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Editors

e-Research Collaboration

Theory, Techniques and Challenges

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M. Anandarajan • A. Anandarajan
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Preface

Research in both academic and non-academic circles has remained virtually identical in its conduct and organization over the last few decades. Disparate groups of researchers have worked on their ideas, projects and inventions in isolated clusters, with little sharing of information and synergies from collaboration. The advent of social networks and Web technologies has led to the creation of new research networks that have dramatically reduced the barriers and obstacles to collaboration for researchers who are geographically and organizationally distant.

Web technologies use broadband connections, improved browsers, and "rich" multimedia in concert with a new generation of websites that encouraged users to contribute to content. Blogs, forums, wikis, and other forms of user-generated content are, in many cases, the major source of content for these websites.

The evolution of social networks began with the truly social networks of friends paving the way for business networks, which in turn led to the current research networks that connect academic and non-academic researchers across the world. Being much more robust than the original social networks and the business networks that followed, collaborative research networks have the potential to eventuate in technological advances, innovation, and economic contributions to both industry and nations.

Currently, tens of thousands of researchers are using research networks, ushering in a new paradigm for research. In this paradigm, collaboration is made much easier, and sharing of research knowledge is instant. Synergies from routine collaboration will yield huge advances in research productivity and innovation. The challenge for administrators in both industry and academia is to understand how research networks are changing the practice of research and to decide how best to embrace such technologies and use them to their best advantage.

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Part I
e-Research Collaboration: Theory

An Overview of e-Research Collaboration

Asokan Anandarajan and Murugan Anandarajan

Abstract In this chapter, we examine the concept of collaborative research. We discuss the origins and elaborate on the factors that contributed to the emergence and subsequent exponential growth of collaborative efforts in research. In particular, we note that the emergence of internet technologies has the potential to provide a strong impetus to growth in collaborative research. It is much easier now to use newly developed internet tools to find researchers who have similar interests, to engage in synchronous conversation with a group of collaborators, to exchange data and to engage in meaningful intellectual discourse. We conclude this chapter by discussing the costs and benefits of collaboration and the obstacles that collaborators have to be aware of when pursuing research in its various collaborative manifestations.

> *You have added much several ways, if I have seen further it is by standing on ye shoulders of Giants.*
>
> From a letter written by Isaac Newton to Robert Hooke, 5 February 1676.

1 Introduction

Most researchers today are of the opinion that the increased complexity of the modern environment, and by extension, increased complexity of research problems, creates the need for multidisciplinary research. This is particularly accentuated by increased specialization across disciplines. Disciplines are gradually getting factionalized into specific areas of specialization. Increased specialization in turn causes a situation where the researcher, to complete a project, requires the services of other

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academics. For example, a researcher may have knowledge about earnings fraud in accounting and have the capability of understanding the intricacies of the problem and what data to collect. But such data may be proprietary and (s)he may have to engage someone in industry to obtain the necessary data. Further, he or she may not have the statistical expertise to know how to create models for actually detecting fraudulent behavior once the data has been collected. Thus, the researcher would also have to bring in an expert in statistical analysis into the team. Other reasons we attribute to increased collaboration in addition to the issue we outlined is the rising costs of technological apparatus and the need to bring in collaborators who have the necessary apparatus and or data. For the reasons mentioned above, collaboration has increased substantially. In today's environment collaboration in electronic research has expanded exponentially due to the features of Web 2.0 which allows for rapid sharing and processing of data. In addition potential collaborators can now find partners with complementary skills using new web based tools such as mynetresearch.com.

In this chapter we discuss the concept of research collaboration, the relationship between social networks and research collaboration, and the emergence of e-research collaboration. We conclude the chapter with a discussion on the underlying challenges of collaboration.

We initially pose the question; "What is research collaboration?" The term collaborate originates from the Latin word *Collaborare* which means to work together. The concept appears simple enough. The Oxford English Dictionary defines collaboration as "work in combination especially in literary and artistic production". In essence, it suggests the working together of individuals to achieve a common goal ostensibly for the purpose of producing or increasing the boundaries of knowledge. The Webster's dictionary defines collaboration as "to work jointly with others or together especially in an intellectual endeavor". Mattessich et al. (2001) define collaboration as a mutually beneficial and well defined relationship entered into by two or more organizations to achieve common goals. This relationship according to Mattessich et al. includes:

- A commitment to mutual relationships and goals
- A jointly developed structure and shared responsibility
- Mutual authority and accountability for success and
- Sharing of resources and rewards

In this chapter we define research collaboration based on a model by Hagstrom (1965) who developed a model to explain academic competition. He defined collaboration as a group of intellectual peers working together over a period of time to solve a research question.

However, this definition begs the question of who are these intellectual peers? And exactly how *closely* researchers have to work together in order to constitute a collaboration. Hagstrom (1965) notes that at one extreme it could be argued that the international research community is one big collaboration; hence basic research can be considered as a truly global activity, where, in a sense, all researchers work to advance scientific knowledge. We define a collaborator as anyone providing an input to a particular piece of research. Leahy and Reikowsky (2008) note that at the extreme, one could make a case that only those scientists who contributed directly to every main research task over the duration of the project should be counted as collaborators. At the other extreme, any party who contributes in any way, such as only collecting the data or assisting the main researcher with respect to writing could be considered collaborators. Leahy and Reikowsky hence note that we are therefore left with the unsatisfactory conclusion that a research collaboration lies somewhere between these two extremes. Typically, collaborators could include the following:

- Those who work together on a research project throughout its duration or for a large part of it, or who make frequent or substantial contributions
- Those whose names or posts appear in the original research proposal
- Those responsible for one or more of the elements of the research (e.g., the experimental design, construction of research equipment, execution of the experiment, analysis and interpretation of data and writing up results in a paper)

In some cases, the list of collaborators may also include

- Those responsible for a key step (e.g., the original idea or hypothesis, the theoretical interpretation)
- The original project proposer and or fund raiser even if his or her main contribution subsequently is to the management of the research

So, in summary, research collaborations can take many forms. In his review of bibliometric studies of research collaboration, Subramanyam (1983) reported that collaboration was found to affect the visibility and productivity of scientists. He identified six types of research collaboration: teacher–pupil collaboration, collaboration among colleagues, supervisor–assistant collaboration, researcher–consultant collaboration, collaboration between organizations and international collaboration. In amore recent study, Bozeman and Corley (2004) conducted a survey of individuals engaged in collaborative research and concluded that individuals who initiate collaborations can be characterized as follows:

The Taskmaster: This is a researcher who searches for people who can stick to schedules and cooperate effectively.

The Nationalist: This relates to a researcher who seeks collaborators who are fluent in the researcher's native language and are of the same nationality.

The Mentor: Those who are motivated to help junior colleagues and graduate students by collaborating with them.

The Follower: Those who are compelled to choose collaborators because someone in the administration requested that they work with the collaborator because of a characteristic of the potential collaborator (scientific background etc) that the administrator found appealing.

The Buddy: Those who choose collaborators based on the length of time they have known the person and the quality of previous collaborations with individuals.

The Tactician: Those who chose collaborators based on whether or not the collaborators have skills that complement their own.

2 Social Networks and Research Collaboration

Edge (1979) and Stokes and Hartley (1989) have found that most collaborations begin informally and are often the result from informal conversation. Informal communication may then lead to increasing commitment to co-operate on a research project. In addition, spatial proximity seems to encourage collaboration since it tends to generate more informal communication (Hagstrom 1965). The closer two potential collaborators are, the more likely they are to engage in informal communication. Katz (1993) found that collaboration decreases exponentially with the distance separating pairs of institutional partners.

Thus, the sum of a researcher's external collaborative contacts is his or her research network. Such a network contains all the relationships with other researchers of all possible types (universities, industry, and government) across the world, connected by a set of socially meaningful relationships. In an in-depth study of collaborative patterns Bozeman and Corley (2004) provide some interesting findings on the breadth of collaborative partnerships. They found that more than 67% of their sample either worked individually or collaborated with colleagues in their immediate work group. Furthermore they report that only 9% of the sample worked with researchers outside their university. Interestingly collaborative research between university researchers and researchers in industry accounted for less than 8% of the sample.

These findings are indicative of a traditional forms of social networks, the participants are local people (e.g., friends, kinship groups, neighbors, people), and the control of the network exists locally, with interactions normally occur between people who physically in the same university. These traditional social networks are often small in size, may exhibit homogeneity among members and nature of network, and be constrained by physical meeting times available among members, and be isolated from research networks.

With the advancements of Information Communication and Technology social networks have evolved from the small local social networks to online social networks that are mediated by computer networks. Perhaps then, instead of collaborations of convenience researchers can now work in global "collaborations of opportunity". Given the recent Web 2.0 trend toward user–generated online content, the Internet has become the main vehicle for distributed production of information, knowledge and research.

3 Web Technologies, Social Networks and e-Research Collaboration

When collaborations between researchers are conducted using the convergent synergy of web conferencing, real-time collaboration technologies, instant messaging, shared online work spaces, and interactive white boards through the Internet this is called e-Research Collaboration.

Without the physical boundaries of traditional social networks, online social networks replicate and enhance the benefits of traditional social networks across time and space and accelerate and globalize the process. For example, researchers can locate and exchange information to supplementing knowledge between distant geographical locations through the network. They can provide solutions to the problems of others. The computer-mediated social network often exhibits more heterogeneity in the social characteristics of members, has more complexity in its network structures, and is interconnected with other networks.

In the early days of e-Research collaboration, technologies such as e-mail increased the speed of communication between researchers and allowed the sending of various file types between collaborators. The evolution of Web 2.0 technologies includes elements from the realm of social networking. These social networks introduced user forums, searchable professional profiles, and new means of communication, such as instant messaging. Blogging, Wikis and forums also makes a natural addition to the research environment, where researchers share their professional experiences and ideas. Networking tools also contribute meaningfully to portals for research collaboration, through contact management, referrals, and communication.

More recently we have begun to see research collaborative portals which are concatenations of these existing technologies. There are a number of Web-based services and applications that demonstrate the foundations of the Web 2.0 concept, and they are already being used in research. These are not really technologies as such, but services (or user processes) built using the building blocks of the technologies and open standards that underpin the Internet and the Web. These include blogs, wikis, multimedia sharing services, content syndication, podcasting and content tagging services. Many of these applications of Web technology are relatively mature, having been in use for a number of years, although new features and capabilities are being added on a regular basis. It is worth noting that many of these newer technologies are concatenations, i.e. they make use of existing services.

4 An Overview of This Book

The chapters are broken into three sections. In the first section the chapters provide an insight into the theory underlying e-research collaboration. An understanding of the key elements of collaboration is essential to improve the quality of the collaboration process. The key concepts in collaboration such as coordination and communication are also discussed. In the second section the chapters discuss current and potential future technology tools that can be used to facilitate collaborative e-research. The collection of chapters also discuss current web based techniques to improving data collection, analysis and reporting. We also discuss pitfalls that collaborators should be aware of that could make research using e-technology tools less effective. In the final section we discuss ethical and legal issues that can act as a constraint to collaborative research and discuss behavioral guidelines to ensure that collaborators act free of ethical and legal violations. We now discuss the key concepts of each chapter in brief.

This book is broken into three sections, namely e-research collaboration theory (section one), a discussion of e-research technologies (section two) and finally challenges that participants should be cognizant of when engaging in e-research collaboration (section three). In the following section we provide a broad overview of the chapters in this book.

5 Part One: e-Research Collaboration: Theory

There are five chapters in this section. In Chap. 2, Harley and Blismus provide a review of collaboration theory as it applies to the online environment. The chapter deals with the key tenets of cooperation, coordination and collaboration. The authors note that, while collaboration is used interchangeably with cooperation and coordination, all three terms have distinct meanings. Harley and Blismus provide a framework for understanding and differentiating between the three elements. This framework enables researchers to obtain a clearer appreciation of these factors, which in turn will guide their effective use of online technologies in the e-research environment.

