these projects 22 notes and 79 files were attached to CMap elements. See Figure 6-9 for an

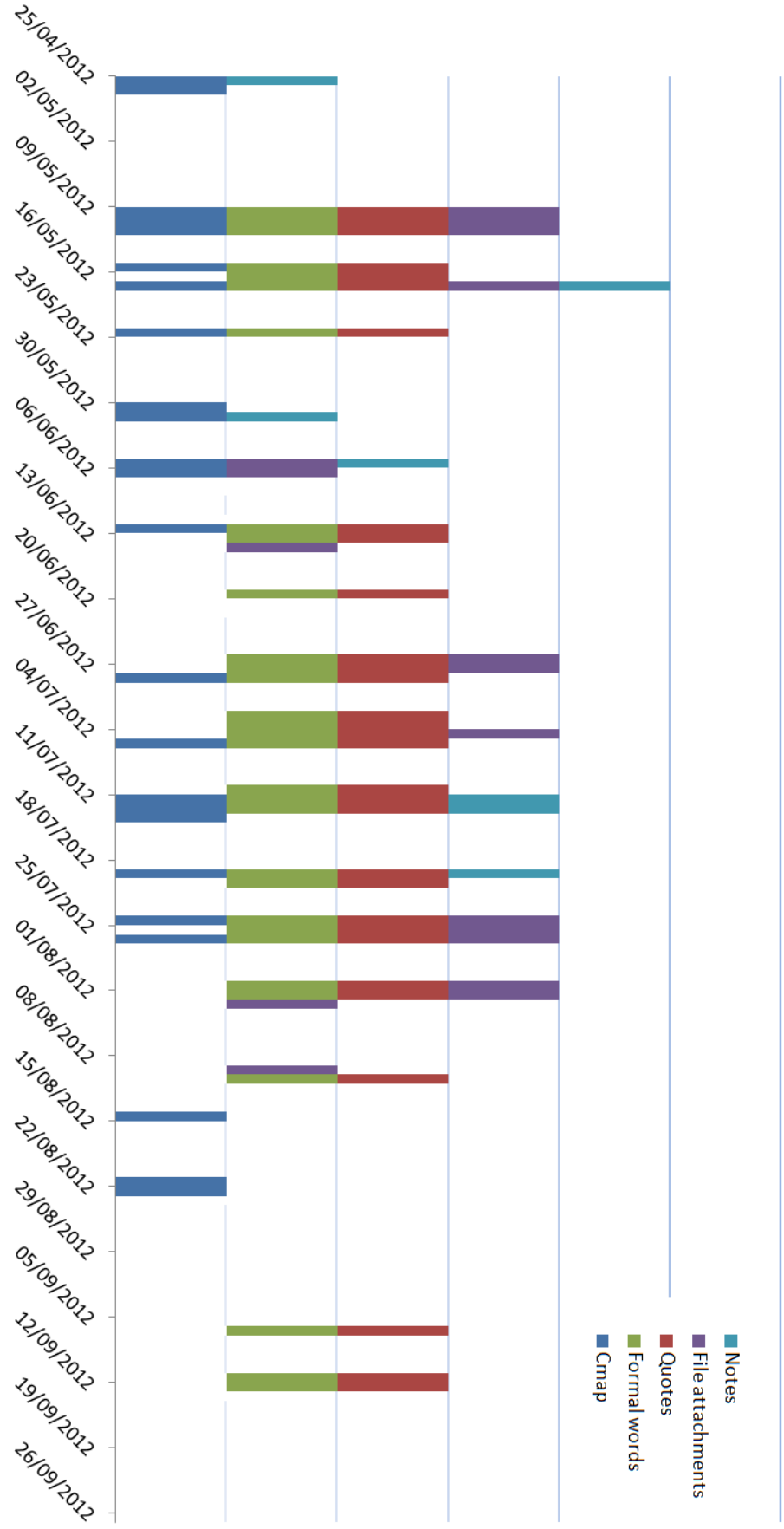


Figure 6-9 User Case 4 usage patterns (represents activity type)

overview of activity across the whole usage period, for more detailed usage information see Appendix 1. It is clear that user 4 worked on a wide range of activities in single login sessions.

6.1.4.2. User 4 Heuristics

Table 6-5 Heuritic Evaluation by User 4 (orange are heuristics not met)

Heuristic	User 4
System Status	yes
Task Sequencing	yes
Emergency exits	yes
Flexibility and efficiency of use	yes
Match between system and real world	yes
Consistency and standards	yes
Recognition rather than recall	yes
Aesthetic and minimalist design	yes
Help and Documentation	no
Error recognition: diagnose and recover	yes
Error Prevention	yes
Skills	yes
Pleasurable and respectful interaction	yes
Quality work	partially
Privacy	yes

User 4's heuristic evaluation is very positive largely reflecting that of Users 2 and 3 (Table 6-5). All questions on the heuristic evaluation were answered. Out of the 15 questions 13.5 were marked as positive. One answer was given a partial answer as it was answered both yes and no. This was in relation to Quality of work and the user left a comment that although it offered "definite support for quality, timeliness and accuracy, but not for aesthetic appeal or completeness".

6.1.4.3. User 4 Interview

User 4 was interviewed after 5 months of activity although they are still using the system regularly. The interview was semi-structured in nature and the guiding questions the same as the interview with users 2 and 3. The interview findings have been summarised into five main topics, user perceptions and observations, suggestions for features or changes, skills, activities and cognitive dimensions.

6.1.4.4. User 4 Suggestions

This user again requested better Word export templates, Word import/export, offline view, improved text editor, backup features (to Dropbox for example), data evaluation tools and improved internal search. These are all valid requests that would be nice additions to the toolset.

6.1.4.5. User 4 Perceptions and observations

User 4 was a little slower to start, *"I didn't know where to start"* and *"At first didn't understand the purpose of all the different functions"*, but *"actually when I started to use it and you showed me how to use it, very quickly it became indispensable, not quite, it was getting there, but it was really useful"*. She suggests it fit a *"niche"* commenting that "*we have got along without it but it does improve things quite dramatically"*, in terms of helping to navigate all your information. She particularly liked the definition and etymology search functions. Oddly it did not match this users natural way of doing things, *"but it improved it"*. In relation to using the CMap space, user 4 was more used to a linear approach to writing and note taking, but quickly learned to utilise the concept mapping space and even used it in *"coming up with a framework"*.

This user also made reference to conventional media such as print outs and paper notes that they would naturally be used to: *"Different connection being made when you're using pen and paper, you do it differently , and I like that", "but you've got me using a lot of technology so... you've done very well"*. She also struggled with reading the HTML rendered PDFs, but could work around that. Interestingly she printed out proxy documents to review on paper, a feature that was requested and easily implementable. The biggest frustration was with the formatting of the exported word documents, more a technical issue than a design heuristic issue.

This user did not suggest that there was a lack of support for academic writing but that CAWriter was complemented by having a good supervisor. If we look at the usage statistics for user 4, they made comprehensive use of almost every tool available, showing extensive understanding of the

use and flexibility of the tools. There was one interesting deviation from the designed intention and user activity; the lack of dedicated note usage and the direct input of notes into the formal drafting space. This needs to be explored further to see how the design may be adapted to either facilitate or augment his process. Further suggestions for minor changes or new features which are collated and presented in section 6.4.2.

6.2. Discussion and Evaluation

The final synthesis of the literature review provided a set of deign heuristics (Table 2-5) that were spread across a number of areas. Chapter 4 saw these heuristics used to describe and inform the design of the CAWriter tool. Activity systems were developed that synthesised elements from relevant pedagogies, core research skills and writing related activities. This section looks for evidence for the desired skill and activity supports that make up these activity systems. This will answer the question as to whether the tools actually support the activity systems they were designed for. The data used for this discussion will largely come from the user case studies as the users were engaged in legitimate activities over an extended period of time.

6.2.1. Skills Support

As was discussed in the literature review the acquisition of research skills (Holz, et al., 2006) is essential for the transition of the novice researcher to a fully-fledged member of the academic community, what is usually referred to as an "independent" researcher. This happens through a process of legitimate *"peripheral participation"* as discussed by Lave and Wenger (1991) in their work on situated learning. Unfortunately these skills are not always explicit and can be difficult to analyse. This section attempts to elucidate the use of the desired skills within the tool, this is achieved from both explicit discussion in user interviews and supplemented by reference to usage activity.

6.2.1.1. Organisational - Record Keeping

All four users from the user studies made reference to supports for record keeping. User two made reference to the fact that *"you weren't carrying around folders around with you or anything like that"*. Although this user did not make extensive use of the file and referencing system, due to bugs that interrupted their workflow, they saw the potential of the system to help user consolidate their information as the system *"is all one, which is great"*. There was also a perception of the

interface as a digital Ph.D. office space where all there information could be kept; this was alluded to by both users 2 and 3, *"feels like you have a whiteboard in front of you plus all your files, plus your actual document. So it is a real workspace... it does actually feel like that when you're on your computer"*.

The effective use of the referencing system by both users 2 and 4 and the extensive use of the file management system by user 4 in particular demonstrate the effective use of the features focused on supporting record keeping. The use of the CMap space by user 2, 3 and 4 may also signify some level of record keeping facilities as they all mentioned going back to review these frameworks. CMap notes were not used extensively except by user 4, but she did mention that she altered her practices to bypass this feature and put notes directly in the formal editing space. This might suggest that the current design needs to be changed to make the notes either more explicit or more tightly integrated into the formal editing space. This may be achieved by adding a feature that easily inserts notes into the section you are working on, but this needs to be discussed further with participants.

6.2.1.2. Organisational - Time Management

Although not designed to explicitly support time management skills, there were several comments that relate to this skill. User 2 suggested it was easy to *"get your head in the zone"*, meaning that it was very quick to get back into work mode once the system was up and running. This was echoed by user 3 who made several references to finding it easy to get back into writing. User 3 also suggested that the features within CAWriter might alleviate an issue she had early in her Ph.D. studies where she *"started reading and taking the odd hand written notes, pretty much a waste of time"*. The quotes and notes features for literature review would record this work as opposed to paper based notes that can get lost in piles of paper.

6.2.1.3. Expressive - Oral

Again oral expression was not an explicit design element but User 4 made reference to how she had used CAWriter to demonstrate to her supervisor "the sort of hierarchies and the relationships I had shown". A number of other users made reference to sharing the content with others, it was not clear if this was in person or virtually. But user 3 makes reference to potentially using it with their supervisor to see if *"they understand my logic"*. This suggests that there is potential to support this expressive skill within the student-supervisor relationship, but it may be dependent on the individuals involved.

6.2.1.4. Expressive - Written

All users made some reference to the support for written expression. User 2 stated *"it was a great way to start when it came to writing"*. As mentioned above in the time management section User 3 found it very easy to get back into the writing process. The real evidence for the support of written expression comes from the content within the system, a total of 45,641 words were written in the formal document editing spaces within CAWriter. Two users did blur the distinction between the informal notes and formal writing within this space, from analysing the contents we can be sure that at least 5,000 of these words are informal notes, as this user had specific note based projects as opposed to formal writing projects. This still leaves over 40,000 words written in the formal writing space. An argument may be made that whether these are formally written words or CMap elements, notes etc., that this all supports written expression. Preliminarily the data seems to suggest that the written expression skill is supported, however content analysis would be necessary to evaluate the quality of the written content, ideally over a longitudinal study, but this is beyond the scope of this study.

6.2.1.5. Expressive - Graphical

Graphical expression supports were largely related to the CMap space. All users perceived support for this skill. User 3 used the concept map to structure the layout of her document and related concepts, *"I have my concept there, main heading and sub headings off there"*. As mentioned above user 4 used the CMap spaces to explain the hierarchies to their supervisor. Users 2, 3, and 4 all explicitly used the CMap spaces when organising and arranging their ideas. A more detailed discussion on how items were arranged in this space can be found in section 6.2.3.3, where the use of perceptual cues explores how the users engaged in their graphical arrangements.

6.2.1.6. Cognitive - Analysis

"A thorough study to comprehend the structure of the learned content, its formal and logic way of organization, in order to detect the elements, outlooks, and methods this content is based upon." (Bloom et al., 1956)

We now look at the first of the cognitive supports, analysis. Again there is consensus among the users, they all agree that analysis is supported although there are differing opinions on where this support lies. User two referred to *"adding comments and notes ... think about it and rewrite it"*. User 3 made reference to the CMap view; "*I suppose I was analysing it and how I saw it was*

different and how I constructed it was different" and "it gives you a space to start formulating your ideas without actually being formal about it". User 3 also talks about the logical way of organising things in the tree view; "*You look at that and see does it make sense or flow or whatever*". User 4 made reference to analysis in relation to the analysis of the literature using the provided tools.

If we look at the definition for analysis above, it is clear that any effort at organising the CMap elements or the tree structure would meet this definition. There is clear evidence that users 2, 3 and 4 engaged in such activity. Whether this is creating conceptual frameworks in the CMap space and relating that to the document structure, or the reordering of tree elements in the tree structure to give the document a logical outlook. In total these three users created 502 CMap elements and organised these into what they viewed as a logical structure. Of these 502 elements, 428 were related to document sections. This suggests a high level of logical organisation, and thus analysis.

User 4's extensive use of the literature review supports, such as quotation and proxy document collation suggests further evidence for analysis of the content upon which the CMaps were created. A number of the proxy documents created by this user explore the methods and approaches discussed in the literature, further supporting the claims for analytical supports.

6.2.1.7. Cognitive - Synthesis

"Establishing a whole new creation by combination of ideas from different sources, in a way that formats and molds will be created, and will stand at the basis of the new creation." (Bloom et al., 1956)

Users 1, 2 and 4 all make reference to supports for synthesis. Although user 1 only considers the system to partially support synthesis. This is not surprising as this user did not utilise the CMap space or the tree structure to any considerable degree. User 2 talked about piecing ideas back together, in reference to her use of the CMap space to organise her ideas and structure document flow. This usage of the CMap space was seen with users 2, 3and 4. User 4 made explicit mention of this usage; "*because you have them together and because you are sort of associating them ... in the CMap*" and "*organising and different ways of representing your information and having it all together, but in a structure that makes sense*". There is crossover with elements of analysis here, but no skill is utilised in isolation as knowledge work is a dynamic process. User 4 also used the CMap space in "*coming up with a framework*". Following on from this statement by User 4 and looking at the constructs that each participant created, whether these are conceptual framework in the CMap view or a document formed using both the tree and formal document editing features,

these artefacts demonstrate the creation of new structures, formats and moulds, based on a process of synthesis.

6.2.1.8. Cognitive - Evaluation

"Judging the values in the ideas through use of standards of estimations, that will determine the accuracy level, purposefulness and practicality of the details." (Bloom et al., 1956)

Each user saw the potential for the system to support evaluation. Use 1 saw the merit of the Quality Assessment forms for helping novice researchers evaluate the literature, but did not utilise the feature. Users 2 and 3 did not use this feature either. User 2 did however suggest that the CMap view allowed one to *"evaluate it as a whole"*. User 4 again saw the potential of the quality assessment forms and said, "evaluation of the literature I'm going to start using more". User 4 did fill out 15 quality assessment forms, but if compared to her proxy document usage, at 66 documents, it definitely displays lower activity. The proxy documents in themselves do offer another layer of evaluation as they draw the user's attention to specific, important and practical elements of the literature. User 4's extensive use of these proxy documents and to a lesser extent the use of the quality assessment form, suggests that the system does in fact support evaluation, at least in the literature review activities.

The literature review protocol and checklist that was implemented to help users self-assess and evaluate their literature review was never tested or explored by the users. This remains an area to explore in future work.

6.2.1.9. Cognitive - Computation

"At a loss for a better word, we termed the ability to cognitively manipulate active abstract objects computation." (Holz et al., 2006, pp. 104).

Although there was no attempt to explicitly design to support computation as a skill, there is an interesting aside that may be discussed, based on the literature review. It may be argued that writing in itself is an act of computation, not in its general sense but on a more abstract level. If we look at the CMap elements and contents of the documents as abstract conceptual artefacts (Bereiter, 2002; Popper, 2002), the definition of computation above becomes much broader. Although this is speculative, it does create an interesting perspective where conceptual frameworks can be "computed" through a process of analysis and synthesis.

6.2.1.10. Meta-Cognitive - Reflection

"can be thought of as the vehicle which transports knowledge between warehouse and learner. As the learner begins a new learning activity, the 'stored' knowledge loaded into the reflection vehicle and delivered to the planning dock so that a strategic approach, which matches task and learner variables, can be created." (Holz, et al., 2006, pp. 113-114)

All users agreed that reflection was supported in one form another. The strongest description of the reflection process came from user 3; *"if you dip in regularly these things become important and possible. The working space that's presented is really conducive to jogging your brain a bit... Your brain is in motion and things occur to you that wouldn't have occurred to you if you hadn't had a look. I guess this is part of the Ph.D. process. It can be extremely slow.... can help you with that process, you're building it... slowly, slowly... it's all there for you to see"*. This very explicitly describes the reflection process. User 4 also alluded to reflection in relation to updating the CMap view and also mentioned the activity log as a means to reflect on ones progress. The CMap activity of users 2, 3 and 4 over the extended usage period and the perceptions recorded in the interview make a good case for support of reflective practices.

6.2.1.11. Meta-Cognitive - Self-regulation

"learners utilize three types of strategies to orchestrate their learning: metacognitive, motivational, and behavioural." ...[strategies include] "setting goals, organizing, self-monitoring, and self-evaluating." (Holz, et al., 2006, p. 114)

User 1 acknowledged that CAWriter supported this skill but it's not clear from the discussion how. User 4 was very explicit that the activity log helped her self-regulate saying *"I'm very competitive"*. This shows that the activity log can be motivational and encourage the user to maintain a regular writing routine, a position supported by user 3.

6.2.1.12. Summary

There seems to be an effective case that suggests CAWriter does exhibit significant supports for a range of skills essential for any novice researcher to acquire. We can tentatively suggest that CAWriter does support a range of research skills, although to answer at what level of depth each of these skills is supported and the prevalence of these supports across the population it would require a more fine grained analysis of user activity, over an extended period of time and a larger sample size.

6.2.2. Creative Phases

An argument has been made above that suggests that CAWriter does indeed support a wide range of research skills. This section will explore in a similar fashion for evidence that CAWriter supports the activities set out in the design heuristics. This section draws on the argument from the previous section where appropriate.

6.2.2.1. Analysis of Problem

Analysis of the problem is a creative phase that incorporates a number of activities such as preparation, fact-finding, idea generation, presentation and collection. Relating these tasks to early Ph.D. writing process suggests activities like literature search, selection, reading and analysis (Holz, et al., 2006; Single & Reis, 2009). Outlining and creating conceptual frameworks are also important when moving towards creating one's own text (Leshem, 2007; Novak & Cañas, 2006; Sharples, 1999; Sharples, et al., 1989; Shibata & Hori, 2002). Basic referencing and file management activities are inherent in this preparation. This section explores at what level CAWriter supports these activities.

Search Literature - Scan Papers - Select Papers

Evidence for supporting this feature is found in user cases 1, 3 and 4. User 1 said that it was very useful for the literature review process, with particular mention of the *"federated search"* and for collecting references. User 3 said her favourite feature was the search and file upload features. This user had 30 files uploaded into the system. User 4 demonstrated extensive use of the literature review acquisition features, with an estimated 79 files acquired via the automated file and reference download system. User 2 had issues with the file upload feature and did not fully understand the full potential of the search function so did not engage in these activities in any major capacity. This suggests that CAWriter does offer support for these activities, but some more work might be needed to clean up the file upload feature to make it easier for users to engage in the task. One method might be to allow the users to simply drag and drop files into file list within the browser. This is now possible with the advent of HTML 5.

Interactive Reading

Single's (2009) interactive reading activity is traditionally conducted with pen and paper. The tradition for this is evident in the user feedback. Users 1, 2 and 4 made reference to preferring to

print out paper to read and annotate, as it's more natural and reading from screens can cause eye strain. User 2 did not use the annotation or quote collection features but did like the idea, however she did suggest that *"that's a whole training area in itself"*. This demonstrates that the interface as it is not completely obvious and more training is needed. This user did however not use the literature reading facilities to any great extent so perhaps with more engagement in the activities adoption may be quicker.

User 4 saw the heaviest usage of the literature annotation and quotation collection features, with 119 inline comments/highlights and 747 quotes collected in total. This was across a total of 93 files. This users natural tendency was to print out paper to read and annotate, despite this she seemed to engage well in this activity even commenting that *"you've got me using a lot of technology so... you've done very well"*. This level of engagement by user 4 suggests that CAWriter does indeed support interactive reading, although improvements can be made to make the process more streamlined and simpler to conduct. There are also a number of bugs that remain in the current system that can still frustrate users, one such bug is the inability to quote across pages.

Interactive Note taking - Analyse Literature - Critique Literature

User 1 thought that the system had potential to support the literature review process, but felt unsure that the *"assignment ... gave* [CAWriter] *the opportunity to shine, in terms of scale"*. This user also requested that the quality assessment form be customisable or at least have multiple options, this seems like a reasonable addition that could help augment the existing system to cater for differing needs and disciplines. User 4 was the only other user to engage in interactive note taking and any extensive analysis of the literature. This user stated that the tool provided a structure to follow while reading the literature. Having completed over 66 proxy documents and 15 quality assessments of the literature, this user demonstrated the analytical and critiquing features provided within CAWriter. Although further note taking supports were provided, the interview revealed that the user changed from using dedicated notes to writing the notes directly into the formal writing space. This has been discussed above and suggests that the note features may need to be augmented to better suit the user's workflow. Further testing with more users should provide better insights as to how well these activities are supported, however user 4's usage is positive and shows the promise of the existing system.

Outlining

Of the 502 CMap elements created by users 2, 3, and 4, 428 of these were related to headings within the formal writing document. All three of these users mentioned the CMap and Tree views as assisting in giving an overview of the document. User 3 said *"Mapping view gives you that overview... The tree structure is so handy, I find that really good ... It's the first thing I click at ... it's really important* [to get an overview]*"*. She also said she finds them *"brilliant ... If you think something else should go somewhere else it's very easy to change it. ... You look at that and see does it make sense or flow or whatever"*. Users 2 and 4 had similar sentiments about structural overview, with user 4 saying that they started with looking at the tree before they started writing anything new.

Conceptual/Context

User 1 seemed to be the only user that struggled with the concept mapping feature; "*it was kinda tough"*. He also made some interesting observations that there may be a danger that one might get stuck in synthesis mode in the CMap space. Although a valid point the Ph.D. context involves a supervisor for this very purpose, to keep the candidate on task and moving forward. CAWriter is not meant to act in a vacuum but is meant to complement the cognitive apprenticeship model for Ph.D. education.

This view was however not congruent with the other three users. Although user 2 naturally used mind maps as part of her workflow before using CAWriter, she converted to using CAWriter as her main method to construct them. She would traditionally use Microsoft Word and a sheet of paper to draw her mind maps. Even when pressure mounted and she had to convert back to Word to write her documents, she still maintained usage of the CMap feature of CAWriter to organise her ideas and structure the flow of her Word document. This user liked the large amount of space provided to create the concept maps, making it seem like a virtual work space, with little chance of losing the contents *"under your coffee mug"*. This change in practice suggests that CAWriter is well suited for the production of concept maps.

Users 3 and 4 did not naturally create concept or mind maps. Despite this they both took to the feature rather quickly. User 4 did have some reservations at the beginning as the approach was not known to her. But once she got her *"head around it"*, she found it to be very easy to use and even created a conceptual framework using the tool. This marked a distinct change in practice for this user, who was very used to working in the traditional linear fashion. This change in practice from a

linear style of work to the non-linear approach is promising and suggests that users' preconceived ideas of their working style are not necessarily an obstruction to the adoption of new approaches, as was the case with user 1.