In Chap. 3, Siemens further discusses the role of communication tools to facilitate collaborative research. Siemens emphasizes the importance of not being over reliant on e-research tools as this may actually hinder collaboration. The author notes that individuals could be susceptible to an over reliance on digital tools. While e-research tools have expanded the opportunities for collaboration among academics, the author notes that, to be effective, global teams need to apply various communication and collaboration tools, drawing upon their respective strengths. Siemens notes that a balance between e-research tools and face to face meetings is needed for effective collaboration.

In Chap. 4, Kertcher presents a theoretical model that illustrates the "gaps" or pitfalls in intercultural collaborative research. Kertcher highlights three types of gaps which he categorizes as (a) collaborative gaps (arising from cultural differences among users; (b) entrepreneurial gaps (arising from differences in priorities between users such as academic innovators and entrepreneurs) and (c) systemic gaps (differences arising from different "paradigms" or views towards research). Researchers may not be aware of these "gaps" thinking others conform to their priorities and views. An understanding of these differences may aid in better and more effective collaboration as differences can be sorted out prior to collaboration.

In Chap. 5, Wilson complements Kertcher's model, with a conceptual framework for developing an effective interdisciplinary online collaboration process. She uses the e-Research Consortium on Climate Change and Population Health project to elaborate and illustrate how an effective framework can be created for interdisciplinary research collaboration.

6 Part Two: e-Research Collaboration: Technologies

This section comprises nine chapters. In Chap. 6, Datta, Rzada, Ang and Hong note that collaboration requires adequate technology to facilitate communication, assimilation and dissemination of knowledge. One problem with existing tools for collaboration is that they all require a dedicated server to synchronize clients and establish a stable network connection. In order to reduce this constraint, the authors present two tools that can be used to build serverless collaboration networking. The tools are PRDMS and SharedMind. PBDMS enables users to share, select and review bibliographic databases, while SharedMind enables real time editing (both synchronously and asynchronously) of notes by authors especially during the initial stage of research when researchers are searching for ideas. The authors discuss the tools and describe both algorithmic and technical challenges in implementing these tools.

In the Chap. 7 Brunvand and Duran examine a variety of tools currently available to support researchers in e-research collaborative efforts. The authors acknowledge that some of the specific tools they highlight may not be available in the near future for a number of reasons but believe that the features and capabilities they provide will be sought after by researchers. The authors discuss, among others, tools of such as:

MyNetResearch: Facilities enabling the researcher to manage research network with collaborators and use tools such as online surveys and citation analysis to increase overall efficiency of the researcher.

Sakai Suite of Tools: An array of communication technologies allowing for sharing of uploaded and online resources and facilitating project management and

OMII-UK: Allows users to submit jobs that require computational processing of data for a collaborator to work on.

In Chap. 8, Willard and Leftingwell describe how to use blogging tools to accelerate peer review of academic and scientific research. Blogging provides the ability to reach out to geographically dispersed experts, and others – such as the students' (often difficult to reach) professors and professional colleagues. The authors describe the growth of blogging and provide recommendations for developing a blog as an internet based collaboration tool. The authors show how blogging can use tools within the blog to optimize information presentation and presence. They primarily focus on peer review of a doctoral dissertation during its various stages, but this is equally applicable to any research project in process.

In Chap. 9, Waetjen, Thorne, Hollander, Shapiro and Quinn provide another example of a web based collaborative research technology which can be used to manage datasets. This is of particular use to the study of long term trend data. The authors present a model for building a data portal that can provide access to event based time series data and mixed data including but not limited to photographs and maps. Basically, using a study that examines the effect of climate change on the butterfly population, the authors demonstrate how, using their model, totally unstructured data can be analyzed and interpreted in a collaborative research situation.

Chapters ten and eleven provide practical applications with respect to successful implementation of collaborative networks. In Chap. 10, Den Besten illustrates how web-based data can be used for “mapping” project progress in a collaborative and asynchronous research environment. He explores two different analytic approaches, Content analysis and Hyperlink analysis for maintaining continuous asynchronous communication and monitoring and updating a project’s progress most effectively until conclusion of the project. In Chap. 11, González-Aranda, Rodríguez-Clemente, and Lozano, provide an application of a system of collaborative research where knowledge sharing and exchange processes occur across organizational, cultural and international boundaries. The authors provide an in-depth description of the design, implementation and maintenance of appropriate e-collaboration tools.

In Chap. 12, Salustri and Weerasinghe explore how Wiki technology has been successfully used for collaboration. The authors’ research involved studying how design research occurs and how wikis can be used to support it. The authors observed, and report on, several instances of design research where wikis were used. They report that the successful application of wikis depends on the software exhibiting certain characteristics. Some of these characteristics include: both WYSIWYG and “raw” editing modes, the ability to edit page elements without editing the entire page, and the ability to comment on or annotate content.

Next Andrea Duffy, describes how MyNetResearch provides the online collaboration capabilities universities. Universities which are ready and willing to ramp up quickly with research collaborative portals such as MyNetResearch will have an advantage over competitors and even better funded institutions for the same grant funds. In Chap. 14, Zaman discusses the impact of Web 2.0 on the doctoral program. She examines issues relating to the development of doctoral students from the time they join the program till they are ready to leave. Suggestions are made as to how the use of Web 2.0 can help make the existing doctoral program be more effective and efficient for the twenty-first century.

7 Part Three: e-Research Collaboration: Challenges

Despite the advancement in e-Research collaboration technologies there are many challenges that can impede successful research collaboration. Take for example the dispute between Robert Hooke and Isaac Newton in 1676. Hooke claimed he had sent his theory on the laws of gravity to Newton so that they could exchange ideas and work together. Hooke later accused Newton of stealing his idea and building on the laws of gravity (and to a lesser extent, light) and publishing it as his own work without giving due credit to Hooke. It was even hinted that Newton destroyed all correspondence with Hooke to ensure that there was no evidence that the idea of gravitation originated from Hooke. The researchers of Hooke and Newton have suggested that, based on their evidence, not only did Newton “borrow” ideas from Hooke he was not always inclined (not withstanding the quote given at the commencement of this chapter) to give Hooke as much credit as he deserved. The same applies to Nicola Tesla and Thomas Edison. Tesla tried to collaborate with Edison but Edison built on the initial work of Tesla and then set out to destroy Tesla's reputation so he could take full credit. So, history is replete with many examples of challenges that prevented collaboration.

In this section we have five chapters which examine various challenges e-research collaboration could encounter. In Chap. 15, Mohd Saaht and Mohd. Salleh notes that collaboration has and will pose ethical challenges. The authors also provide pitfalls that a research collaborator, should be aware of, especially in the international arena. A variety of potential ethical violations and other threats to collaborators are discussed and possible solutions are provided. For example, collaboration projects across disciplines or nations which are governed by different rules cannot be easily resolved. So, the question is which rules should be adhered to? The authors provide guidelines to research collaborators that should help them stay within accepted ethical bounds. The authors discuss various ethical issues that are pertinent to collaborators. They also focus on other threats to e-research collaboration such as distortion of data arising from technological glitches.

In Chap. 16, Dinescu further examines the influence of e-techniques on academic research. In particular, she focuses on Web 2.0. She analyzes whether, and to what extent, Web 2.0 taken as a whole, is important to enhance quality of research. How does Web 2.0 facilitate new methods of sharing for the purpose of enhancing the quality of research? Does Web 2.0 facilitate high standards of academic accuracy and accountability? The author provides examples of different types of networks that have emerged such as facebook, lindekin and twitter and the opportunities arising thereon. However, these networks have specific purposes: Linkedin is a business network while Facebook and twitter are social networks. Dinescu concludes by discussing one of the latest research tools, MyNetResearch which is a purely academic research oriented network and explains why it is the fittest tool out of the many that are now available for academic cooperation, especially in finding another researcher with identical skills and interest for the purpose of collaboration. The author concludes by discussing pitfalls with respect to *sources* of research. She notes that the proliferation of information oriented websites such as Wikipedia, while increasing the sources of knowledge, does not necessarily enhance the accuracy of reported facts as such information is not vetted and can be incomplete, outdated, biased our unsuitable for serious academic research.

In Chap. 17, Balliet discusses why computer mediated mediums of communication are less effective at improving communication and cooperation among collaborators. These include lack of social clues to examine the credibility of commitment, less leadership and poorer mentoring of other's behavior. The author proposes several means for addressing this. Balliet also notes that the promising benefits of online research collaboration are met with additional challenges – in particular the exacerbation of the free rider problem. The author explains the free rider problem and makes the case that online communication is less effective at resolving this problem. The author attempts to resolve this issue by suggesting that online research collaborators consider integrating reputation building mechanisms that monitor past behavior of collaboration.

In the following complementary chapters, Man Li discusses similar concepts but focuses on how Web 2.0 technology can be used to share knowledge during collaborative research focusing specifically on the real estate and construction disciplines. In the last chapter, Anandarajan and Arinze investigate the emergence of Web technologies and their role in developing social capital needed for effective research collaborations. They propose a theoretical framework to understand how virtual collaborative teams are created in such environments and how they affect the development of social capital. Furthermore they examine features and properties of Web technologies that facilitate the creation of social capital required for the successful research collaborations.

8 Conclusions

The research on the phenomenon of collaboration stretches back four decades. With the emergence of internet technologies, researchers are looking for ways to extend their research effectiveness through collaboration. This has led to the rapid growth of Internet-facilitated virtual collaborative research teams and online communities. Knowledge creation is fundamentally a social process that involves individuals sharing tacit knowledge in order to derive a group-level understanding as the basis for successful collaboration. This implies the existence of social capital, that is, the value of connections and cooperation created in networks of social human relationships.

To date, scant research has examined the impact of Internet-based technologies on virtual relationship-building. Facebook's 350+ million members underline how Internet technologies have led to the creation of social capital in networks. These Web 2.0-based networks have dramatically lowered the barriers that hinder people from interacting with each other. The impacts of these technologies have begun to extend to research collaboration.

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An Anatomy of Collaboration Within the Online Environment

James Harley and Nick Blismas

Abstract The focus of this chapter is the review of collaboration theory as it applies to the online environment. It will deal with the three terms of cooperation, coordination and collaboration, and in doing so, seek to uncover the differentiating elements of each. By understanding these elements, the chapter provides a clearer appreciation of the factors guiding the use of online technologies in the eResearch environment. In distilling the key elements that allow for the comparison of the three terms, the chapter identifies each term as existing along a progression or scale with cooperation at the start of the scale, coordination in the middle ground and collaboration as high or complex involvement of the particular element. Collaboration, it is argued, is the result of mature manifestations of the elements, not all of which may be required within a particular collaborative engagement, nor be required to exist or operate at equivalent mature levels. The implications for this framework enable an understanding and appreciation of how collaborative online research activity can be measured.

1 Introduction to Collaboration Theory

The rise of the internet has seen a change in the way people communicate and relate to each other. Whereas distances were considered a barrier for communication in pre-internet times, now the internet provides not only the opportunity but the technological environment in which transcontinental and intercontinental communication can exist. The internet has long provided a network infrastructure for collaborative technologies that supports communication between people and groups (NECTAR 2007).

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With the increasing connectivity to the internet, the power of the world wide web, and the distributed nature of organisations, multiuse computer systems (groupware) are becoming more common (Gutwin and Greenberg 2000). The business imperative of web-enabled technology has flowed through to the research environment. The contemporary research environment can extend to multiple sites, several teams and in many circumstances multiple locations, all of which can benefit from a tool that assists with the operational aspects of the job.

Online collaborative toolsets (OCTs) or groupware help people work together even though they may be remotely located from each other (ForakerDesign 2007; Gutwin and Greenberg 2000; McDonald 2003; TechTarget 2007). The OCT can be as simple as providing an online space for community engagement, through to delivering sophisticated and innovative workflow and I.T. solutions. This proves attractive to the research field, as OCTs offer a central online teamspace where shared information can be stored and accessed at any time, and where team dynamics can be facilitated (ForakerDesign 2007).