With over 502 elements created by users 2, 3 and 4, and the relation of 428 of these to document sections suggests that CAWriter does effectively support the conceptual and context creation activities.

Referencing system

The referencing system received mixed reviews. Users 1, 2 and 4 found the tool hugely beneficial. Despite this user 2 had issues with the system and requested a system overhaul. This may have been because this user manually uploaded and attached references. This approach was not optimised and had a number of usability issues, first you had to add references using BibTex format and with the lack of templates it was difficult to construct references manually. There is definitely room for improvement here. The discrepancy between user 2 and the other users most likely arises due to users 1 and 4 using the automated referencing and file download system; this system drastically streamlined the process.

Users 2 and 4 both used the automated reference insertion tool for the document editing space, but only user 4 used this extensively. This user did use the tool for a library assignment on referencing styles which did highlight some of the limitations of the system; there were a number of errors in formatting and only a single formatting type available. These are functional issues that can be fixed given time, but do emphasise that CAWriter is not at a stage to effectively produce a finished document. Other tools such as MSWord and Endnote may still be needed; CAWriter does however allow the user to export the document to MSWord and your reference list in BibTex format.

6.2.2.2. Generating Ideas

Generating ideas is the second creative phase that incorporates a number of activities such as incubation, idea-finding, response generation, idea creation and relation. Although there are a number of crossovers with the previous section we have highlighted three specific tasks related to the early Ph.D. writing process: citable notes, long outline, drafting and regular writing (Holz, et al., 2006; Sharples, 1999; Sharples, et al., 1989; Shibata & Hori, 2002; Single & Reis, 2009).

Citable Notes

The citable notes task raised the most interesting design questions. Although there were specific features to attach notes to CMap elements and files, it seems that in practice all users put their citable notes straight into the formal document draft view. This suggests that either the note features provided are redundant or that they need to be more explicit and integrated into the workflow. User 4 did start with using the notes but her practice changed to be more focused on the formal document. The notes view is located to the far left of the screen and perhaps this distance creates a disconnect between these working elements. This issue was already discussed in section 6.2.1.1.

Despite this difference in design intention and practice there is still evidence that CAWriter still facilitated this activity, just not in the envisaged way. For Example User 4 added the citable notes directly to the formal drafting space.

Long Outlining - Drafting – Revision - Regular Writing

The long outline and drafting activities are facilitated by the formal drafting space. The best evidence to suggest that CAWriter can help facilitate this phase are the 45,641 words that were written into the formal drafting spaces by the 4 users. Even if 5,000 of these words are removed as notes, this still leaves a substantial amount of written content. There are also numerous mentions from users saying that it made getting into the writing process very easy. The tree structure adds another dimension to the formal document drafting space, as user 3 put it *"like messing around with the tree, I find the tree brilliant ... If you think something else should go somewhere else it's very easy to change it. ... You look at that and see does it make sense or flow or whatever"*. This was discussed in more detail in section 6.2.1.4.

The regular writing routine is further supported by the comments users made about the activity log motivating them to write, this is discussed in more detail in section 6.2.1.11. As we can see there is sufficient evidence to support the claim that CAWriter can support the drafting and revision process.

6.2.2.3. Evaluating Ideas

Evaluating ideas is the third creative phase and incorporates a number of activities such as verification, idea evaluation, response validation, idea creation and relation. We focus on two main methods with which we can support these activities, the first is through collaborative feedback (D.

Boud & Lee, 2009; Hopwood & McAlpine, 2007; Leshem, 2007; McCotter, 2001) and the second is self-review protocols (Boote & Beile, 2005; Brereton, et al., 2007; Ravenscroft & McAlister, 2008).

Collaboration

The idea behind collaboration as a method of evaluation is based on the cognitive apprenticeship and peer learning models. Here more knowledgeable others can provide insight and criticism that the individual would not achieve by themselves, this can be described as legitimate peripheral participation.

Unfortunately the collaborative features with CAWriter were never tested. There is in built functionality to share CMap space and document drafts. Further functionality was to support collaborative feedback on drafts and basic communication and awareness tools. But as these features were never tested in legitimate situations there can be no claims as to how well they function or integrate into practice. However, each participant did make some comment towards the possibility of using the tool with others. User 1 was hesitant as he is sensitive to criticism, but still saw the potential of the functionality; he even invited other students to review his work, although they did not reciprocate. User 2 even commented "*I could see myself sharing with someone I was trying to impress"* and suggested that it could be used to present ideas to supervisors and others. This was echoed by user 3 who thought it might be useful to see if her supervisor will *"understand my logic"*. Finally user 4 did in fact use CAWriter to discuss the structure and hierarchies of her ideas with her supervisor, but we do not have any detailed information on that particular interaction.

So although there is no evidence to suggest that CAWriter supports collaboration, it has been designed to support such activity and the users do see potential here.

Self -Review Protocols

The self-review protocols were the latest addition to CAWriter's tool kit and have also gone untested. These include a checklist to review one's own literature review (Boote & Beile, 2005) and a list of argumentative prompts (Ravenscroft & McAlister, 2008). An extension called AfterTheDeadline was also added to the text editing fields to help analyse text for spelling and grammatical errors. The purpose of these features is to allow the user to be critical about their own work by asking questions that they might not normally consider, this is the advantage of prompts. As these have never been tested by user there is no evidence that these tools are effective or useful.

6.2.3. Cognitive Dimensions

The final elements in exploring the user experience using CAWriter are the cognitive dimensions that informed the design heuristic. Although these dimensions were kept in mind from early in the design process, their impact was difficult to elucidate in the first interview. Users 2, 3 and 4 were asked specific questions relating to these dimensions in their interviews. The findings are discussed below.

6.2.3.1. Delayed Gratification

All three users that were asked about this dimension reported that there was no major delay in gratification. User 2 made the comment *"I've stopped using the paper version"* as a point that there was in fact a benefit seen beyond conventional media, which itself is viewed as having the least delay in gratification. User 3 found it very easy to get back into writing finding it no harder than she is used to. User 4 found using the CMaps very easy once she got her *"head around it"*.

There were a number of issues related to file uploads that both users 2 and 3 mentioned. This issue does need to be addressed as a number of the literature review features rely on having files uploaded.

6.2.3.2. Terseness

Terseness was mentioned by all three users. User 2 viewed the CMap view with mini-map navigation as an excellent way to get an overview of her ideas in a quick and timely manner. User 3 made reference to both the mapping and tree structures as helping to give an overview: *"Mapping view gives you that overview... The tree structure is so handy, I find that really good ... It's the first thing I click at ... it's really important* [to get an overview]*"*. User 4 echoed these sentiments stating that the usually started writing by looking at the tree structure.

This offers substantial evidence that the interface allowed the users to get a quick overview of the information displayed and did not require them to open up and read through a full document to get back to work.

6.2.3.3. Perceptual Cues

Perceptual cues were mentioned by all three users. User 2 used all the features within the CMap space from linking elements and post-it notes. This user also used proximity of object as a

"memory trigger" for ideas that are somewhat related but that relationship had yet to be defined. This approach was also seen by user 3 and 4, with user 3 stating *"Some elements are just there. So I don't forget them. I put them near. Not always clear what goes where. If I was doing that in a word document it's easy to get lost"*. User 3 rated the system as *"7 out of 10"* as compared to conventional media such as pen and paper. When asked if the system could provide any more notations or perceptual cues the users seems satisfied with what the system currently offered.

CAWriter seems to offer an adequate level of perceptual cues as users were happy and did not feel they required any more functionality beyond what they system already provides.

6.2.3.4. Accessibility

Only users 3 and 4 made reference to accessibility within the system although this dimension does leverage heavily off perceptual cues and terseness already discussed, and have found to be present. User 3 suggests that CAWriter is much more accessible than a Word document: *"You can see where you are at easily. The mapping area and tree you can see it really quickly"*. User 4 found it easy to access their information but thought that the internal search function could be improved, an observation that the author agrees with. The internal search function was limited and could do with revising.

6.2.3.5. Premature Commitment

Each user made some reference in relation to premature commitment and how CAWriter did not force users to commit. User 4's natural tendency was to work in a linear mode which leads to *"downsliding"*, however she noted that CAWriter had opened her practice to be more open. *"You can always change it"* was a statement made by user 2, suggesting that there was no sense of enforced permanence that can accompany writing on paper. User 3 made comments to feeling free to *"mess"* with ideas, something that she deemed difficult in software such as Word.

One issue that user 4 had in terms of premature commitment was the inability to undo quotations easily. This highlights the need and desire for undo features across a wide range of user interactions.

6.2.3.6. Viscosity

All three users made reference to viscosity. As we have seen user 2 stopped using paper and pen to use the CMap feature within CAWriter. This suggests that the tool offered low enough viscosity

compared to paper and pen that this user changed their natural practice to adopt using the tool. Users 3 and 4 both found the system very easy to use and get their ideas down, once they got their heads *"around it"*.

6.2.3.7. Formalness

This is probably the most interesting of all the cognitive dimensions, but there is only tentative data available from this study. There were perceptions that the CMap space could be used to convey meaning but that dialogue may be needed to describe and explain the semantic relationships of the content. This varied perspective of content may be viewed as either a failure or benefit of the system, but it warrants further investigation. This would involve collaboration using the system, something that is technically possible with the existing system but has not been tested.

6.2.4. Participatory Heuristic Evaluations

Following the Participatory Design approach, heuristic evaluations (Figure 6-10) were carried out over a two year period, all with Ph.D. candidates. The initial six heuristic evaluations were conducted after a one hour testing and feature explorations. These sessions were run in the period of October 2010 to September 2011. These were used to evaluate the usability of the system and record feedback before deployment of long term usage in legitimate activities. For a full breakdown of the results see Appendix 2.

An initial evaluation of an early prototype was conducted with a HCI Ph.D. candidate in October 2010. The evaluation was conducted after a short walkthrough and a testing of functionality. Out of the fifteen questions, 4 were considered not applicable as it was not possible to fairly evaluate the system after only an hour of usage. This resulted in a positive response to nine of the remaining eleven answered questions. The two weak areas that recorded a negative result were match between system and real world and consistency and standards.

The subsequent five heuristic evaluations occurred at a group participatory design sessions where discussions and testing took place. These sessions were conducted with a multidisciplinary group of Ph.D. candidates ranging from early stage Ph.D. to those that were nearly finished. The responses ranged from nine to twelve positive results. An interesting aspect is that three users gave all positive responses to the answered questions, again unanswered questions were deemed inapplicable. The user that rated the system with twelve positive responses, answered all questions but marked the remaining two as only being partially positive. The most negative response was a

user that rated the system with only nine positive responses, two partially positive responses and one negative result. This user did not answer the remaining three questions.

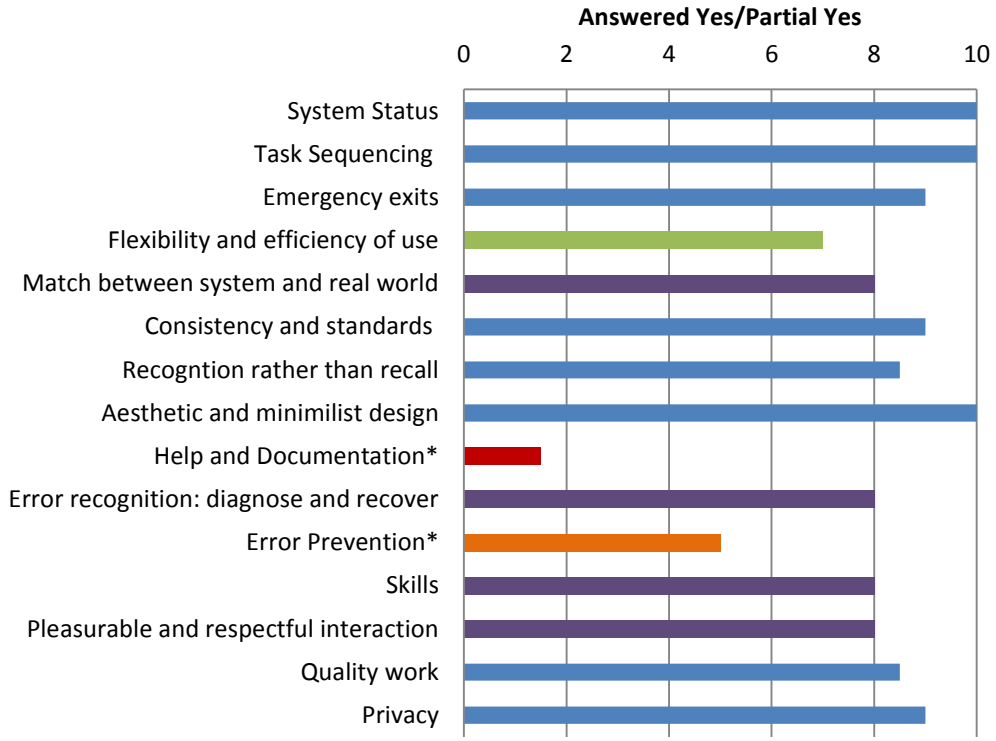


Figure 6-10 Participatory Heuristics Results (10 participants)

The final four heuristic evaluations were conducted with the long-term users discussed in the user cases above. User 1, the user experience expert, gave seven positive responses, leaving two unanswered. Users' 2 and 3 both gave fourteen positive responses with all questions answer. User 4 responded with thirteen positive responses and one partially positive answer out of fifteen, with all questions answered.

Overall the heuristic evaluations suggest a high level of usability with a largely positive response. A detailed breakdown of results may be found in Appendix 2. Looking at the questions that scored lower provides an opportunity to address the limitations and deficiencies of the system.

The lowest scoring heuristic was that of Help and Documentation. This is probably the most interesting result as four of the participants considered this question not applicable. There is also a divide between the short term testers and the long term users, the four users that rated it not applicable were one time users. This suggests that in the time they used it there was no need to request help, there is also the case that the author was present to offer support and advice if needed.

Help and Documentation received only one positive response and another comes from one user who gave it a partially positive response. These two users considered video tutorials that were made to support beginners as a help function, the user that provided a partially positive response considered these videos inadequate but better than nothing. The long term users all rated this heuristic as negative, this result is understandable as there were no help features built into the system other than outdated video tutorials. This low score was deemed unimportant as a design decision was taken after the initial video tutorials were created to halt any creation of help documentation and handle issues in person. This decision was chosen for two reasons. Firstly due to the iterative and evolutionary design approach, documentation would quickly become obsolete. Providing help in person, rather than constantly changing help documentation to match the latest system updates, would help reduce the author's workload. Secondly, providing help in person provided an opportunity to gain feedback from users about issues they were having, this instant feedback could be used to fix bugs or implement features on the fly. Although this heuristic was ignored in practice, if a finalised system was to be deployed, help functionality with index and search facilities would be essential, it just was not practical as part of this implementation.

The second lowest heuristic score was that of Error Prevention with only five positive responses. Looking at the data for this heuristic reveals that five users rated this as not applicable and the other five users gave it a positive response. This means that this heuristic actually received a fully positive response from those users that considered it applicable. This put this result in an unusual position, we can either view this heuristic as receiving a fully positive result or consider it not applicable.

Flexibility and efficiency of use was the next heuristic with a respectable seven positive responses. Two users from the test group rated this as not applicable, which makes sense as they only used the system during one session. A single long term user gave a negative response. Looking at this users usage we can see that this user's activities largely focused on the document editing feature which is the most limited feature of the system. This may help explain this response as they did not engage in record keeping, concept mapping or literature review activities. There also seemed to be misconceptions as to the purpose of the other features, perhaps this was a failure on the part of the author in explaining the functionality.

Match between system and real world received eight positive responses, although a high score it is interesting to note that the users that rated this heuristic negatively were both HCI specialists. Although speculative it may be that these users were more aware and critical of the user interface than regular users. The long term user with a HCI background did also raise some interesting

suggestions about workflow during the interview. The suggestions were to display the working document when you initially enter into a project, as the system only opened the CMap space when you first opened a project. Changes were made to the system based on this feedback and this may have influenced the other long term users positive responses as their usage occurred after these changes.

Error recognition also received eight positive responses. This received one not applicable response from the early HCI specialist and a negative from a single functionality tester. The functionality tester did comment on this question saying *"work in progress".* All the long-term users gave this a positive score.

Skills again received eight positive responses. Two not applicable answers explain the loss in score. Oddly user 1, the HCI specialist from the user case studies answered not applicable to this despite making suggestions that skills were positively supported during interview.

The heuristic pleasurable and respectful interaction received another eight positive responses. This received one not applicable and one negative result. The negative response was from user 1, interview data suggests that the system did not match his natural workflow, it is likely that this may have influenced this negative response.

Recognition and recall received eight positive responses and one partially positive response. The partially positive response was from a functionality tester and the single negative response was from user 1. The functionality user commented that *"at times, it wasn't the easiest to find action unless told"*. User 1 as a HCI specialist would be naturally more critical of computer systems. All other long term users rated this heuristic positively.

The heuristic for quality work received eight positive results and one partially positive result, this particular heuristic is of interest as the negative responses came from two long term users. Again user 1 gives a negative result; this is understandable as the interview revealed that he struggled a little with the workflow and that the export of the document to Word was less than ideal, even suggesting preloaded templates. This lack of aesthetic appeal was again the reason user 4 gave only a partially positive response. Fixing the output of the MSWord export function may help to alleviate these concerns and increase the perceived quality of work achievable within the system.

No other heuristic received any negative scoring from the long-term users. As such it may be reasonable to assume that those heuristics that received nine positive responses had their issues resolved or that these issues were not perceived by the long-term users.

One final comment is necessary in relation to the heuristic results. There were only four users who evaluated the system with less than twelve positive responses. It was observed by the author that the users whom provided more negative responses were more inclined to offer constructive criticism, which may indicate why they were more critical of the system. This does raise the issue if the other participants were overly supportive as the result of peer comradeship, an issue that can occur in peer meeting (Borders, 1991). Despite these reservations there is sufficient evidence that the heuristics suggest a high level of perceived usability of the system, whether short term user or long-term. For a more in depth look at the long-term usability of the system we now explore the case studies perceptions and observations of using the system.

6.3. Evaluation

If we review the central sub questions of this research:

a. How can we frame and describe the rich and dynamic the Ph.D. process, with the aim of designing tools to support that process?
b. What do the developed tools, as a technology probes, tell us about this class of application?
    i. Are the developed tools usable, did people use them, if so, how?
    ii. What are the user's experiences, perspectives and observations on using the tool?
c. What can we learn from the developed tools, as an encapsulation of the framework and requirements gathered?
    iii. What were the lessons learned from the prototype implementation?

The first sub question about framing the Ph.D. process was answered through the development of the Activity System framework and Design Heuristics developed in the Literature Review chapter. This framework was used to develop CAWriter which was then implemented with a small cohort of users. This implementation has been presented and discussed throughout the preceding chapter. These findings and discussions are used to attempt answering the remaining research questions.

After discussing the findings from the heuristic evaluations, user perceptions and cognitive dimensions it is clear that CAWriter is largely usable in legitimate working contexts, but that more work is needed to improve the functionality if greater adoption is to be successful. This demonstrates that CAWriter has been a useful and valid tool to probe this class of application and as a result it can be compared with other existing commercial products used for similar purposes. It highlights the wide variety of tools that a knowledge worker uses during their work and the

challenges in design for such work. The usability issues are largely technical in nature and do not impact on the original activity systems or design heuristics. This helps us answer our main question, is the tool usable?

For those users that engaged in the variety of tasks that CAWriter offers to support there was a unanimous positive reaction. As we have discussed above there was significant engagement in a range of research skill and activities related to early stage dissertation writing. There are a number of areas that require more research such as the informal notes versus formal drafting space and testing of features that explore the third creative phase, evaluating ideas. On a whole there seems to be a case that where the tools were deficient, these were largely technical in nature and that the activities and skills that they were aiming to support were still beneficial and desired. This suggests that the CAWriter toolkit is indeed a useful tool and that there are many future possibilities and directions it can take.

As an encapsulation of the developed framework, design heuristics and requirements, there is considerable evidence that CAWriter achieved what it set out to. There are three areas where the results are either questionable, need improvement or unanswered. The referencing and file upload systems require an overhaul. Notes and citable notes usage with the formal drafting space needs to be revisited. Finally there is no evidence that the "evaluating ideas" creative phase was addressed. Although there is inbuilt functionality they remain untested. This suggests that CAWriter has largely met the criteria for the first two creative phases, which is in line with the early stages of the Ph.D. process.

The response from users using CAWriter over an extended period while engaging in legitimate Ph.D. activities was largely positive. The issues that occurred were either a failure to communicate the features and uses of the CAWriter or functional issues relating to poor implementations or bugs. As these are largely technical issues there is a strong case to be made that the design heuristics allow for the creation of both usable and at times enjoyable user experiences.

The heuristic evaluations discussed in the previous sections of this chapter do suggest that CAWriter is usable in general, but a deeper analysis of the user's experience will provide greater insight into the usability of such a tool in legitimate work practices.

Finally there are limited but positive suggestions that the cognitive dimensions have influenced the usability of the tool. There are a few issues such as the file upload, search and undo of quotations that have caused a few issues with users, but overwhelmingly the results are positive, suggesting

that CAWriter can both compete with and even surpass existing tools such as Microsoft Word and even conventional media, in some cases.

However the fact that CAWriter is not perfect or finished captures the evolutionary epistemology that guides this work. It is important to note again that CAWriter is the culmination of a participatory action research and design process, the following section provides an opportunity for the author to reflect on the development to date and whether this was indeed a participatory action research and design process.

The complexities of the Ph.D. process and hence in the design of tools for this process highlights the difficulties involved when designing such tools. CAWriter has preliminarily demonstrated that such tools are both useful and positively received by Ph.D. candidates, but that for application in this domain, there is a need for a wide array of tightly integrated features. Once these features are successfully integrated it will allow the Ph.D. candidate to focus on higher order skills rather than mere functional organizational skills. CAWriter and this thesis present a first step guide for this complex feature set, for both future designs and further research in this domain.

6.4. The Emergent Ph.D.

The title of this section is meant to reflect how both the design of CAWriter and this thesis emerged over a period of four years. It offers a reflexive space where I, the author, can express my own observations and perceptions openly and honestly, and hope to answer any questions that can only be explained through the subtleties of my subjective perspective. This section attempts to answer the questions related to the methodology, namely participatory action research.

- Did the project build logically from the collected data?
- Was there legitimate collaboration?
- Has the work empowered the participants?
- Was there any change and did the solution make a difference?
- Was the research disseminated to appropriate audiences?

We start with a look at both the requirements and brainstormed ideas gathered during the three Future Technology Workshops conducted in the early stages of the design process. A self-evaluation of the tool is conducted to gauge my perceptions as to whether I believe that the requirements were met or not. This is followed by a similar section looking at bug reports and feature suggestions throughout the design process. This discussion is then used to answer the

questions above. This is followed by a brief reflection on my role in the project, lessons learned and my own perspectives with using the CAWriter tool.

6.4.1. Future Technology Workshops

Table 6-6 Brainstormed activities deemed outside the remit of this project

Brainstorming	Going to conferences
(Outside Remit)	Case studies / data collection
	Summer schools
	Maximising attendance workshops/conferences
	Running/designing experiments
	Data collection analysis
	Presenting

There were three separate Future Technology Workshops conducted early in this research project. In each the participants were asked to envision future tools to support the Ph.D. process, to think "blue skies". The intention was to get them thinking of advanced technologies to support the Ph.D. process in general. The first brainstorming session outputs activities to support, those that fell within the remit of this project are presented in Table 6-7. Those outside the remit can be seen in Table 6-6.