However, the use of an OCT does not automatically develop collaboration amongst team members, nor are specific collaborative attitudes mandated when using OCTs. This gives rise to questions about how collaboration is understood in the research environment, and specifically how it differs from cooperation and coordination. Thus, the focus of this chapter is the review of collaboration theory as it applies to the online environment. It will deal with the three terms of cooperation, coordination and collaboration, and in doing so, seek to uncover the differentiating elements of each. By understanding these elements, users can gain a clearer appreciation of the factors that will guide their use of online technologies in the eResearch environment.

2 Defining Collaboration

Defining collaboration is made complex by ambiguities in practical usage and general disagreement about, or flexibility in, the way in which the term is applied. It is not uncommon to see in practical use the term “collaboration” being used interchangeably with “cooperation” and “coordination” (Fitzek and Katz 2006; Mattessich et al. 2001). However, cooperation, coordination and collaboration have distinct meanings and it is these meanings that this section will address.

2.1 Cooperation

Cooperation is characterised by informal relationships that exist without any commonly defined mission, structure, or planning effort. Information is shared as needed, and authority is retained by each organisation so there is virtually no risk.

Resources are separate as are rewards (Mattessich et al. 2001). It has also been described as the action or process of working jointly towards the same end (Pearsall 1999). Argyle (1991) defines cooperation as acting together in a coordinated way at work, leisure, or in social relationships, in the pursuit of shared goals, the enjoyment of joint activity, or simply to further the relationship. Cooperation can also be understood as joint action for mutual benefit, and is the strategy of a group of entities working together to achieve a common or individual goal (Fitzek and Katz 2006). This is in contrast with Schermerhorn's definition of cooperation, where he sees it as deliberate relations between otherwise autonomous organisations for the joint accomplishment of individual operating goals (Schermerhorn 1975). The definition of cooperation is therefore complex, where it can also be seen to be taking place on a small or large scale with few or many collaborating entities (Fitzek and Katz 2006). The use of one term to describe another supports the quest of this chapter to provide some clarity around the different terms.

2.2 Coordination

There are also many definitions for coordination with an associated lack of consistency (Rogers and Whetten 1982). Rogers and Whetten propose that coordination can mean different things for different people, and due to the many ways in which its elements can be used or incorporated into processes and strategies, the term has been used synonymously or confused with a variety of related concepts including cooperation. This lack of agreement about meaning has led the authors to note that propositions about coordination are tenuous at best and they caution practitioners to be wary of applications developed for this use (Rogers and Whetten 1982).

Coordination can be defined as the action or process of bringing different elements of a complex activity or organisation into a harmonious or efficient relationship (Pearsall 1999). Coordination is characterised by relationships that are more formal and which have an understanding of compatible missions. Mattessich et al. (2001) note that some planning and division of roles are required, and communication channels are established. Authority still rests with the individual organisations, but there is some increased risk to all participants. Resources are available to participants and rewards are mutually acknowledged (Mattessich et al. 2001).

As coordination often exists across two or more organisations, the term has been linked with intra and inter-organisation coordination. Rogers and Whetten (1982) define inter-organisational coordination as the process whereby two or more organisations create and/or use existing decision rules that have been established to deal collectively with their shared task environment. Other authors also acknowledge the connection with the inter-organisational condition. Hall et al. (1977) define coordination as the extent to which organisations attempt to ensure that their activities take into account those of other organisations. Warren et al. (1974) also conceptualise coordination within the inter-organisational domain and note its relevance to decision-making. They define it as a structure or process of concerted decision-making or action wherein the decisions or action of two or more organisations are made simultaneously, in part or in whole, with some deliberate degree of adjustment to each other.

2.3 Collaboration

There are many variations to the definition or application of collaboration, with some seeing it as being simply equal to participation (Romano et al. 2002), while others consider it to embrace an ability of two or more people or groups to transfer data and information online (Breite and Vanharanta 2003). Collaboration can, however, connote a more durable and pervasive relationship other than this rudimentary level of interaction. Mattessich et al. (2001) consider that collaboration has the capacity to bring previously separated organisations into a new structure with full commitment to a common mission. Such relationships require comprehensive planning and well-defined communication channels operating on many levels. In these new relationships, authority is determined by the collaborative structure and risk is much greater because each member of the collaboration contributes its own resources and reputation. Resources are pooled or jointly secured, and the products are shared (Mattessich et al. 2001) in the collaborative relationship.

The definition provided by Pearsall (1999) does not provide significant difference between the terms cooperation and collaboration, noting collaboration is also an act of working jointly on an activity or project; whereas Schrage (1990) notes that collaboration is the act of constructing relevant meanings that are shared by all parties involved to achieve congruent goals. For Gricar (1981) however, collaboration refers to the interaction between two or more organisations where they identify and acknowledge the ways in which they are mutually interdependent with regard to a particular issue or set of issues.

This is consistent with the definition that collaboration includes two or more people sharing complex information on an ongoing basis for a specific goal or purpose or to achieve common goals (Coleman and Antila 2004; Mattessich et al. 2001). Mattessich et al. (2001) also note that the collaborative environment includes a commitment to mutual relationships and goals; a jointly developed structure and shared responsibility; mutual authority and accountability for success; and sharing of resources and rewards.

Given the above definitions for the three terms, it appears they are closely aligned, and yet are being used in different settings and without clarification. The melding of the three terms is a constant reminder of not only the various manners in which words are applied in common or everyday use, but also strikes a chord when one word in particular, “collaboration”, is applied consistently to a suite of software products or research environments.

3 Essential Elements of Collaboration

A review of the literature around collaboration reveals seven essential elements that contribute to collaboration being present in a specific environment. These elements include communication, trust and respect, equality and power, strategic alliances or partnerships, incentives, negotiation, and inter-organisational knowledge sharing.

It is not the intention here to contribute to the development of the theoretical understanding of cooperation, coordination and collaboration, but rather to provide an overview of the issues related to collaboration's essential elements, and the manner in which it manifests within the eResearch environment. This enables a review of the role these elements occupy within the eResearch environment, and increases our understanding of the inter-relationships between them. Given this, the material presented here offers a general overview of each of these seven collaborative elements in context. Each element will now be reviewed individually.

3.1 Communication

Collaboration does not occur in a vacuum, and as such, communication plays an important role (Sclater et al. 2001). This is especially the case in virtual and distributed project teams (Qureshi et al. 2005). Communication can be considered essential for any group-undertaking as without it (in whichever format or medium it may occur) the message cannot be delivered with any accuracy.

The ability to communicate effectively is critical if information is to be shared and/or distributed. It has been described as the key that holds together a channel of distribution (Batt and Purchase 2004). It is not coincidental that communication appears as the primary element for collaboration (and is implicit in the understanding of the other terms – coordination and cooperation). Open and frequent communication is considered to be a critical factor that can influence the success of collaboration, as is the importance of establishing informal relationships and communication links (Mattessich et al. 2001).

However, the number of channel options available to the project team may affect the quality of the communication. The variety of channels include telephone (land line and mobile), fax, voice mail and email – add the OCT to this suite, and the research environment requires discipline to ensure the most suitable medium is used at the most suitable time, even to the extent of team members foregoing communication by other media for specific types of information (O'Brien 2000). Communication is crucial in these channels, where it can serve as an ideal process by which persuasive information is transmitted, participative decision-making is fostered, programs are coordinated, power is exercised and commitment and loyalty are encouraged (Batt and Purchase 2004).

There are instances that can lead to problems occurring with communication, for example social barriers, where the lack of experience working within a collective environment can present other problems (Sclater et al. 2001), or where there is a lack of communication skills which affects the manner and effectiveness of collaboration (Bharadwaj et al. 2004). These problems are barriers to communication and can be due to issues such as not knowing the collaborators in advance, not having clearly defined roles and responsibilities, misunderstandings between members and conflicting institutional or organisational cultures (Sclater et al. 2001).

The ability to effectively communicate across the research project is inextricably linked not only to the content and motivation behind the desire to disseminate the information, but to the management of the collaborative environment itself (Davenport et al. 1998). Without the capability to communicate, it is difficult to manage the expectations of others, and the collaborative environment. This has a flow-on effect in the fulfilment of trust and respect, and sharing information within the research environment.

3.2 Trust and Respect

It is important to gauge the level of trust and respect that may exist between the partners within the research environment (Austin 2000), as the notion of trust occupies a central position for practitioners involved in collaborative initiatives (Vangen and Huxham 2003). Trust is seen to be the essential intangible asset of collective alliances, the interpersonal webbing that knits organisations together and facilitates concerted effort. Trust is reciprocal, in that one has to give it in order to receive it, and is built step by step over time (Reina and Reina 2006). It is also one of the key areas of concern in maintaining a good relationship (Austin 2000; Batt and Purchase 2004) and effective communication (Qureshi et al. 2005).

Barnes et al. (2000) see trust as being an integral success factor for collaboration. Trust develops through active engagement and participation with others and the delicate fabric of human relationships (Reina and Reina 2006). The research environment provides an excellent situation in which these relationships can be tested, as it draws on various team members from different business units, partnering organisations or affiliated companies. The effective operation of the team will require an understanding of trust and respect, and the factors that may impact on its presence, including the team members' perception of themselves, of other team members, and of other stakeholders involved with the project (Herzog 2001).

As has been noted for collaboration in general, there are many different forms of trust that can exist in the project, including contractual, competitive, goodwill, communicative, emotional and ethical trust. It is the combination of the different types of trust that influences collaborative levels of trust (Reina and Reina 2006).

Trust features in many organisational frameworks. This is because effective inter-firm links and associated learning between partners depend on high levels of trust (Davenport et al. 1998). In an inter-organisational environment, trust can become a major governance mechanism in that it facilitates coordination and collaboration and assists with knowledge sharing (Black et al. 2002).

Notions of trust, knowledge sharing and collaboration become central elements of inter-organisational relationships (Black et al. 2002; Vangen and Huxham 2003). These elements are particularly important for the research environment if inter-organisational relationships are to involve the mutual participation of people, and an element of cooperation, coordination or collaboration. Trust in this instance, is best understood in terms of the ability to form expectations about the aims and the partner's future behaviour in relation to these aims. A necessary condition for trust is that expectations can be formed on the one hand, and fulfilled on the other (Vangen and Huxham 2003). Trust has also been shown to play a major role in the effectiveness of information sharing and organisational learning, and in knowledge and information sharing in inter-organisational relationships (Black et al. 2002). Of note however, is that cooperation does not require trust, and it may be induced by coercion; even though trust is considered vital to bringing about increased cooperative processes.

Much has been written about the development of trust building and the mechanisms for maintaining trust. For our purposes, it is sufficient to say that trust remains a core element within the application of the three terms of cooperation, coordination and collaboration.

3.3 Equality and Power

Even when attention is paid to the research environment and the management of trust within relationships, the inherent fragility of the trust loop is evident. Alongside the issues relating to the dynamic nature of collaboration, power issues in particular have the capacity to affect this loop (Vangen and Huxham 2003). Power in collaboration lies not in controlling the behaviour of individuals, but rather in creating a situation that constrains or enables individuals (Walker 2003). Collaboration involves both aligning the economic goals of the network and the development of the social dimensions. Power is an essential characteristic of social organisations and an inevitable instrument for organisational coordination (Batt and Purchase 2004). It entails parties being able to understand the relationship so that their own interests can be articulated clearly in order to function within the operating environment (Walker 2003).

A paradox of collaboration is whilst the process of collaboration creates dependency between the partners; inevitably some will be more central to the enactment of the collaborative agenda than others. This frequently leads to perceptions about power imbalances between those viewed as principal versus those viewed as subsidiary members (Vangen and Huxham 2003).