At the end of this research project these lists were revisited and analysed, with the perceived support for each item in the list rated on a scale from 0 to 1, in 0.25 increments (Table 6-7). No support was 0, elements supported was 0.25, partial support was 0.5, adequate support was 0.75 and substantial support was rated as 1. Out of these 25 ideas I rated CAWriter as having achieved 75% of these ideas supported. This is of course subjective so the same task was assigned to user 4, the most extensive user of CAWriter to compare results. Interestingly she gave a much lower rating of 57%. The discrepancies have been highlighted if the value of difference was greater than 0.5. It may also be noted that all of the highlighted elements were rated higher by me, despite user 4 having rated other supports higher under other categories.

Table 6-7 Self-evaluation of CAWriters Support for FTW Brainstormed Activities

Brainstorming (Within Remit)	**Designer**	**User 4**
Getting feedback – as many people as possible	0.5	0.5
More collaboration	0.75	0.5
Managing bibliographies easily	0.75	1
Writing/rewriting	0.75	0.25
Diary/journals	1	0.75
Publishing	0.25	0.5
Structuring /assimilation ideas – better capture tools	1	0.75
Brainstorming	1	0.75
Literature review in every expanding knowledge base	0.75	0.5
Linking between activities	0.5	0.75
Better facilitation of collaboration	0.75	unsure
Structuring/organizing work/deadlines	0.75	1
Reading (+notes)	1	1
Reading + writing group	0.75	1
Mind Mapping	0.75	0.75
Notes	0.75	0.5
Visualisation of document relationships	1	1
Literature collecting	0.75	0.5
Tight integration of data/literature elements	1	0.75
References + bibliography	0.75	0.25
Networking	0.5	0.25
Integrated communication	0.75	0.25
Reference network	0.5	0.25
Writing review (feedback)	0.75	0.25
Editing	0.75	0.25
Total (out of 25)	18.75	14.25
(%)	75	57

Table 6-8 Self-assesment of CAWriters Supports for FTW Requirement Activities

Requirements (Within Remit)	**Designer**	**User 4**
The cloud	1	1
Structure ideas	1	1
Multiple views (with comparisons)	1	1
Avoid data overload	0.75	0.75
Intuitive capture	1	0.75
Easily integrated pervasive	1	0.75
PDF files with metadata	0.75	0.75
Seamless integration(consumption-production ...	0.5	0.75
Ubiquitous network access	0.75	0.75
Different views of information	1	0.75
Reference management - including "auto" linking	0.75	0.25
Communication collaboration	0.75	0.25
Advanced search	0.5	0.75
Community directed development	0.75	0
Customisable tools	0.25	unsure
Automated quote "grabbing"	1	1
Community knowledge base	0.5	unsure
Organise facilitate writing groups	0.5	0.25
Privacy controls	0.75	0.75
Models templates for workflows	0.75	0.75
Linguistic readability	0.5	1
Mind Mapping	0.75	0.75
Automated reference system	0.75	0.5
Reference network	0.25	0
Categorisation	1	unsure
Document network	0.5	0.5
Peer comments	0.5	0.5
Total (out of 27)	19.5	15.5
(%)	72.22	57.41

This might be confirmation bias to a certain extent on my part, but two of these score related to activities this user did not use but the features are present, these are writing feedback and the integrated communications. If we look at the others they tend to reflect the issues this user was having with the tool, such as referencing formatting and MSWord export aesthetics. These aspects definitely require improvements and this discrepancy highlights the need for these features. This was a useful exercise to gain insight into the users perceptions of the supports found in CAWriter, based on the desires of previous participants in the Future Technology Workshops.

Table 6-9 Requirement activities deemed outside the remit of this project

Requirements	Graphing tools
(Outside Remit)	Data visualisation
	Crowd sourcing metadata
	Optionally remote attendance of conferences
	A.I.
	Context Awareness
	Planning workflows
	Social network
	Data network
	Auto-summarising

The final part of each Future Technology Workshop was a summary of the requirements that the participants desired for any future technologies. The results are presented in a similar fashion as the brainstorming activities.

Table 6-8 is the full list of requirements that fall within the remit of supporting the writing process, Table 6-9 shows those desired requirements that fall outside this remit.

There are again similar differences in result, although user 4 was unsure about three of these requirements. Again collaboration came up, but as user 4 has not used the potential features the result makes sense. I am unsure if we both perceived the reference management with auto-linking as the same thing, CAWriter does include a number of features that allow the user to click on

references in the drafting space and bring up the file associated with it. I am disappointed that there was no perceived community directed involvement, but as this user is also the newest user they were not involved in the early stages of the process. On this topic it was difficult to maintain participant interest with a half working prototype in the early stages of the research. To expect users to invest their precious time using a half-baked tool did not seem ethical beyond the short heuristic evaluations, it was only when a substantial amount of the bugs were fixed and suggestions implemented before long-term users could benefit from the tools. These bugs and suggestions were collected throughout the early design process from both participant feedback or the authors own observations during use. These bugs and suggestions are discussed below.

6.4.2. Bugs and Suggestions

This section looks at the resolution of bug fixes and implementation of suggestions gathered throughout the design process. They were collected both formally and informally from participants and from my own personal observations during personal usage of the tool. A brief look at the statistics related to these resolutions is followed by a look at the suggestions that the long-term user made during their interviews. This represents the users' desires for future development and should act as a guide for further changes to CAWriter.

Table 6-10 Bugs fixed

Total	52
Fixed	45.5
Percentage (%)	87.5

Bugs were rated as not fixed, partially, usable fix: 0, 0.5, and 1 respectively. Of those recorded 87.5% were resolved. Those left unresolved were the inability to print out the whole concept map space, no auto-save, quotes across pages, occasionally links between CMap elements would not render for child elements and book references not displaying location as per the APA style. There were three others that had partial fixes.

Again suggestions were rated as not fixed, partially fixed or totally fixed: 0, 0.5, and 1 respectively. This time we have a lower score of 64.9%, this was in part because priority was given to resolving bugs. There were also a number of requests that developed on top of existing features that involved considerable work. These were not deemed essential as the focus was to cover the activity systems set out in the design chapter. Examples of those ignored are offline mode, email notifications,

branching CMaps and collect phrases. Although all the suggestions have their place, the entire system was maintained and developed by a single person, which constrained the possibilities that could be pursued. Items were prioritised and others acknowledged but left for future iterations.

Table 6-11 Suggestions Implemented

Total	84
Implemented	54.5
Percentage (%)	64.9

6.4.1. Participatory Action Research and Design

This section attempts to answer whether this research was a legitimate action research project.

- Did the project plan build logically from the collected data?

If we take the finding, discussion and the previous sections into account, it is fair to say that the project did develop logically as data and insight emerged throughout the process. Chapter 5 demonstrates the process by which these changes were made and the reasoning behind each step and iteration.

- Was there legitimate collaboration?

The previous section has demonstrated the designer's commitment and perceived resolution of community issues. However it is not clear at what level the participants collaborated in the project, they did have input and affected change as a result, but as they were not involved with the actual programming of the system, the word collaborative is questionable. If they were involved in the programming and development of the tool it would have most definitely been collaborative and this would have been closer to the Meta-Design (Fischer, Nakakoji, & Ye, 2009; Giaccardi, 2005; Giaccardi & Fischer, 2008) approach to design. I do however have reservation about this sort of approach based on my personal experience during this research. When using CAWriter to conduct writing and knowledge work based activities I would regularly encounter a bug or something that could be fixed or tweaked. This interrupted my academic workflow as I delved into the code.

Without an extreme level of discipline it might be hard for users to be designer as well, especially in an early system such as this.

- Has the work empowered the participants?

There seems to be considerable evidence that the tools supported the users in their various activities and skills. But as there was no control group or pre and post testing the extent is difficult to judge. If empowerment is defined as the augmentation of their educational and social practice, I believe that this is the first step towards that goal.

- Was there any change and did the solution make a difference?

The use of a tool such as CAWriter to engage in Ph.D. activities is a major change based on my experiences over the past four or more years at university. You do see the occasional use of concept or mind mapping, but not anything that integrates such a broad range of activities into a single interface. On a more subtle level two users did notice a positive change in their practice. User 2 moved away from pen and paper to the CMap functionality of CAWriter and user 4 changed her natural mode of linear practice to the non-linear approach facilitated by CAWriter. Although minor they do signify some change in practice. I have also noticed my own practice having changed as I write this thesis, as I have to finish the document in Word I have made every attempt to make it as similar to CAWriter as possible. I find the document map, which is equivalent to the tree view in CAWriter an essential navigation and structuring element while drafting and editing. Unfortunately this is limited as structure cannot be altered via this view as it can be in CAWriter.

- Was the research disseminated to appropriate audiences?

I have two publications on this subject, one presented at the British HCI conference and a book chapter in a book titled "*Collaborative and Distributed E-Research: Innovations in Technologies, Strategies and Applications".* I have also made a number of presentations at graduate summer schools sessions and other Ph.D. candidate oriented events. There has also been interest from overseas as the tool is online it can be found via a simple web search.

Although an action research approach was adopted it was not necessarily delivered in the strictest sense of definition. This was largely due to the practicalities and limitations and the social context within which the research occurred. It was a huge undertaking to try and build, deploy and get users to use an experimental system such as CAWriter. The results we have discussed above indicate that we are on the right track, but there is more to be done.

"Furthermore, what goes beyond nature emanates from within us (as our creation) based on the template of the schemas. This is crucially dependent upon the possibilities that are unleashed from Pandora's Box by Hyper Being. Without those possibilities, there would be no emergent creation beyond what is in nature. It is our nature to create artefacts based on the schemas, and what we create is artificial because it is based on the timespace schematization that is built into us naturally." (Palmer, 2009, p 283)

6.5. Summary

This chapter has shown that there does indeed seem to be a case that CAWriter provides significant support for a range of skills and activities essential for any novice researcher to acquire. We can tentatively answer yes to this question relating to support for research skills, but there is need for a more fine grained analysis of user activity, over an extended period of time and how and if these skills change or improve. There is also positive evidence that CAWriter supports a range of early Ph.D. writing activities, but there are three areas where the results are either inconclusive, need improvement or remain unanswered. The referencing and file upload systems require an overhaul. How notes and citable notes are used in conjunction with the formal drafting space needs to be revisited. Finally there is no evidence that the evaluating ideas creative phase has been supported. Although there is inbuilt functionality that is designed to support this phase, this functionality remains untested. This suggests that CAWriter has largely met the criteria for the first two creative phases, which is in line with the goal to support the early stages of the Ph.D. writing process.

As for questions of usability, there was a unanimous positive reaction from all the user cases. As we have discussed above there was significant engagement in a range of research skills and activities related to early stage dissertation writing. On a whole, it would seem that where the tools were deficient, these were largely technical in nature and that the activities and skills that they were aiming to support were still beneficial and desired. This suggests that the CAWriter toolkit is indeed both a useful and usable tool and that there are many future possibilities and direction it can take.

The action research element of this research is open to debate but it did offer a guide and structure that guided the work and offered the motivation to attempt a change of practice within our own institution. To fully realise the goals of action research, we need to evaluate CAWriter over a longer period of time to see if and how it empowers and alters the users practices. This may call for some modifications and collaborative working scenarios to be tested.

However the fact that CAWriter still needs to be evaluated in a number of areas and that a number of augmentations may need to be made suggests that future work is necessary before CAWriter can be implemented as a complete solution to support the Ph.D. process.

7. Contributions and Future Work

This thesis has presented an explicit perspective of the Ph.D. process as one of "Knowledge Work" or creative design. The acquisition of research skills is what allows the Ph.D. candidate to engage in this creative process and the output is their contribution to knowledge, whether this is their thesis or some other artefacts. This research aimed to create a schema to describe this process and delivered an Activity Theory based system that describes the sociotechnical context within which the Ph.D. candidate works. Focusing on writing as a specific instance of "Knowledge Work" and creative design, this Activity System schema motivated the creation of a set of design heuristics that were developed to describe the skills and activities involved in early stage Ph.D. writing processes.

A tool was then designed to embody these design heuristics. This tool, CAWriter, was tested by a number of users, both as short usability studies and extended usability user case studies in legitimate Ph.D. activities. The heuristics were then used to evaluate the tool as to its general usefulness and usability. The limited results suggest that CAWriter can support both research skills and early stage writing activities. The limitations of the findings will now be discussed.

7.1. Limitations

There is little if no HCI literature known to the author that deals explicitly with designing a tool for novice Ph.D. candidates, as a result this work has explored the high-level issues related to designing systems to support for this community. This high level approach brings with it its own set of limitations.

As the literature was lacking an in depth analysis of the Ph.D. process from a design perspective, it was necessary to construct a set of design heuristics from a wide variety of sources. These were then used to design a tool. These heuristics are only a single perspective and are not a comprehensive picture of all elements of the Ph.D. process and related subjects. Furthermore the level at which this framework was evaluated was shallow as there was considerable effort involved in developing a multipurpose tool that could be used in legitimate practice. The short timescales for both the analysis and use of the tools only allows for a small glimpse at the activities and skills that were engaged within the user studies. Although a significant amount of data was collected a more in-depth analysis and look at users' work in progress might provide more explicit details about how

the participants engaged in specific research skills. For example, more fine grained metrics and content analysis techniques may be used to look for evidence of synthesis of ideas that relates use of the CMap space and text written in the formal drafting space. Likewise “sub” evaluations may be carried out on specific tools, such as the use of the search feature, CMaps or proxy document usage. The design heuristics presented here lay the groundwork for these types of studies, which may now explore the use of these skills and activities in the context of tool usage in legitimate practice.

There is also the issue of scale. Working with people is inherently difficult and getting people to participate willingly requires an extensive amount of effort especially when dealing with an experimental tool such as CAWriter. Ph.D. students view their time as precious and to get users to trust the system for legitimate practice was a big ask. More heuristic evaluations could be carried out or even more formal usability tests may be employed. There are a variety of usability studies to choose from; SUMI, WAMMI, SUS, QUIS (Blecken, Bruggemann, & Marx, 2010; Kirakowski, 1994; Kirakowski & Claridge, 2008). These types of test would only be an appropriate if the prototype is approaching a stable version, with all the bug fixes mentioned in the previous chapter addressed. These would need to be administered to approximately15-25 experienced participants, where they would be set a number of tasks to complete.

The literature also suggest that with heuristics and general user testing all that is needed is 5 expert users using the tool extensively to capture 85% of the issues (Turner, Lewis, & Nielsen, 2006). This only requires a slight increase in user numbers before being achieved. It does however emphasise the limitations of the results presented above.

There is also the possible case that the participants did not report honestly. This is an issue that is exemplified by experimental demand (Nichols & Maner, 2008), where participants alter their behaviour based on the realisation that they are being assessed. This can result in participants reporting and answering questions in manner that they think the researcher “wants” to hear. This may be evident in the heuristic evaluations where it was noted that the lower scores were given by the users more inclined to offer constructive criticism rather than unfettered enthusiasm. Using larger sample sizes and detaching the researchers presence from this process may help reduce this affect in future tests.

Just as the design heuristics represent a single perspective of the Ph.D. process, CAWriter also represents only a single possible realisation of these heuristics. There were many alternative implementation possibilities that arose throughout the development process that could have been

analysed in detail. It was decided that experience and momentum were important to bring the tool together. Although deeper analysis of each support system could have been carried out before implementation it was not practical to do so and this was beyond the scope of this work. There are probably many possible Ph.D. theses hidden among the variety of tools found with CAWriter, but the focus of this research was to develop a well-rounded tool that could be used in real world and situated work practices. Although this did introduce subjective decisions into the design process it provided momentum and kept development moving forward. There is also the case that the authors experience and skill developed over the research project places them as an expert in this domain, suggesting that although subjective, the designs were still informed.

Finally, there is evidence that not enough support was offered to participants. User 4 was the most active user and their proximity to the researcher may have had an influence on this. They were both in the same office and had a number of chances to discuss the usage and issues with the tool. This is speculative, but the level of engagement of this user compared to the others is significant. This proximity of the more knowledgeable other, is at the essence of cognitive apprenticeship and this dynamic should be explored in more detail.

7.2. Future Work

Developing on from the last point, it may be beneficial to look at the existing usage of the system for best practices and use this information to develop a tutorial or training program. This could easily be integrated into an existing graduate workshop and would easily fit in at Trinity College where the Single System is taught as an approach to managing thesis writing.

The short term would see the addressing of the issues raised in the user studies, further exploring the collaborative elements of CAWriter and how it may be used in both Supervisor and peer learning scenarios. To support collaboration reading and writing groups may be used to promote the “Single System” and the further adoption of the prototype. This will provide the community of practice and peer supports beyond what is found in the supervisor-student relationship. While also providing an opportunity to engage the wider community in participatory design processes, with hope of altering or at the least augmenting practice.

As discussed in above there is room for more granular analysis of the skills and activities discussed in the findings of this thesis. This might elucidate the finer usability concerns of the existing tool and help optimise workflow. There is also room to explore supports for the later end of the

dissertation writing process. As was acknowledged the system described above has only been tested in relation to the first two phases of the creative process and more work is needed to test and implement features relating to both the “evaluating of ideas” and “donation” phases. We have already included suggested features to address these issues.

There is also the potential for the tool to be used with other novice researchers whether this is at masters, undergraduate or lower. The tool could be used by a wide range of users. As in essence the tools are for “Knowledge Work” in general it may also be possible to extended or augment the tools sets to fit other work practice in both education and industry.

One danger or risk from the approach discussed in this thesis is the potential development of such a tool into a "one-size-fits-all" thesis generation tool. This might be motivated by bureaucratic elements within universities trying to reduce risk of attrition in Ph.D. programs in the name of efficiency (McWilliam, 2009). One possible mitigation strategy would be to focus designs on supporting research skills rather than simply automating them, another would be to develop flexible systems that may be augmented by supervisors, research groups and Ph.D. candidates to suit their approaches and research styles, rather than a "one-size-fits-all", "risk" free paradigm. Designs that supports, but does not replace, the users cognitive and meta-cognitive skills and is flexible enough to support a variety of research approaches should mitigate against the potential Ph.D. "thesis-by-numbers" and supports the complex and creative processes involved in Ph.D. theses that truly contribute to our collection knowledge.

Finally there is need for a more explicit research methodologies and design approaches that are suitable for the development of tools in complex social systems such as the Ph.D. process. Activity theory offers a start but perhaps lessons can be learnt from organisational complexity theory that might help bring elements from varying disciplines such as education, linguistics, computing, design, philosophy and enterprise. It is believed that this thesis has made a first attempt at this, but a more rigorous and explicit methodology is needed to explore and develop these systems that will make up the basis of our “knowledge economy” in the 21st century.

7.3. Contributions to Knowledge

The major contributions of this work can be summarised as follows:

- Activity System framework/schema for the Ph.D. process
- Design Heuristics and Requirements for Supporting the Ph.D. Process
- CAWriter artefact, as an encapsulation of the Framework and Heuristics

It is important to emphasise that there are no claims that the above contributions are the best or only solutions. They are simply working heuristic schemas that have motivated and directed this study. They are a metaphorical stick given to Popper's blind man, that allows us to probe the darkness and to explore beyond the boundaries of both our own knowledge and that of others.

Readers should understand that CAWriter is just one encapsulation and interpretation of the Activity System, Design Heuristics and user requirements. The implementation and findings are a limited, yet represents real case studies of such a design implementation. Chapters 2 and 4 contain contributions that are more general in nature and could be used to describe and or design other applications or tools in the same class as CAWriter. The design and implementation of CAWriter described in Chapters 5 and 6, and the resulting findings are of a more limited nature, but do offer a real world example that demonstrate that these principles can be applied successfully to the design process and implemented with real user in legitimate settings.

7.4. Synopsis

By exploring a number of existing tools and approaches in designing tools to support human computer interaction and computer supported collaborative activities, this thesis provides a base for those interested in the design and use of technologies to support doctoral candidates and other novice researchers in their transition to legitimate members of the academic community, with particular interest in supporting writing skills.

An example of our current work on the computer supported collaborative writing tool, CAWriter and the design heuristic and design approaches taken were presented. This practical example provides a guide or template for those interested in developing technologies to support novice researchers in general, with particular emphasis on early writing supports. The design narrative emphasises that the process is not always straightforward calling for iterative and adaptive design decisions. It also reflects the importance of HCI methods and community involvement in such an endeavour.

CAWriter is a unique piece of software that combines and tightly integrates a number of existing systems into one easy to use package. It takes elements from existing referencing, word-processing and concept mapping systems. This provides the users with a system that is relatively quick to learn and easy to use, providing them with an instant overview and access to all their work while they draft a document. Although there is more work to be done on CAWriter, the limited results

discussed in this thesis suggest that CAWriter can support both research skills and early stage dissertation writing activities, in a useful and usable package.

As Leonard and Becker (Leonard & Becker, 2008) suggest, a lot of work to date on doctoral training does not put the doctoral candidate at the centre of the study. It is hoped that this project has made some progress in addressing this shortfall by putting the doctoral candidate at the heart of the problem and empowering them to be part of the solution through their involvement in a Participatory Design approach.

'... education, because of the nature of objective knowledge, is far more than organized mutual self-expression. It is at once the enactment, the reconstruction, and the creation of culture. The teacher must represent a structure of knowledge that he does not fully understand to a student who also cannot hope fully to understand it. This is perhaps the smallest social unit in the "marketplace of ideas", but it illustrates, once again, how – despite all distortions – such a market acts as a discovery process. This is part of "The Use of Knowledge in Society". And it illustrates, again, that "we never know what we are doing".' (Bartley III, 1987, p. 451)

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Appendix 1

User 4 Usage Activity in detail

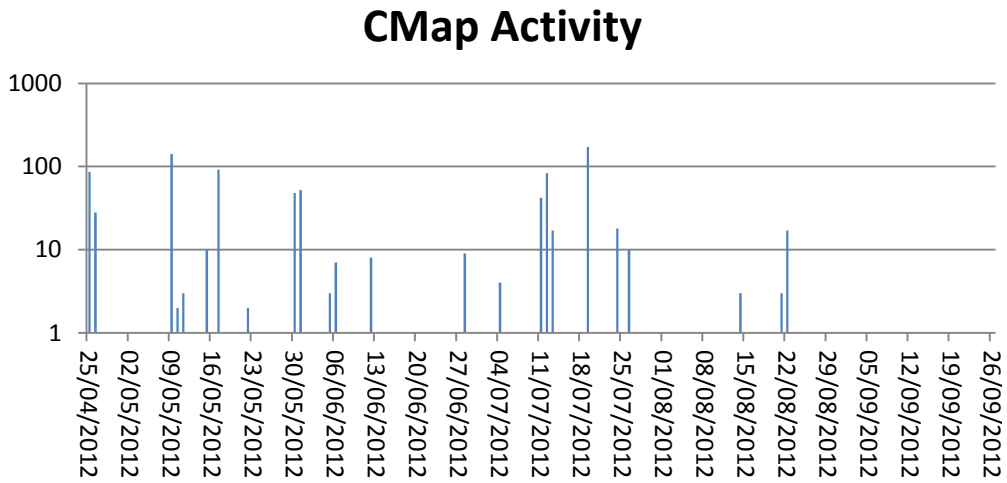

Figure A-1 User 4 CMap activity (note logrithmic scale)