Power in collaboration is typically fragmented, yet teams can achieve collaborative advantage by finding ways to ensure shared power is maximised. The way in which parties negotiate their positions of power and equality within their environment leads to the fulfilment of an effective partnership and strategic alliance. And while it is inevitable that the collaborative partners may have unequal power bases, the assumption is that all collaborative participants will be, and should be, equal within the confines of the collaborative project (Walker 2003).

Technology has the capacity to enable information sharing, but it is dependent upon people in teams wanting to share their information with others. One reason given for people's unwillingness to share information is that information is linked to power and money (Barua et al. 1997), while another suggests that even in collaborative environments, people are uncomfortable giving power away (O'Brien 2000).

3.4 Strategic Alliances

Firms and organisations do not operate in isolation but must seek to collaborate with other organisations and within other networks in order to achieve their goals and desired outcomes. Networks have risen to prominence due to industrial restructuring, large scale downsizing, vertical disaggregation and outsourcing, and the elimination of management layers. Replacing them are leaner, more flexible firms focused on core technology and processes. These firms are closely aligned in a network of strategic alliances and partnerships with customers, suppliers, distributors and competitors (Batt and Purchase 2004). This network is evident across the contemporary research environment, which often shows input from several specialist firms or affiliated suppliers/contributors.

The strategic alliance contains relationships between two or more suppliers that are servicing the same customer base, and are thus partners in a horizontal association. The driving force initially behind the alliance includes cost savings, greater efficiencies, synergy, critical mass, stability, and/or competitive advantage (Lendrum 1998).

Collaboration is closely tied to the key characteristics of strategic alliances (Yoshino and Rangan 1995). The first characteristic of a strategic alliance entails the participating organisations pursuing a set of common goals, and remaining independent subsequent to the formation of the alliances. The second characteristic involves the partnering organisations sharing the benefits of the alliances and control over the performance of the tasks or activities. The third characteristic is where the partnering organisations continue to contribute in one or more key strategic areas.

A firm's position in the alliance or network will depend on the nature of the direct and indirect relationships it has with other players in the network, the nature of the project, and the associated structures that contribute to the delivery of the outputs. It is determined by the different types of research environments possible within a collaborative network and the organisational structures that are in place to manage these. Each of these environments, including research, project management, and government to name a few, would have a different requirement for their project team relationships and role of their strategic alliance partners.

The commitment members give to the partnership is crucial in ensuring that the relationship can sustain the project timelines. Other factors to consider when reviewing the strategic alliance are whether the partners understand the level of commitment required, what are their expectations and whether these are commensurate with execution capabilities and their competency in the area, and if the alliance is considered to be managed properly (Austin 2000; Davenport et al. 1998).

Ultimately, however, the players or partners within these projects are contributing to a shared or common business objective, or have an incentive for their participation. They share a stake in both the process and the outcome, have multiple layers of participation, and are flexible regarding the process and structure of the collaboration (Mattessich et al. 2001).

3.5 Incentive and Value

For the collaborative partnership to work, partners need to invest. It is important for members to perceive the collaboration as in their self-interest (Mattessich et al. 2001), even though the purpose of the partnership is to have a shared vision with attainable goals and objectives.

The creation of value is therefore an element that facilitates the return on investment for the participating partners. Partners may be looking at the research environment to identify certain areas where value can be achieved as an incentive to participate; for example team-based rewards provided in anticipation of a return in better teamwork (Barua et al. 1997). Partners may choose to identify specific benefits that may flow out of the collaboration, consider whether social value can be generated from it, and if there are new resources, capabilities or benefits that are being created as a result of the collaboration (Austin 2000).

Reciprocal behavior within the relationship also emerges from a perceived self-interest in a world of permanence and trust, where a team provides information needed by another in anticipation of receiving a similar favor in the future (Barua et al. 1997). This suggests that concepts of incentive and value are closely associated with the type of partnerships or “collaborative” environments that can occur, as well as the expected returns for this engagement. A shared incentive may also decrease the number or severity of disputes, as there is a mutual financial imperative to complete the project.

3.6 Negotiation

Collaboration requires a degree of negotiation to occur between the participating partners so they can come to an understanding of the terms of conditions and rules of engagement of their relationship. These negotiations assist in drafting and creating a consensus on operating factors such as the roles and responsibilities of the partners. These negotiations can, however, be made complex when there is no legitimate authority present to manage the situation and where power and politics become mission critical elements. Participants can remain relatively autonomous within the network, and may need to be convinced to act on their own volition, as there is no legitimate authority that can demand cooperation (Phillips et al. 1998). Negotiations can be undertaken in a variety of ways. They can be fluid or in a structured environment, be influenced by market and authority-based relationships, or can be based on autonomous participation (Phillips et al. 1998; Walker 2003).

Ultimately, in order for a research project to survive, partners must embrace a notion of collaboration, one that includes a collective strategy in which organisations cooperate rather than compete, and can compromise when required (Mattessich et al. 2001; Phillips et al. 1998).

3.7 Inter-organisational Knowledge Sharing

Knowledge is a vital resource in project-based industries. In order for collaboration strategies to occur, partners should be willing to both distribute knowledge to other members and integrate knowledge made available to them (Halme 2001). This task presents new and challenging processes for the electronic research environment (van Donk and Reizebos 2005).

Advanced I.T. has prompted many organisations to invest in distributed computing systems and to decentralise the management of information. Yet while decentralised and distributed information management may result in gathering high-quality information, there is a risk that this information emerges in isolation rather than being shared across the project.

For this reason, the role of the information system within a collaborative environment can be to create linkages among sub-units through the development of appropriate policies, guidelines and standards. Today's research organisation requires an effective information-exchange to bridge information gaps between different decision-makers or teams controlling specific information or data sets, and to share resources to achieve project deliverables (Romano et al. 2002).

Inter-organisational collaboration has the capacity to improve strategic performance in a number of areas within the project, by helping to spread risk, share resources, enhance flexibility, increase access to technological know-how and information, and provide formal and informal communication links (Mattessich et al. 2001; Phillips et al. 1998).

Knowledge developed in projects and subsequently distributed among project participants provides a vital mechanism for the eResearch environment, allowing multi-project organisations to support decisions on a variety of fronts including resourcing and skills development (van Donk and Reizebos 2005).

Knowledge sharing in projects will include explicit as well as tacit and embedded forms, the latter expressed in actions, procedures and/or artefacts (Katzy et al. 2000). These are likely to vary considerably across different project environments or work scenarios and are much more difficult to transfer. Tacit or embedded knowledge cannot be separated from the work culture and the social construction of the work processes in each organisation, and as such is inextricably linked to the culture of the research environment and the associated relationships. Explicit knowledge transferral can be understood by reviewing and analysing communication patterns within the organisation, while implicit knowledge transfer needs to be judged by how the knowledge is applied (Katzy et al. 2000).

Knowledge can be distinguished as something that is possessed by either an individual or a group. It may also be viewed as an organisational-level phenomenon, embedded in organisational forms, social expertise, and as "knowledge-in-practice" situated in the historical, socio-material and cultural context in which it occurs (Black et al. 2002). The factors that influence whether, and how effectively, knowledge is shared may also include experience, trust, motivation and the level of difficulty experienced when actually engaging in the knowledge transfer (Binz-Scharf 2005).

The authors, van Donk and Reizebos (2005), identify three main aspects of knowledge in project-based organisations. The first is entrepreneurial, and includes the knowledge that pertains to acquisitions within the research environment. The second aspect is technical, which is limited to the technology applied to the project, and includes the technical sense of the project. The third aspect embraces the project management knowledge. This aspect combines the theoretical knowledge on project management, which may include associated techniques, with the real experience in conducting and managing the project (van Donk and Reizebos 2005). Given that much of the information contained within these three aspects is also likely to be distributed amongst several project teams, it is critical that these types of knowledge are effectively distributed and shared across the research environment. Failure to do so could result in risking the delivery of the key result areas or outcomes of the project. This can also lead to tension within the project environment, where problems with information sharing can be attributed to the divergence in goals and objectives of different teams within the research environment, or to a symptom of an ineffective partnership (Barua et al. 1997; Binz-Scharf 2005).

Importantly, the research team requires a consistency of members and partners to ensure strong interpersonal bonds are maintained and information sharing continues across the environment (Austin 2000). This sharing environment can be threatened by outside forces, including the perception of non-permanence or permanence of interactions between the teams, disparities in information processing capabilities and rewards systems, and inefficient information-sharing behaviour from both the individual and organisational perspective (Barua et al. 1997). In these instances, mutual trust is a necessary condition for any successful knowledge-sharing environment (van Donk and Reizebos 2005).

4 Comparison of Cooperation, Coordination and Collaboration

Mattessich et al. (2001) propose four key categories to understand and compare the differences between the terms cooperation, coordination and collaboration. These categories present a series of elements that has a varying or gradated relevance to the three terms. In most instances, the element applies less to cooperation and more to collaboration, with coordination occupying the middle ground. This gradation is a theme that will be revisited later in this chapter. These categories are:

– Vision and Relationships: includes relationships, missions and goals, and interaction
– Structure, Responsibilities and Communication: includes roles, planning and communication
– Authority and Accountability: includes authority, leadership and risk
– Resources and Rewards

Tables 1–4 provide an overview of the elements within these four categories as they apply to cooperation, coordination and collaboration.

Furthermore, Rogers and Whetten (1982) provide a list of five criteria with which to explore the distinctions between cooperation and coordination. Their criteria are:

– Rules and formality
– Goals and activities
– Implications for vertical or horizontal linkages
– Personnel resources and
– Threat to autonomy

In this matrix, cooperation and coordination are differentiated by the degree to which the terms are relevant to the specific criteria. In the first of the criterion, the two terms are differentiated by how formal rules are managed, with cooperation having very few formal rules, whilst coordination entails a greater use of decision rules. In the second criterion the individual organisation's goals and activities determine the type of goals that are emphasised, whilst joint goals and activities are aligned closer with coordination. The third criterion entails the extent to which inter-organisational linkages occur. In this criterion, cooperation is contained within its own organisational domain, whilst coordination has the capacity to spread

Table 1 Vision and relationships

Element	Cooperation	Coordination	Collaboration
Relationships	Basis for cooperation is usually between individuals but may be mandated by a third party	Individual relationships are supported by the organisations they represent	Commitment of the organisation and their leaders are fully behind their representative
Missions and goals	Organisational missions and goals are not taken into account	Missions and goals of the individual organisations are reviewed for compatibility	Common missions and goals created
Interaction	Interaction is on an as needed basis and may last indefinitely	Interaction is usually around one specific project or task of definable length	One or more projects are undertaken for long-term results

Table 2 Structure, responsibilities and communication

Element	Cooperation	Coordination	Collaboration
Roles	Relationships are informal and each organisation functions separately	Organisations take on roles, but function relatively independently of each other	Creation of new organisation structure and/or clearly defined and interrelated roles that constitute formal division of labour
Planning	No joint planning is required	Some project-specific planning is required	More comprehensive planning is required that includes developing joint strategies and measuring success in terms of impact on needs of those served
Communication	Information is conveyed as needed	Communication roles are established and definite channels are created for interaction	Many levels of communication roles are created as clear information is a keystone of success

Table 3 Authority and accountability

Element	Cooperation	Coordination	Collaboration
Authority	Authority rests solely with the individual organisation	Authority rests with the individual organisation but there is consultation among participants	Authority is determined by the collaboration to balance ownership by the individual organisation with expediency to accomplish purpose
Leadership	Leadership is unilateral and control is central	Some sharing of leadership and control	Leadership is dispersed, and control is shared and mutual
Risk	All authority and accountability rests with the individual organisation which acts independently	Some shared risk, but most of the authority and accountability falls to the individual organisation	Equal risk is shared by all organisations in the collaboration

Table 4 Resources and rewards

Element	Cooperation	Coordination	Collaboration
Resources	Resources are separately serving the individual organisation's needs	Resources are acknowledged and can be made available to others for a specific project	Resources are pooled or jointly secured for a long-term effort that is managed by the collaborative structure
Rewards	Nil	Rewards are mutually acknowledged	Organisations share in the products: more is accomplished jointly than could have been individually

and link to other organisation structures. The fourth criterion reviews the type of personnel that are involved, with cooperation having relatively few members drawn from subordinate or lower positions within the organisation, whilst coordination may necessitate an increase in resources, commitment and involvement from more senior members of the organisation. The fifth criterion refers to the autonomy of the organisations and notes that the cooperative organisation will engage with little threat to its autonomy, whilst the threat to autonomy increases within the coordinative organisation. Table 5 details these five criteria and their relevance to cooperation and coordination.

Argyle (1991) notes that cooperation is required to perform tasks within the material world and to sustain basic social relationships, including familial, domestic, social and working environments. Argyle also notes that in order for cooperation to be successful, it requires communication and interaction (Argyle 1991).

Cooperation within the working environment can take several forms. The first form is consistent with the performance of a task as noted above, where a worker may undertake a task independently or in partnership with other workers (e.g., in manufacturing on an assembly plant). The second form entails a supervisory relationship where the person may not actually do the work, but is responsible for ensuring that other people have performed the work correctly and to a pre-set or agreed standard. The third form includes other social relationships that may be found within the work environment such as sharing information, discussions, negotiating and providing expert advice (Argyle 1991).

Cooperation can be used to describe any relationship where all participants contribute and this action exists in order for the participant to obtain an advantage by giving, sharing or allowing something to happen (Fitzek and Katz 2006). Cooperation can also lead to or encourage the division of labour between individuals who may specialise in different parts of the job, have differing competencies, or where tasks are interdependent (Argyle 1991). Rewards and incentives assist to enforce the rules within the cooperative environment.

The condition of cooperation is therefore based on the premise that each participating entity is gaining more by cooperating, regardless of the extent, than if they operated alone or independently. Cooperation is dependent upon the interests of the cooperating person or group, and as such may take different forms depending on the circumstance to which it is applied (Fitzek and Katz 2006). It may

Table 5 Cooperation and coordination criteria of Rogers and Whetten (1982)

Criteria	Cooperation	Coordination
Rules and formality	No formal rules	Formal rules
Goals and activities emphasised	Individual organisation's goals and activities	Joint goals and activities
Implications for vertical and horizontal linkages	None, only domain agreements	Vertical or horizontal linkages can be affected
Personnel resources involved	Relatively few – around the lower ranking members	More resources involved – higher ranking members
Threat to autonomy	Little threat	More threat to autonomy

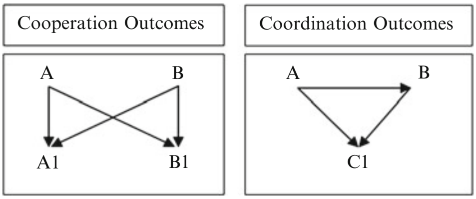

Fig. 1 Juxtaposition of outcomes (Rogers and Whetten 1982)

also involve varying motivating factors or external rewards, such as to further a relationship or to participate in shared activities (Argyle 1991; Fitzek and Katz 2006).

Coordination similarly can be for individual or independent purposes, but has the added condition of being a mechanism for planning, action or joint activity between organisations. In these circumstances, organisations can be both independent and share coalitions of activity that may influence joint decisions and actions (White 1968). An example of this is expressed in Fig. 1, where the outcomes of cooperation and coordination are juxtaposed. In the figure, Organisation A and B can be shown to relate to each other (in a cooperative fashion) in order to accomplish their respective goals, some of which impact on each other. In a coordinative scenario, the creation of outcomes may be different from their initial preferred outcomes (Rogers and Whetten 1982).

As the application of coordination across organisations increases, emphasis has shifted from reviewing the issues around controlling internal activities and managing external constraints, to discussions around resource control (Thompson 1967). Of interest for this work is the identification of those activities that are most suited to coordination.

Coordination involves undertaking tasks within the shared and inter-organisational environment. In these situations, tasks are spread across multiple organisations, divisions, or business units, with each organisation interacting at different levels depending on the requirements. The task environments of these organisations are pluralistic (Thompson 1967) and operate without an overarching authority structure in place between the participating organisations. In these circumstances, establishing and maintaining a successful inter-organisational coordination program is much more difficult than managing a similar interdepartmental or intra-organisational program, and is more about managing uncertainty (Rogers and Whetten 1982).

Organisations may also choose to use competitive or cooperative strategies to help reduce the uncertainty caused by the task environment. If the organisation has sufficient power or authority, it may choose to follow competitive strategies, but if the acquisition of power is difficult, the organisation is more likely to chose cooperative strategies, including contracting for services, co-opting and coalescing, or entering into a combination or joint ventures with other organisations. As previously noted, as the environment becomes increasingly complex, organizations become more specialized, leading to a greater need for increased inter-organizational coordination (Rogers and Whetten 1982).

5 Practical Implications for Collaboration Theory

As discussed, there are many models and applications for the terms cooperation, coordination and collaboration, with each one varying slightly depending on the environment or circumstances for which it is intended. This chapter has attempted to distil the key elements in order to compare and contrast all three terms, now presented here in Table 6. What becomes evident in presenting the elements in this format is that each can be understood depending on whether it is being applied to cooperation, coordination or collaboration. Furthermore, the description against each term is relative to each other – that is to say, that each element can be understood as existing along a progression or scale with cooperation at the start of the scale, coordination occupying the middle ground and collaboration being described as high or complex involvement of the particular element.

This analysis of collaboration identifies the scale, and highlights the degree to which the elements must be present in order for collaboration to occur. An alternate way of understanding collaboration and the degree to which it occurs within the eResearch environment, is to revisit the explanation of collaboration previously discussed in Rogers and Whetten (1982). Whilst the authors argue that cooperation begins with a relationship in order to accomplish respective goals, and coordination may result in the creation of outcomes that may be different from their initial expectations (Rogers and Whetten 1982), we propose an amendment to this model. In a reworking of the authors' diagram and in the context of this discussion, we propose that collaboration is a complex interaction of intra/inter-organisational linkages and connections with cooperation as the entry point in this interaction, progressing through coordination, and reaching maturity at the collaboration stage (Fig. 2).

The diagram shows collaboration as an amalgam of the three terms, and when viewed separately, each term can play a role in the eResearch environment. In this approach, the conceptual framework enables a greater understanding of how online tools can contribute to the eResearch environment by identifying different elements within collaboration, which in turn may identify different approaches and functions in eResearch activities. We argue that collaboration is the result of mature manifestations of these elements, not all of which may be required within a particular collaborative engagement, nor be required to exist or operate at equivalent mature levels.

For example, cooperative activities will benefit the eResearch team, while some activities will require coordination of processes. Not all activities will necessarily require collaboration, but when it is required, the impact on the use of the online tool will require a complex interaction, as opposed to a simple transmittal of information or request for a meeting, as would be required for cooperation or coordination.

This highlights many possibilities for investigating the eResearch environment and the associated measurement of collaborative activity. Indeed, we would argue that the use of online tools in the eResearch environment contributes not only to

Table 6 Summary of cooperation, coordination and collaboration

Element	Cooperation	Coordination	Collaboration
Rules and formality	Nil	Formal	Formal and shared processes
Goals and activities	Individual organisation goals and activities	Joint goals and activities	Project goals and activities
Vertical and horizontal linkages	Temporary or none	Vertical and horizontal may be affected	Vertical and horizontal mandated
Personnel/resources involved	Relatively few, drawing from lower ranking members	More resources involved from higher ranking members	Increased due to sharing of resources across tasks Interdependence high
Autonomy	Little threat Proprietary strategies that maintain possession and control over resources and protect boundaries	More threat to autonomy Strategies require negotiation with other organisations	Authority implicated with organisation structure Strategies require participation from many organisations
Relationships and strategic alliances	Informal	More formal	Complex
Communication	Nil/ad hoc	Communication channels established	Complex
Information sharing and knowledge distribution	Shared as needed	Shared	Complex
Rewards and incentives	Separate	Mutually acknowledged	Shared (from a unifying action)
Risk	Nil	Increased	Spread and reduced
Defined mission, structure or planning effort	Nil	Understanding of some compatible missions Some planning and division of role required	Interdependence
Decision-making	For the sake of the organisation	Inclusive	Concerted
Tasks/interdependence	Low	Increased but still separated	Complete

Source: Austin (2000), Argyle (1991), Baura et al. (1997), Davenport et al. (1998), Fitzek and Katz (2006), Katzey et al. (2000), Mattessich et al. (2001), Phillips et al. (1998), Rogers and Whetten (1982), Romano et al. (2002), Thompson (1967), Vangen and Huxham (2003), Walker (2003), White (1968)

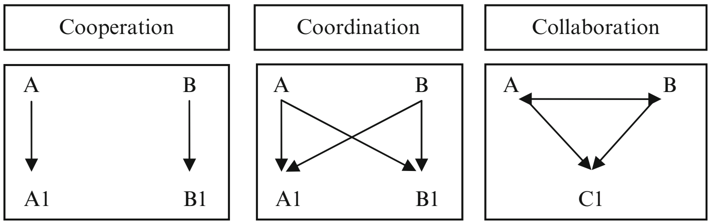

Fig. 2 Amended juxtaposition of outcomes with reference to Rogers and Whetten (1982)

attaining research topic objectives, but to developing and nurturing strong social/research/academic networks that are essential to the health and longevity of research practices.

The implications for this framework are many, not the least being an understanding of what constitutes collaborative online research activity. The advent of online toolsets to facilitate and manage the collaborative environment further adds to the opportunities resulting from social aspects of collaboration. This is most evident when research teams are geographically spread and require access to distributed data and information.

This chapter has argued that collaboration within the eResearch environment can involve activities that are spread across the three terms – cooperation, coordination and collaboration. By understanding these terms and their associated elements, users can gain a clearer appreciation of the factors that will guide their use of online technologies in the eResearch environment.

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Time, Place and Cyberspace: Foundations for Successful e-Research Collaboration

Lynne Siemens

Abstract Electronic research (e-Research) collaboration tools have created new opportunities for research and communication among individuals. These digital tools facilitate communication and collaboration and allow people across many geographical locations to coordinate tasks and research output. At times, given the extensive use of these tools, teams may have an over-reliance on digital tools to the exclusions of others. Other means to facilitate communication, coordination and collaboration exist and play an important part in effective research. This chapter explores the role of both digital and in-person collaboration tools and considers the need for balance between these within the context of Digital Humanities research teams, a case study population. First the uses, benefits and trade-offs of various communication channels are outlined, particularly within the context of interdisciplinary and geographically disperse research teams. From there, the role of in-person interactions, digital tools and social software within the case study community and their impact on collaboration will be explored. The primary implication from the research is that there must be balance between digital tools and social software and in-person interactions. Technology can supplement, but not replace face-to-face interaction in collaboration totally. Best practices and recommendations for academic research teams will conclude the chapter.

1 Introduction

The purpose of this chapter is to explore the role of digital and in-person collaboration tools and to discuss benefits and trade-offs of different communication channels used in collaborative research. Electronic research (e-research) collaboration

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tools have created new opportunities for research and communication among individuals, particularly for those who are geographically dispersed (Cummings and Kiesler 2005). As most individuals can contest, email, a most basic of e-research collaboration tools, is used to communicate even with those who might be located just down the hall. Further, documents are routinely shared electronically through email or online project spaces, rather than physically. And, for many, skype and other Voice Over Internet Protocol (VOIP) systems have replaced the telephone for conference calls.

These digital tools facilitate communication and collaboration and allow people across many geographical locations to coordinate tasks and research output. However, e-research tools still have not totally conquered the challenges associated with collaboration at a distance (Cummings and Kiesler 2005; Deepwell and King 2009). Thus, teams need to expand their collaboration tools to include or reincorporate in-person interaction. This raises the issue of balance between on-line and in-person interactions and the use of tools which can facilitate this balance within collaborative working relationships.