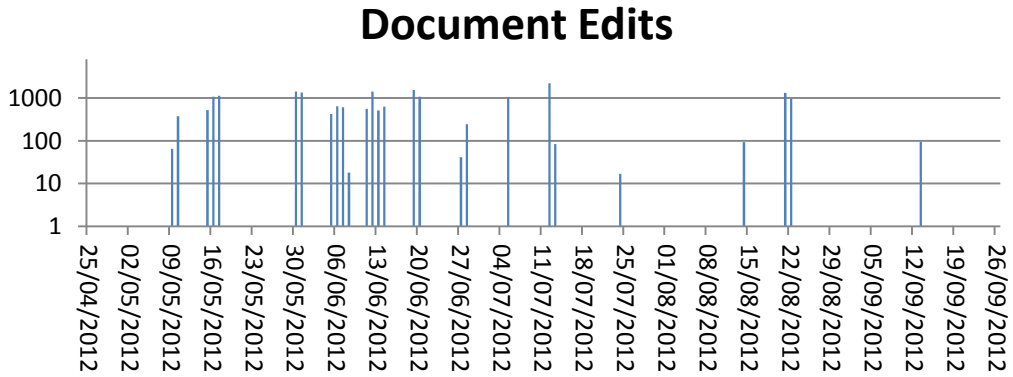

Figure A-2 User 4 Document Edits (note logrithmic scale of word count)

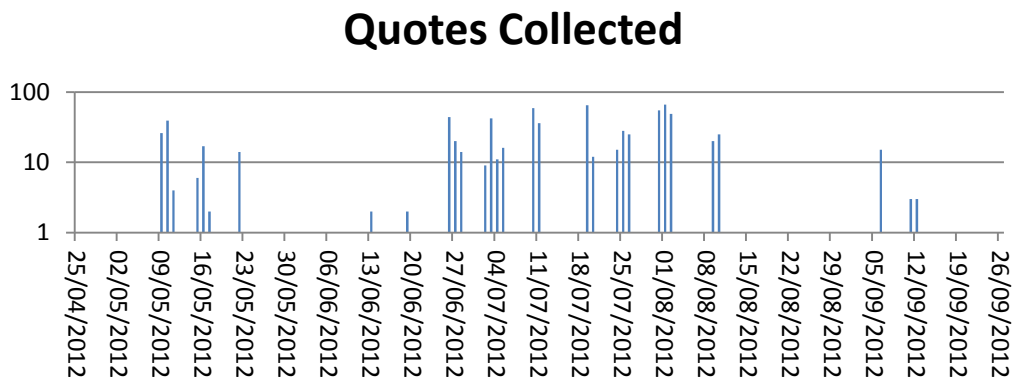

Figure A-3 User 4 Quotes Collected (note logrithmic scale)

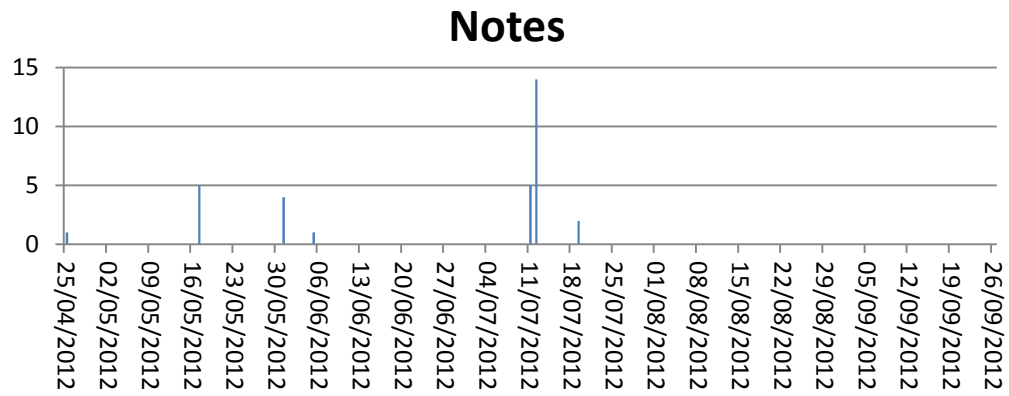

Figure A-4 User 4 Notes creation

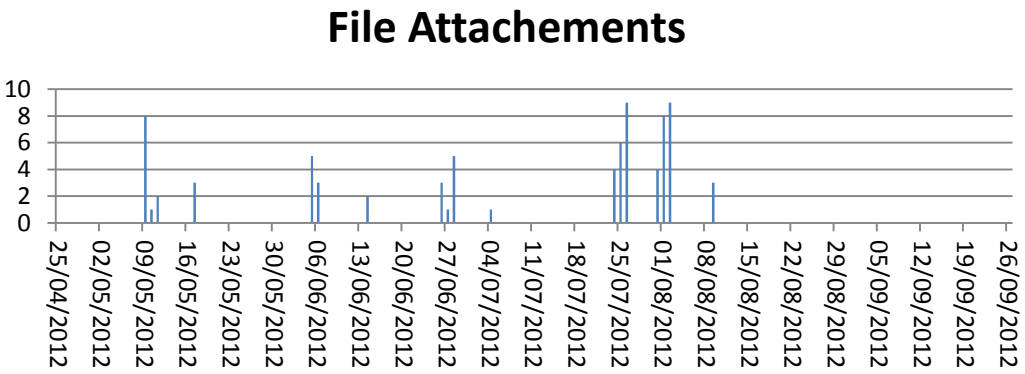

Figure A-5 User 4 Files attached to CMap elements

Appendix 2

Heuristic Evaluations

User Alias	S	C	J	L	E	R	1	2	3	4	Totals
System Status	1	1	1	1	1	1	1	1	1	1	**10**
Task Sequencing	1	1	1	1	1	1	1	1	1	1	**10**
Emergency exits	1	1	.5	1	1	.5	1	1	1	1	**9**
Flexibility and efficiency of use	_	1	_	1	1	1	0	1	1	1	**7**
Match between system and real world	0	1	1	1	1	1	0	1	1	1	**8**
Consistency and standards	0	1	1	1	1	1	1	1	1	1	**9**
Recognition rather than recall	1	1	.5	1	1	1	0	1	1	1	**8.5**
Aesthetic and minimalist design	1	1	1	1	1	1	1	1	1	1	**10**
Help and Documentation*	1	_	_	_	_	0.5	0	0	0	0	**1.5**
Error recognition: diagnose and recover	_	1	0	1	1	1	1	1	1	1	**8**
Error Prevention*	1	_	_	_	_	1	_	1	1	1	**5**
Skills	_	1	1	1	1	1	_	1	1	1	**8**
Pleasurable and respectful interaction	_	1	1	1	1	1	0	1	1	1	**8**
Quality work	1	1	1	1	1	1	0	1	1	0.5	**8.5**
Privacy	1	1	1	_	1	1	1	1	1	1	**9**
Score	**9**	**13**	**10**	**12**	**13**	**14**	**7**	**14**	**14**	**13.5**	
						Average Score:					**11.95**

Appendix 3

Heuristic Evaluation Form

From: Methods & tools: participatory heuristic evaluation (M.J. Muller, L. Matheson, C. Page, R. Gallup), In interactions, ACM, volume 5, 1998.

System Status

1 SYSTEM STATUS. The system keeps users informed about what is going on through appropriate feedback within a reasonable time.

(Circle) Yes No N/A

User Control and Freedom

2 TASK SEQUENCING. Users can select and sequence tasks (when appropriate), rather than the system taking control of the users' actions. Wizards are available but are optional and under user control.

(Circle) Yes No N/A

3 EMERGENCY EXITS. Users can Easily find "emergency exits" if they choose system functions by mistake (emergency exits allow the user to leave the unwanted state without having to go through an extended dialogue).

Make their own decisions (with clear information and feedback) regarding the costs of exiting current work. Access undo and redo operations.

(Circle) Yes No N/A

4 FLEXIBILITY AND EFFICIENCY OF USE. Accelerators are available to experts, but are unseen by the novice. Users are able to tailor frequent actions. Alternative means of access and operation are available for users who differ from the "average" user (e.g., in physical or cognitive ability, culture, language, etc.).

(Circle) Yes No N/A

Consistency and Relevancy

5 MATCH BETWEEN SYSTEM AND THE REAL WORLD. The system speaks the users' language, with words, phrases, and concepts familiar to the user, rather than system-oriented terms. Messages are based on the users' real world, making information appear in a natural and logical order.

(Circle) Yes No N/A

6 CONSISTENCY AND STANDARDS. Each word, phrase, or image in the design is used consistently, with a single meaning. Each interface object or computer operation is always referred to using the same consistent word, phrase, or image. Follow the conventions of the delivery system or platform.

(Circle) Yes No N/A

7 RECOGNITION RATHER THAN RECALL. Objects, actions, and options are visible. The user does not have to remember information from one part of the dialogue to another. Instructions for use of the system are visible or easily retrievable whenever appropriate.

(Circle) Yes No N/A

8 AESTHETIC AND MINIMALIST DESIGN. Dialogs do not contain information that is irrelevant or rarely needed (extra information in a dialog competes with the relevant units of information and diminishes their relative visibility).

(Circle) Yes No N/A

9 HELP AND DOCUMENTATION. The system is intuitive and can be used for the most common tasks without documentation. Where needed, documentation is easy to search, supports a user task, lists concrete steps to be carried out, and is sized appropriately to the users' task. Large documents are supplemented with multiple means of finding their contents (tables of contents, indexes, searches, etc.).

(Circle) Yes No N/A

Error Recognition and Recovery

10 HELP USERS RECOGNIZE, DIAGNOSE, AND RECOVER FROM ERRORS. Error messages precisely indicate the problem and constructively suggest a solution. They are expressed in plain (users') language (no codes). Users are not blamed for the error.

(Circle) Yes No N/A

11 ERROR PREVENTION. Even better than good error messages is a careful design that prevents a problem from occurring in the first place. Users' "errors" are anticipated, and the system treats the "error" as either a valid input or an ambiguous input to be clarified.

(Circle) Yes No N/A

Task and Work Support

12 SKILLS. The system supports, extends, supplements, or enhances the user's skills, background knowledge, and expertise. The system does not replace them. Wizards support, extend, or execute decisions made by users.

(Circle) Yes No N/A

13 PLEASURABLE AND RESPECTFUL INTERACTION WITH THE USER. The user's interactions with the system enhance the quality of her or his experience. The user is treated with respect. The design reflects the user's professional role, personal identity, or intention. The design is aesthetically pleasing—with an appropriate balance of artistic as well as functional value.

(Circle) Yes No N/A

14 QUALITY WORK. The system supports the user in delivering quality work to her or his clients (if appropriate). Attributes of quality work include timeliness, accuracy, aesthetic appeal, and appropriate levels of completeness.

(Circle) Yes No N/A

15 PRIVACY. The system helps the user to protect personal or private information—belonging to the user or to his or her clients.

(Circle) Yes No N/A

Appendix 4

User 1 Interview Notes

Perceptions and observations

- Believes there is a need for a tool like this, based on my own experience
- Believes novice researchers need structure and no other tools provide this
- Structure helps shapes content/arguments
- Doesn’t like reliance on groups in course work
- From a process point of view it's [CAWriter] is great
- Doesn't like peer review, doesn't take criticism well
- Really likes the idea of the tool
- Particularly liked the search access to library and Google Scholar
- No natural dialogue with him
- Couldn't recall what some things did, had to request help over twitter
- As a part-time student, worked remotely from Denmark, Germany and Ireland and “used it all the time”.
- Used it on different platforms: Mac, Windows “and everything”.
- Thought it was a good way at organising research material, but “it was not so great at getting that into a paper format.”
- Is not surprised that people have issues with structure and hierarchies: “common if you’re used to a format based thing like word”
- Did not know about the tree view.
- Web based nature of tool not an issue, in fact likes it and thinks it opens up a lot of possibilities
- Liked not having to install something locally: “all I needed was a browser and an internet connection”.
- “Nearly always” prints what he reads, academic two column structure can’t be read online. Annotations on paper, notes will be written online.
- Prefers to “work in the live document”.
- Liked the idea of being able to add others.