To that end, this chapter explores the role of both e-research collaboration tools and in-personal interactions and considers the conditions necessary for effective e-research collaboration, within the context of academic research teams. First, the uses, benefits and trade-offs of various communication channels are outlined. Then, the role of digital tools and social software within a case study of an academic community and their impact on collaboration will be explored. Best practices and recommendations for academic research teams will conclude the chapter.

2 Context: Role of Communication in Collaborations

To be effective, a research team must find ways to communicate and collaborate in order to develop trust, build consensus around research questions, methodologies, and tasks, and coordinate the actual work. Within this context, communication plays two primary roles. At a basic level, it facilitates the sharing of the information needed to define, implement, and coordinate tasks. Through discussions, team members can outline and gain agreement on tasks and responsibilities, and report progress, moving the entire research project towards its objectives. Second, communication builds a working relationship among team members through the creation of a common understanding of the research project as a whole. A productive working relationship creates collaboration and trust while ensuring effective and efficient communication.

Academic teams, particularly interdisciplinary ones, face additional challenges in developing these work relationships. The potential for tension is great for these teams due to differences and ambiguity in the research problem, methodology and terminology (Fennel and Sandefur 1983). In some cases, academic research teams may even need to develop a new working vocabulary specific to their particular research project, which may include redefining commonly used terms to ensure specific understanding (Bracken and Oughton 2006). Additionally, academics are not often prepared for the levels of interdependence required within team research given their academic training (Birnbaum 1979).

Further, geographically dispersed teams, as are many academic teams, face additional challenges. Cramton (2001) defines geographically dispersed teams as "groups of people with a common purpose who carry out interdependent tasks across locations and time, using technology to communicate much more than they use face-to-face meetings" (Cramton 2001, pp. 346). These teams may differ in degrees of "virtuality", with some collaborating solely on-line while others combining digital communication with face-to-face meetings (Poole and Zhang 2005). While communication in all forms is a prerequisite to effective collaboration, even small geographical distances between group members can reduce the amount of communication between individuals, and by extension, may limit innovation and productivity (Cech and Rubin 2004). Geographical dispersion may occur even when team members are at the same institution since disciplines are often located in different buildings. This communication gap may be further complicated by the fact that virtual teams may also have members who come from different cultural backgrounds as well as different organizations. Team members may not share information about their local context and may be less able to discern differences between individuals from different cultures (Cramton and Webber 2005). Virtual collaboration also requires more coordination due to the distance while at the same time, teams face reduced flexibility in available meeting times given time zones and travel costs (Lawrence 2006). As a result, geographically dispersed teams must carefully evaluate their communication patterns to ensure that they are supporting the collaborative relationship.

Communication and collaboration is conducted through several channels, depending on the location and time of the sender and receiver, as seen in Table 1. Each channel employs a different technology and presents benefits and trade-offs to a research team.

By definition, face-to-face communication is synchronistic, in that it occurs when the sender and receiver are in the same place at the same time. This form of communication is the richest media of all the communication channels because it allows for both the sender and receiver to observe body language and other cues such as facial expressions, tone of voice, and other gestures, all of which add context to the actual message. Given the potential for immediate feedback from

Table 1 Categorization of communication/collaboration channels

	Same time	Different times
Same place	Face-to-face collaboration	Asynchronous collaboration (email, listserves, wikis, e-research collaboration tools)
Different places	Distributed synchronous (conference calls through telephone and/or VOIP, instant messaging)	Distributed asynchronous collaboration (email, listserves, wikis, e-research collaboration tools)

Adapted from Precup et al. (2006)

the various cues, participants can react quickly and provide or ask for further clarification. This communication channel also allows team members to more easily learn about each other, thus contributing to the development of trust and commitment to a project (Connaughton and Daly 2004; Kraut et al. 1987–1988). Used at the outset of a project, face-to-face discussions can facilitate the development of project vision, policy, tasks, group interaction guidelines, other coordination mechanisms, research objectives and outcomes; these issues are often ambiguous, have potential for conflict or are very complex in nature (Connaughton and Daly 2004; Poole and Zhang 2005). From these personal connections, the relationship can then be sustained through telephone and electronic communication channels (Connaughton and Daly 2004). Interestingly, despite the increasing reliance on electronic communication, the need for face-to-face interactions has not diminished, even in the 20 years since Daft et al. (1987) argued for this interaction.

However, geographically dispersed teams face trade-offs with face-to-face interactions. First, travel time and costs can limit the frequency of such meetings, which can slow decision making and project reporting. In addition, unlike text-based communication channels such as emails and listserves, no deliberate record is created from these meetings. A team member must be assigned to create these records after the fact.

Emails and other text-based asynchronous communication, such as blogs and wikis, are a second channel used in collaboration. These forms overcome some of the barriers that are inherent in face-to-face communication because the sender and receiver do not have to be in the same place at the same time. In addition, this method is relatively inexpensive, especially when compared to the current cost of travel. Project updates can also be sent to many people at once and quickly without waiting for a meeting. This can become particularly important when team members are distributed across a wide geographical area. Finally, with the ability to archive, permanent records of decisions, tasks and deadlines can be created (Poole and Zhang 2005).

However, this communication channel presents other challenges. Producing text-based communication can be very time consuming and may require more effort than verbal communication. In some cases, people type slowly and may omit details that they may be more likely to share orally, especially since a permanent record is created. In addition, due to the asynchronous method of accessing email, team members may be limited in their ability to participate in decision making in a timely manner (Warkentin et al. 1997). This problem can be acerbated further when a team is working across many time zones. In some cases, one person may find themselves excluded from email discussions given that their working day does not correspond easily with their team members. While emoticons provide some, text-based communication does not provide all the cues present in face-to-face communication which may present difficulties in developing consensus or resolving conflict (Poole and Zhang 2005; Warkentin et al. 1997). In addition, given the complex and ambiguous nature of many academic research projects, email may not be the most effective method for resolving "complex problems about conceptual and methodological developments" (Newell and Swan 2000, pp. 1308). Finally, people are not

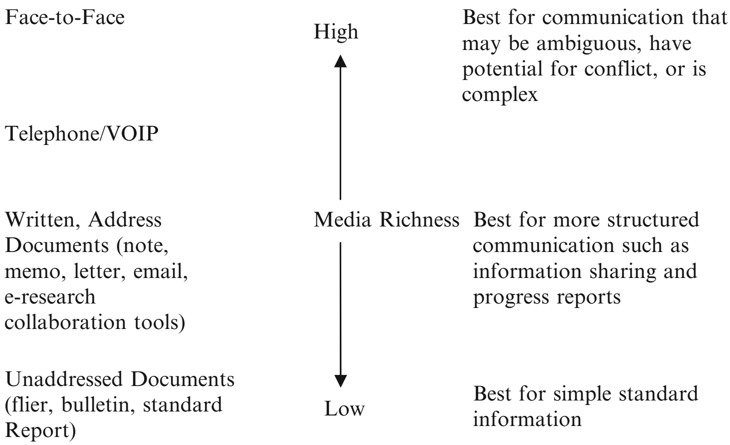

Fig. 1 Hierarchy of richness (Connaughton and Daly 2004; Daft et al. 1987; Poole and Zhang 2005)

always reliable in answering email promptly due to travel and other commitments (Lawrence 2006). Team members may also have differing expectations of appropriate response times for email and other text-based digital tools.

Conference calls, either by telephone or VOIP, and instant messaging/chat rooms overcome the same space requirement inherent in face-to-face communication while still allowing for real time communication and feedback, and transmission of some important cues (Daft et al. 1987). The integration of video cameras into many computers has allowed some teams to incorporate the visual within conference calls. However, these calls come with their own challenges. Sometimes, people may talk over each other, an annoyance which can be further complicated by time delays and problems in transmission. In the case of instant messaging, those individuals who type slowly may be left out of the conversation (Warkentin et al. 1997).

As can be seen, each communication channel presents benefits and tradeoffs. As a result, each team must decide the best methods for communication and collaboration given these. One tool which can guide decision making is the hierarchy of richness proposed by Daft et al. (1987), as shown in Fig. 1.

Within this context of communication and collaboration, the question to consider is the ways in which interdisciplinary academic research teams draw upon collaboration tools, digital and others, to facilitate their research. To answer this question, a case study of one academic community heavily involved in e-research collaboration will be explored.

3 Methodology: Case Study of Digital Humanities Community

Drawing upon the experiences within an interdisciplinary academic community, the role of in-person interactions and e-research tools and their impact on collaboration will be explored. The academic community is Digital Humanities (DH), which is a field of study that is, by necessity, interdisciplinary. Broadly speaking, DH involves the application of computers and various digital tools and resources to the study of Humanities. This community has been among the early adopters of e-research tools. Given the research complexity, teams are often comprised of content experts, computer scientists, programmers and software developers, library and information specialists, and students. Research outcomes include analytical software, databases, electronic manuscripts and texts, and websites (Schreibman et al. 2004). For examples of Digital Humanities projects, please see TAPoR (http://portal.tapor.ca/portal/portal), INKE (http://www.inke.ca/), Internet Shakespeare Editions (http://internetshakespeare.uvic.ca/index.html) and others. These teams are generally geographically dispersed while the research remains highly integrated and coordinated (Siemens 2009).

The data reported on in this chapter is drawn from a larger study examining research terms within this community (Siemens 2009). This research used a qualitative approach with in-depth interviews with members of various multi-disciplinary, multi-location project teams in Canada, the United States and the United Kingdom (Marshall and Rossman 1999). The interview questions focused on the participants' definition of teams; their experiences working in teams; and the types of supports and research preparation required to ensure effective and efficient research. As part of the interviews, participants discussed their use of digital tools for communication and collaboration.

A grounded theory approach guided the analysis with a focus on the themes that emerged from the data. This analysis was broken into several steps. First, the data was organized, read and coded to determine categories, themes and patterns. These were tested for emergent and alternative understandings, both within a single interview and across all interviews. This is an iterative process, involving movement between data, codes and concepts, constantly comparing the data to itself and the developing concepts. The literature was also drawn upon to support the data analysis and interpretation (Marshall and Rossman 1999).

4 Findings: e-Research Communication Tools, Uses and Drawbacks

The individuals interviewed currently are and have been part of a diverse range of team projects, in terms of research objectives, team membership size, budget, and geographical dispersion. Team membership was drawn from their own institutions and, in many cases, from other organizations nationally, and/or internationally, meaning that these teams operated across time zones. The roles they play were and continue to be varied and include research assistant, researcher, computer programmer and developer, lead investigator, and others. Within their work, these individuals and their teams rely on face-to-face communication, conference calls, emails, listserves, wikis, and blogs.

Table 2 Tools, uses and drawbacks

	e-Text	Verbal
Types of communication and collaboration tools	• Wikis • Blogs • Websites • Email/listserves • Online project spaces • Instant messaging	• Face-to-face (formal and informal meeting) • Conference calls (telephone and VoIP)
Uses	• Recordkeeping/archives • Information sharing/reporting progress in timely manner	• Meals/drinks as motivation • Create personal connections/ bonding • Create a sense of team/ commitment and obligation to the project • Social atmosphere • Deal with "thorny" issues • Develop work plans • Scheduled work time on project tasks
Drawbacks	• Seen as one more thing to do • Easy to ignore • Difficult to create personal connections	• Time/travel/costs • Difficult to demonstrate progress/ results on conference call

Given the nature of DH research and the geographical spread, the teams in which these interviewees were members showed an affinity for electronic communication within their collaboration. However, despite the community's networked relationship, the need for face time has not disappeared. This particular point will be explored below. A summary of the various communication and collaboration channels and uses are outlined in Table 2.

The e-research tools were primarily text-based and included wikis, blogs, websites, email, listserves, shared online project spaces, and instant messaging. For example, many teams established wikis and blogs for record keeping of decisions, tasks and deadlines. Two participants mentioned that wikis were used to take notes during meetings, thus creating instant records. Another interviewee reinforced this use of wikis and listserves by stating "that a successful team needs recordkeeping". In fact, one participant stated that they missed the project blog "when it had to be shut down for a while". This blog ensured that "information pertaining to standards and protocols are available in the latest form to all team members" and provided a "history of the project".

Emails and project listserves are particularly useful for sharing information with many people. Teams generally established rules for listserves to ensure that information is sent to all team members without evaluating in advance who might need it. As one participant stated, "all email, no matter how trivial or focused on one person, needed to go to the listserve... because one does not know for whom that information will be relevant in advance". Another echoed this by saying that "everything is put on the listserve because one cannot decide in advance whether an item is important to a few". To manage potential information overload, many groups had a general listserve for the whole project with additional ones dedicated to subproject areas. Some teams also incorporated instant messaging for quick exchanges in real time. Finally, some teams used collaborative writing tools. One participant stated that "all of his grants are collaborative" and the teams in which he is involved use google.docs for writing and version control. Overall, these various tools prove to be particularly effective for those teams whose members are geographically dispersed and very busy.

However, despite all their benefits, the participants identified some challenges with these e-research text-based methods. For example, wikis were often perceived by group members as just one more task added to an already full schedule. In addition, participants were disappointed that wikis are not yet fulfilling their expectations as a collaborative writing tool. They felt that this change may come as people become more familiar with the software and process. Of course, all participants identified the challenge of overflowing email inboxes and the fact that some team members do not respond to emails in a timely manner, if at all. Also, they stated that email is often susceptible to misinterpretation because it lacks context. One participant also highlighted that "people read the email and think that they understand and may be totally wrong". Finally, the participants found that it is difficult to bond and create the personal connections necessary for trust and accountability over email. To overcome this often impersonal nature of email, one team posted all members' pictures to their project bulletin board and ensured the photos accompanied all messages. While this was originally thought to be slightly "hokey", this move was useful in creating connections, especially given the project's geographical diversity. This team plans to explore the potential of video conferencing to further exploit the advantages that come from "seeing the face".

These research teams also draw upon verbal communication channels. Regular conference calls are standard for many teams, though the telephone has been replaced largely by VOIP systems, primarily due to cost. This community appears to be among the early adopters of this technology. Besides conference calls, the various research teams use face-to-face meetings to facilitate the collaboration. The frequency of these interactions varied according to the team and project. The importance and value of these face-to-face conversations should not be underestimated. From these discussions, the crucial atmosphere of personal obligation was created. As one participant stated, people do not necessarily feel responsibility for the work or team unless they meet in person or communicate by phone. In fact, one respondent stated that one project that they had worked on "was not successful because they did not have any face-to-face contact". Funding was not available to meet in this manner. In this interviewee's opinion, "phone does not replace the face-to-face". Another stated that "being in the same room meant that social capital could be built up in tangible ways". To reinforce this idea, a third participant stated that these meetings allowed for "cohesion building", though they were not done primarily for that purpose.

One interviewee stated that yearly team meetings served two primary purposes. First, the gatherings were an opportunity "to review the previous year's work and outline the tasks for the upcoming year". Second, they were also the time to resolve those "thorny" issues that could not be easily addressed on conference calls or by email. As one participant stated, breakthroughs came when people met together. The meetings were also a time to have a "big dinner with wine, leaving everyone happy" as they return home, in the words of one interviewee. Another participant echoed this thought with their own experience. Their planning consisted both of the formal agenda as well as dinner and drinks. These two different types of interactions serve to reinforce "the working relationship that sustained the team through the project's stresses and strains". They went on to state that "since the team did not have day to day frequent interaction, there was potential for the project to spiral out and for people to do their own thing otherwise". Another participant stated that their research group did not feel as much like a team when there was too much time between meetings. Finally, several participants commented on the value of conferences as another avenue for personal communication and an opportunity to continue developing personal relationships. In fact, one participant realized that they no longer attended many papers while at conference because they were busy meeting with their collaborators.

Besides regular planning meetings, some of the research teams scheduled face-to-face work time. These opportunities provided concentrated time, often away from home institutions and daily commitments, for team members to work collaboratively on assorted project tasks. The participants who used these types of interactions stressed that the time was not for meeting, but rather concentrated work time that allowed for clearly identifiable progress and "to push past obstacles" on the research project. As one interviewee stated, "lots of work gets done" at these sessions. Ultimately, in-person meetings helped to refocus everyone back on the project or "reboot the machine". One interviewee felt that "three to four people is an efficient size" for this type of meeting.

As can be seen, these teams draw upon the more media rich channels for the more complex discussions, the ones focused on resolving conflict, planning work and deadlines, and creating productive working relationships. The face-to-face meetings are critical in this regard with the combination of formal agenda and informal discussions over meals. To date, these teams have not found a way to replicated these within the online environment. Again, the use of these media rich channels becomes important for developing the relationship that sustains the work once teams collaborate in the electronic environment. The less media rich channels such as emails, listserves, wikis, blogs, and project spaces are used for information sharing and recordkeeping. At the time of the interviews, these participants were not using social networking, such as facebook, within their teams, but that may be another e-research tool to explore for its potential.

5 Implications of Research Results: Finding the Balance Between e-Research Tools and In-person Communications

DH teams are similar to other types of academic research teams. They draw upon a variety of collaboration and communication tools to facilitate the research and experience similar types of challenges, including coordination, communication, and others (Cummings and Kiesler 2005; Deepwell and King 2009; Lawrence 2006).

Perhaps the primary implication from this research is the need for balance between e-research tools and in-person interactions. Digital technology can supplement, but cannot fully replace the face-to-face in collaboration. The balance between these will change over time according to different research objectives and the relationship between team members (Kraut et al. 1987–1988). A greater use of digital tools may be possible in research projects where people have an extensive history of collaborating with each other. In her review of a large e-research science project, Lawrence (2006) found that since many of the members had worked together previously, the team was able to incorporate greater use of e-research technologies. However, the team still relied on "old-fashioned" methods with video and telephone conference calls to build links with new members.

This balance needs to be built into project plans and budgets. As discussed, the in-person interactions not only allow for project planning, but also provide an opportunity for team members to learn about each other on professional and personal levels. Handy (1995) argues that the more that a team operates virtually, the more that it must create opportunities for face-to-face interactions. These types of meetings focus on process and facilitate learning about each other and building trust, rather than solely on tasks. These are particularly important at a project's beginning stages, where the ambiguity and potential conflict are at their greatest, especially when individuals from different academic backgrounds and training are involved, and when team members must develop a common understanding of the research project, methodologies, tasks and deadlines (Cramton 2001). These initial meetings set the tone upon which team members can operate effectively and efficiently in the virtual environment. At the same time, regular face-to-face meetings, both for the hard discussions that can be difficult over email, but also for reinforcing that sense of team, must be scheduled. A caution in this regard, travel may become less exciting over time (Cummings and Kiesler 2005) and may be hard to balance with other obligations over the longer term. As teams move to incorporate e-research tools, they need to ensure that everyone's computer is adequate for the job; otherwise, frustration can ensue.

As the collaboration and research progresses, project leaders and other team members might consult the hierarchy of media richness to determine appropriate communication and collaboration channels in advance. For example, for discussions, particularly for those potentially contentious issues, face-to-face meetings or conference calls might be the most appropriate. Dedicated work time as a team can also be a possibility for deliberate forward movement on particular project tasks (Ruecker et al. 2008). On the other hand, text-based communication might be the most appropriate for record keeping and document storage. As individuals become more comfortable with wikis and other similar tools, on-line collaborative writing might become more popular. These online tools can facilitate the various tasks, such as brainstorming, outlining, drafting, reviewing, revising, copyediting and controlling document versions, associated with collaborative writing (Lowry et al. 2004).

While these participants were silent on the characteristics of effective e-research tools, other research suggests what is needed. Ultimately, teams need to easily develop, manage, track and store tasks, information and documents, facilitate ongoing communication, make group decisions, and schedule meetings and other tasks (Cummings and Kiesler 2005; Deepwell and King 2009). The range of e-research tools that accomplish these include, and by no means limited to, portals, data repositories, software, data sources, content and project management, document sharing and e-publication. Examples might include mynetresearch (www.mynetresearch.org), Sakai Project (www.sakaiproject.or), webex (www.webex.com) and basecamp (www.basecamphq.com) to name but a few. To be useful, any e-research tool must work across computer platforms and operating systems. The key challenge for teams is to find ways to incorporate these effectively and efficiently (Severance et al. 2007). Again, a balance must be struck within the use of e-research tools. They cannot generate additional work for team members or otherwise they will not be incorporated. In addition, any tool must be simple and easy to use, especially for those using collaborative technology for the first time. Teams might also consider using the tools, such as email, online calendar systems, listserves and conference calls, already at their disposal more effectively and efficiently, rather than incorporating new ones (Deepwell and King 2009). Lawrence (2006) suggests the establishment of communication and collaborative norms and expectations with questions such as “Who should be informed of events?” “What issues need to be discussed and in what format (email, teleconference, face-to-face)?” “What are expectations of requirements for participation, frequency and timing of meetings?” “How will time zones be rotated?” and “What are protocols regarding flagging urgency in emails and decision-making?” Ultimately, she suggests that simple may be best while teams strive to communicate while not overwhelming individuals. Teams must agree to use these tools and abide by the norms over the life of the project. At the same time, opportunity exists to revisit these decisions, especially as technology becomes cheaper and more accessible. For example, many computers now come with video cameras opening the possibility for inexpensive video conferencing.

Research teams must communicate regularly through a variety of channels to develop collaborative relationships. Through communication, team members can share information and build trust and excitement (Poole and Zhang 2005). Geographically dispersed teams can be overwhelmed by time zone differences which may create a sense of isolation among team members (Deepwell and King 2009; Poole and Zhang 2005). Regular communication, especially that which incorporates the personal, can address this. In these cases, the personal can include discussion of the weather and family, the types of interaction that often occurs between colleagues meeting in the hall or at mailboxes. Posting pictures to project websites can also be useful in this regard (Majchrzak et al. 2004). Research teams must establish the collaborative relationships, in whatever form, early in the project and realize that it takes time for a team to incorporate these tools into their work patterns (Deepwell and King 2009). Finally, the importance of informal communication which occurs at non-project meetings, such as conferences, should not be underestimated. These opportunities can facilitate the building of trust among team members without necessarily engaging difficult topics.

Finally, an opportunity for advocacy with granting agencies exists. Many funding agencies are strongly encouraging collaboration between researchers across universities, other research institutions and the general community in order to deal with complex and integrated research questions and problems (Newell and Swan 2000). To achieve the level of collaboration that these grants require, researchers must argue for increased travel and hospitality funding. As discussed, face-to-face meetings are an important collaboration tool which cannot be easily replaced with e-research tools. Funding agencies must realize that increased cost and coordination is involved in these types of collaborations and then provide the necessary resources (Cummings and Kiesler 2005; Lawrence 2006). At the same time, funding agencies can also play a role by developing guidelines and best practices for collaboration, face-to-face interaction and e-research tool use (Deepwell and King 2009; Lawrence 2006). As one example, Canada's Social Sciences and Humanities Research Council (SSHRC) commissioned a review of the Major Collaborative Research Initiatives (MCRI) Program which provided a series of best practices to support large scale collaborative projects (Kishchuk 2005).

6 Conclusions and Recommendations for Global Research Teams

In conclusion, e-research tools are expanding the opportunities for collaboration among academics, particularly those who are geographically dispersed. No longer is recruiting the right person to a project limited by geography (Cramton and Webber 2005), but that geography still creates challenges that must be overcome by the team. To be effective, global teams need to apply various communication and collaboration tools, drawing upon their respective strengths, in a variety of purposes within the project. As discussed, a balance between e-research tools and face-to-face is needed for effective collaboration. Given the importance of face-to-face meetings for creating and reinforcing personal relationships, establishing research direction, and resolving ambiguities and "thorny issues", global teams could envision these types of meetings at the beginning of the collaboration and at regular intervals in the project's life. From that base, teams could rely further on e-research tools for task coordination, recordkeeping, document sharing, and reporting, using these tools to their best advantage. Ultimately, as explored above, each research team must negotiate the right balance of these tools for their members given factors such as the history of the work relationship among team members, the team's geographical spread, comfort level with various e-research tools, travel and hospitality budgets, and others.