- Thinks people work like in an agile software development process: “put everything in there and stir it around a bit”, “People work in a haphazard way”
- “Doing the bibliography is painful” in general

Suggestions

- Thought the design was good but finicky at times, over engineered
- Thinks it has possibilities but "I think it could be simplified"
- Thinks what you need to see is getting messages that you are actually creating something, whether “using a progress bar”, or the “point of entry immediately is the editing screen”.
- Better natural dialogue might lead to “faster adoption” and “more satisfied user”.
- An issue with Ph.D. studies completion or non-completion thinks they don’t feel like they are making progress. Some “indication that you are making progress” that is highly visible might help combat this.
- Probably want a way for hiding CMap view [refers to it as "some way of flipping that structure thing off or less obtrusive"] for novices
- Beginners might want to get in and edit like they would do with word.
- Main obstacle was not seeing his progress: “where’s my stuff as Amazon would say”
- Going straight into the document would be his natural dialogue
- Offline access would be nice: “Maybe HTML5 offers some capabilities for that”, “Not a show stopper”
- Sees the Quality Assessment results as a good way of organising, perhaps a “visual map” of quality might give greater insights: red, green, yellow.
- Having this Quality Assessment overview might provide a clue as to when you can stop the literature review process.
- New paper prompting would be nice.
- Actionable events from within content: maybe for meeting or scheduling tasks.
- Pre-loaded paper templates for Word, for quick output
- “get them with what they are familiar with”
- Issue with unsaved changes and loss of data
- Branding: “I’d like to feel like I’m in Trinity”
- Import and export into word
- Would like to see the tool used by 1st year students or even leaving certificate. Or even for bloggers

- would like to be able to customise the Quality Assessment questions, or have a shorter version

Skills

- Record keeping – answered positively in a discussion on the topic
- Graphical expression – answered positively in a discussion on the topic
- Written expression – answered positively in a discussion on the topic
- Analysis – answered positively in a discussion on the topic
- Evaluation [but didn't use it] - Sees the merit of the Quality Assessment forms for novice researchers
- Synthesis - partially
- Self-regulation – answered positively in a discussion on the topic
- Monitoring – answered positively in a discussion on the topic
- Reflection - partially supports

Activities

- Concept View - Not enough clarity about concept mapping related tasks: "it was kinda tough"
- Literature review supports - Tried to use the literature review supports: "I'm not sure the assignment ... gave [CAWriter] the opportunity to shine, in terms of scale "
- Concept View - Danger of getting stuck in synthesis mode in CMap view
- Concept View - Doesn't think mind maps or concept map are for novice academics, reserved for "professional academics or some kind of hipster"
- Literature review supports - Thought it was great for the literature review process, with federated search and assembling references.

User 2 Interview Notes

Perceptions and observations:

- "it was good. It worked well."
- "not necessarily" needed, "but neither is endnote. But it's really beneficial. It definitely helped bring it all together. It was a great way to start when it came to writing. Signing into

the system and setting yourself up and everything was there already. Whether I was at home or here or ... you weren't carrying around folders around with you or anything like that."

- Academic writing support tends to come last from supervisor
- Took a while to get used to CAWriter, not awkward, just natural learning curve
- When the pressure came on she reverted to Word, due to familiarity
- "It was ergonomic. It made sense to me"
- Liked the idea of uploading PDFs and automated file and reference retrieval, but found it awkward and buggy, was under pressure
- Didn't realise the extent of the search functionality
- Sees the benefit of having all files and notes in a single interface and database
- tried the file attachment feature, had trouble
- Normal practice would create document structures on paper
- Normal practice would print out literature documents for review and annotate on paper

Suggestions

- Improve the referencing and uploading – hugely advantageous but poorly implemented
- Export to PDF
- Comparing documents, tracking changes and version control all important when collaborating.
- "you could do exactly what you wanted to do on paper"
- "I could see myself sharing with someone I was trying to impress"
- Could use CMaps to present to people, supervisor for example
- Web based nature – "brilliant. The fact that you can access it from wherever", used it while at a conference
- Needs help function
- Word export formatting could be improved

Skills

- Time management - "It was good to get your head in the zone." (the app as my office space)
- Can see the supports for record keeping – is she had used the file and referencing system
- Written –" It was a great way to start when it came to writing"
- Graphical – using CMap to represent ideas

- Analysis – “adding in comments and notes”, “think about it and rewrite it”
- Synthesis – piecing it back together
- Evaluation – “evaluate it as a whole”
- Reflection – “You weren't going back to an entire document that you had to read through to start writing again. You were going back to a specific section.”
- Record Keeping – “you weren’t carrying around folders around with you or anything like that.”

Activities

- Concept View - Most used feature was the CMap space, even maintained usage after reversion to Word, to create headers and make sense of them.
- Analysis of Problem - Used post-its, notes, links
- Concept and Drafting views - Practice before involved Word and a mind map on paper- CAWriter “is all one, which is great”
- Interactive Reading - Likes the built-in quotation collection system but “that’s a whole training area in itself”
- Outlining - Having structures help you get an overview of the document
- Outlining – handy to get a look at it as a whole

Cognitive Dimensions

- Viscosity and reduced delayed gratification - found it very easy to get ideas down – “I stopped using the paper version”
- Premature commitment – “you can always change it.”
- Terseness rated high – CMap and mini-map
- Perceptual cues- Relation by proximity as well as linkages – “memory trigger”
- Viscosity – made sense except for file upload

User 3 Interview Notes

Perceptions and observations

- “brilliant idea, writing space with files attached, visually very good, you can see everything, it's not in another window or somewhere else on your desk. Informal space to work on.”
- “Refill pad you could lose pages”
- “Useful if you are a student who is left to their own devices a lot, it gets you another support mechanism then as well.”
- Found it natural
- “feels like you have a whiteboard in front of you plus all your files, plus your actual document.. So it is a real workspace... it does actually feel like that when you’re on your computer.”
- Sticks with the basics once familiar
- Difficult to use on small screens (laptop), great on other screens
- CAWriter gives you the freedom to mess around with it without the fear of messing it up.
- Wouldn’t be as inclined to mess around in word as it would be “painful”
- Finding support for writing is difficult – laid back supervisor, workshops are too busy
- Feels more than just opening a word document
- Web based nature wasn’t an issue, even gets around having multiple versions on different devices
- See as potentially useful for use with supervisor – “will they understand my logic”
- Nice to know the information won’t get lost
- Didn’t feel she was at the stage for Quality Assessment forms

Suggestions

- Biggest frustration was loss of work by navigating away, add warning or auto-save
- A data analysis add-on would be nice

Skills

- Self Regulation - Activity log is motivating
- Graphical - “I have my concept there, main heading and sub headings off there.”

- Record Keeping - Thinks there's a need – "when started Ph.D. at first, started reading and taking the odd hand written notes, pretty much a waste of time"
- Record Keeping - Likes the unified nature of the tool, as opposed to endnote and word as she is not naturally organised
- Record Keeping - Used file attachment
- Record keeping –"helping keep track of document, what you read etc."
- Analysis – "I suppose I was analysing it and how I saw it was different and how I constructed it was different." "it gives you a space to start formulating your ideas without actually being formal about it"
- Analysis - Really liked playing around with the tree structure – "like messing around with the tree, I find the tree brilliant ... If you think something else should go somewhere else it's very easy to change it. ... You look at that and see does it make sense or flow or whatever."
- Reflection - "if you dip in regularly these things become important and possible. The working space that's presented is really conducive to jogging your brain a bit... Your brain is in motion and things occur to you that wouldn't have occurred to you if you hadn't had a look. I guess this is part of the Ph.D. process. It can be extremely slow.... can help you with that process, you're building it... slowly, slowly... it's all there for you to see."

Activities

- Used the formal document space informally - citable notes going straight to formal view
- Regular writing - "If you spent 1hr a day you would be doing very well."
- Concept View - The freeform of the CMap allows you to almost as free as paper
- Concept View - Used CMap links
- Analysis of the Problem - Good for novice researchers – "Upload your file and write a few notes. This tool helps prepare for the formal writing process so I think it's a great tool for anybody starting"
- Concept View - "It gives you that space to group everything ... visually and in a word document you just don't have that"
- Literature Search - Favourite features were the search, file upload and the huge amount of space to work on

Cognitive Dimensions

- Perceptual cues - “Some elements are just there. So I don't forget them. I put them near. Not always clear what goes where ... doing that in a word document it's easy to get lost.”
- Terseness - “Mapping view gives you that overview... The tree structure is so handy, I find that really good ... It's the first thing I click at ... it's really important [to get an overview]”
- Perceptual cues - “7 out of 10” compared to paper, could be more but didn’t use the features
- Accessibility - it's much more accessible than a word document... You can see where you are at easily. The mapping area and tree you can see it really quickly
- Viscosity and reduced delayed gratification - Easy to get back into writing, as easy to edit as any other document, except perhaps for file uploading.
- Formalness – semantic potential - Potential for others to view the CMap elements differently

User 4 Interview Notes

Perceptions and observations:

- “I didn't know where to start. But actually when I started to use it and you showed me how to use it. Very quickly it became indispensable, not quite, it was getting there, but it was really useful. “
- At first didn’t understand the purpose of all the different functions
- Thinks it fits a niche: “We have got along without it but it does improve things quite dramatically.”
- It’s very handy and helps with navigating your information.
- Having an excellent supervisor complements the tool
- Reasonably natural, not awkward: “but I’d change a few things”
- Didn’t match natural way of doing things, “but improved it”
- Does not trust the Google Scholar citation indicator in the Proxy document.
- Liked the definitions and etymology search options
- Biggest frustration was formatting issues when exporting to Microsoft Word
- HTML renders of PDFs are difficult to read on occasion – “hard on eyes”
- Still uses pen and paper, used with printed proxy documents

- “Different connection being made when you’re using pen and paper, you do it differently , and I like that”, “but you’ve got me using a lot of technology so... you’ve done very well”
- Web based nature is fine.
- Never collaborated on a document
- “you don’t need to learn it”
- Temporariness in the sense that some projects act to hold information that is not necessarily for a particular future event.
- Tended to print out the proxy document

Suggestions

- Internal search needs improvement
- Possible to add reading time to activity log?
- Likes the idea to support data evaluation supports
- Better Word templates with options
- Offline would be nice: “I’ve never needed it”
- Back up features, to Dropbox with import feature if possible
- Import and export of Word and Latex documents
- Text editor could be improved
- Big arrow to grab text from PDFs is annoying on occasion

Skills

- Record keeping– answered positively in a discussion on the topic
- Graphical– answered positively in a discussion on the topic
- Written– answered positively in a discussion on the topic
- Analysis: Analysis of papers
- Synthesis: “because you have them together and because you are sort of associating them ... in the CMap”
- Evaluation: “evaluation of the literature I’m going to start using more” – Quality Assessment forms
- Synthesis - “organising and different ways of representing your information and having it all together, but in a structure that makes sense”
- Reflection: activity log and CMap edits

- Monitoring and self-regulation aren't an issue at the moment
- Self-regulation - Liked the activity log: "I'm very competitive"
- Oral and Graphical - Used CMap space to show supervisor "the sort of hierarchies and the relationships I had shown"

Activities

- Interactive reading– answered positively in a discussion on the topic
- Interactive note taking – answered positively in a discussion on the topic
- Regular writing routine– answered positively in a discussion on the topic
- Concept mapping was not known to her: "I used it coming up with a framework"
- Citable notes - Moved away from using dedicated CMap notes to just entering text directly into formal document view.
- Referencing - Used the automated file and reference acquisition "a huge amount ... to bring in and read"
- Interactive Reading and Note taking - Went from annotating papers to writing in the formal space.
- Focus Statement - Most people will put a description at the top anyway
- Gave structure to follow for reading literature

Cognitive Dimensions

- Premature Commitment – not an issue, except for an undo feature for quotation collection
- Premature Commitment - Natural tendency before would be to "downsliding" or to focus attention on fine grained attention to sentence structure, but practice has been changed to be more open
- Formalness: faithful conveying - It does support asynchronous communication with others and oneself
- Perceptual cues – linking and proximity and highlighting
- Terseness in CMap and Tree outline – start with looking at the tree structure
- Low viscosity and reduced delayed gratification with CMaps once she got her "head around it"
- Accessibility of information is easy, except maybe in internal search