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Gaps and Bridges in Interdisciplinary Knowledge Integration

Zack Kertcher

Abstract By definition, e-Research is one of the largest and most diverse laboratories pursuing interdisciplinary knowledge integration. Using a qualitative analysis of a prototypical e-Research collaboration, this chapter presents a theoretical model of knowledge integration across professional cultures. This model, supported by the theory of epistemic cultures, highlights three types of "gaps": a collaborative gap results from cultural differences among innovators and entrepreneurial users; an entrepreneurial gap stemming from cognitive discrepancies between entrepreneurial users and mainstream adopters; and a systemic gap that is rooted in paradigmatic differences across fields of practice. Accommodating these gaps are three "bridges", individuals, organizations and technologies that connect the otherwise separate cultures and facilitate the transfer of knowledge. Implications of gaps and bridges to e-Research and recommendations to technology development are suggested.

1 Introduction

Combining knowledge from different domains is the essence of innovation (Anderson and Tushman 1990; Fleming 2001; Leonard-Barton 1995), as it offers individuals and organizations a potent recipe to break away from cemented, path dependent cognitive molds (Dosi 1982, 1988; Nelson and Winter 1982). Firms have realized some of the potential of integrating knowledge beyond their boundaries through increased use of alliances, by forming joint ventures, or as a part of a network where knowledge is transferred across organizations (Owen-Smith and

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Powell 2004; Garud and Karnøe 2003). For almost a decade large-scale science and technology initiatives around the world, named Cyberinfrastructure, e-Science, or more generally e-Research (Hey and Trefethen 2005), have forged new paths by experimenting with a new model of knowledge integration: instead of combining knowledge across organizations based on their core competencies (Prahalad and Hamel 1990), they combine knowledge across different communities of practice (Brown and Duguid 2001; Carlile 2004).

A typical disciplinary composition in e-Research projects involves several computer science innovators who collaborate with entrepreneur users from an academic field, such as physics or biology. Together, innovators and users develop a new technological platform that is based on distributed computing to offer a markedly unique alternative to the technologies and practices of a scientific community. The fundamental premise of e-Research is that these alternatives will gradually diffuse to mainstream users, ultimately bringing about radical change across fields of science and engineering (Atkins et al. 2003; Foster 2005).

Integrating knowledge across different communities enables e-Research projects to have a transformative potential. At the same time, the manifestation of this potential is particularly challenging because it involves individuals who are embedded in different disciplinary cultures. Every community fosters its unique "epistemic culture" (Knorr-Cetina 1999), involving unique professional jargon, objectives, organizational structures, use and perception of technology. These distinct cognitive frames that are tightly coupled with community-specific practices may not be easily integrated with knowledge from another community. Indeed, several recent studies have demonstrated barriers surrounding interdisciplinary knowledge integration to prevail in the context of e-Research (Barjak et al. 2009; Cummings and Kiesler 2005; Jirotka et al. 2005).

Through a qualitative study on an e-Research project in the social and behavioral sciences, this chapter contributes to research on diffusion of innovation and to studies of institutional change (DiMaggio and Powell 1983, 1991; Rogers 2003). Building on the theory of "epistemic cultures" (Knorr-Cetina 1999), and related works on communities of practice (Brown and Duguid 2001; Carlile 2004), I identify three types of challenges, or "epistemic gaps" to interdisciplinary knowledge integration. This theory is divided into three parts, each one corresponding to the location and the timing of gaps: the collaborative gap, the entrepreneurial gap and the systemic gap. Using data collected from a case study on the responses of collaborators to the challenges they confronted and the strategies they followed to address these gaps, I explore the roles of "epistemic bridges" in interdisciplinary knowledge integration. The main argument in this chapter is that while e-Research projects that integrate knowledge across communities of practice are designed to bridge epistemic gaps at the systemic level, gaps found at the institutional and collaboration levels stymie these efforts. However, the use of social and technological bridges at these stages can serve innovators to overcome gaps and support the transformative potential of the innovation across different communities of practice. In the final section of this chapter, implications of gaps and bridges to e-Research and recommendation to innovation development are suggested.

2 Knowledge Integration Within and Beyond Epistemic Cultures

Originally developed utilizing a comparative ethnography on high-energy physics and molecular biology, the theory of "epistemic cultures" provides a well-known conceptual framework for the analysis of professional communities (Knorr-Cetina 1999). An important aspect of this framework is the consideration of the culture of a professional community – such as a medicine or biology – as a primary vessel of practice. Along with developments from Brown and Duguid (2001) and Carlile (2004), the epistemic approach suggests that being a part of a community of practice provides individuals with a common set of tools necessary to carry out their roles. These tools include specialized paradigm, knowledge, routines, artifacts, technologies – as well as perception of these technologies – organizational structures, specialized jargons, methodologies and validity claims that are shared by members of a professional community. All these tools are intrinsically related to one another, a relationship that provides each one of them with a significance that is particular to a community.

The theory of epistemic cultures also highlights the process that leads to associations among diverse cultural building blocks as a collective enterprise. Individuals who carry out their daily tasks both enact their professional culture as well as continuously refine it in infinitesimal ways. Specialized journals and publications help to synchronize a shared professional consciousness that enables thousands of photocopier technicians in Xerox and in other firms, or molecular biologists around the world, to understand, communicate and collaborate with their peers (Brown and Duguid 2001; Knorr-Cetina 1999).

3 The Puzzle of Interdisciplinary Knowledge Integration

The epistemic culture framework helps to understand the intricate cultural mechanisms that govern work and make professional communities distinct from one another. At the same time, pooling knowledge across communities of practice is an important feature of innovation (Brown and Duguid 2001; Carlile 2004; Leonard-Barton 1995). Since innovators are typically more focused on the technology they produce than the community they cater to, it is advantageous for them to team up with entrepreneurial users who can provide crucial knowledge about the epistemic culture of their community (von Hippel 1986).

The need to incorporate entrepreneurial users in innovation development becomes more essential when an innovation – like e-distributed computing technology in e-Research – is expected to go beyond an established market, or to involve multiple communities that are less known to innovators. Being more familiar with the culture of their own community of practice, entrepreneurial users also play an important role in disseminating knowledge about the innovation to their peers. The conceptual challenge, then, is to understand how the process of interdisciplinary knowledge integration works in light of divergent epistemic cultures of innovators and entrepreneurial users. To address this puzzle, I propose to first consider the possible barriers of interdisciplinary knowledge integration projects, which I term "epistemic gaps".

Figure 1 illustrates the location and timing of the three main gaps. The first one becomes evident in the initial stages of interdisciplinary collaboration. Collaborators from each of the participating fields bring unique competencies. Innovators bring knowledge and ideas about their innovation, such as a computer technology. Entrepreneur users contribute knowledge that is specific to the epistemic culture of their community. However, because different epistemic cultures are involved, each one with specialized professional language, unique objectives and idiosyncratic understandings of technology, collaborations are bound to suffer from cultural impediments to interdisciplinary collaborations. I term these types of challenges

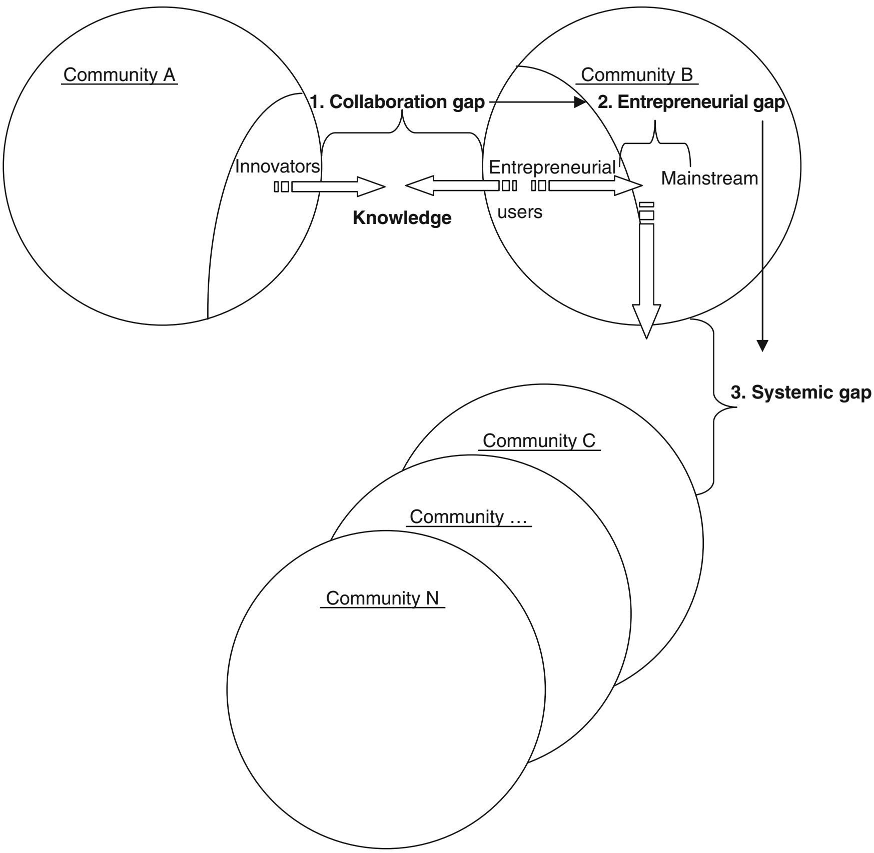

Fig. 1 The location and timing of epistemic gaps

the "collaboration epistemic gap". Interdisciplinary epistemic gaps are found in a variety of cases, including Galison's (1997) analysis of the cultural gaps found in the interdisciplinary team that developed the radar, and a stream of recent ethnographies on e-Research projects (Jirotka et al. 2005; Zimmerman 2008).

Innovation graveyards are full of technologies that did not attract adopters beyond a small group of entrepreneurial users. If the development team manages to overcome collaboration gaps and integrate specialized knowledge from the different communities involved, innovators and particularly their collaborative entrepreneurial users need to solicit other prospective users who are not a part of the small groups of entrepreneurial users to adopt their mutual innovation. Engaging these users is arguably the most challenging part of the innovation process (Moore 2002). I call this challenge the "entrepreneurial gap".

As indicated in the demarcation of entrepreneurial users in Fig. 1, the entrepreneurial gap is placed between the smaller population of "lead" or entrepreneurial users and the large body of their more mainstream peers. The boundary around entrepreneurial users in this figure also indicates that they are cognitively distinct from their colleagues. It is the difference between what Rogers (2003) has called: "innovator" adopters to "majority" adopters. Found in every community of practice, the former ones are keen to consider innovative ideas that are distinct from those practiced in their community in significant ways. They are likely to have better knowledge and ability to integrate these new technologies, and if they do not, entrepreneur users are willing to assume the learning cost associated with cumbersome, preliminary designs (Rogers 2003) – often gaining considerable advantages from doing so (Porter 1985). At the same time, the majority of adopters are risk averse adopters and less willing to explore new ideas. They do not necessarily have the time, desire or ability to experiment or to learn an innovative technology; they follow the practices of their community more strictly.

The most radical innovations are those that not only change the practice of individuals in different fields of practice, but also lead to the creation of new ones (Schumpeter 1942). To paraphrase, these innovations constitute a bridges across epistemic gaps among different communities, serving as objects that enable collaboration around shared constructs, regardless of idiosyncratic epistemic cultures (Bowker and Star 1999; Carlile 2004; Star and Griesemer 1989). Accomplishing this task has been the premise of e-Research. Through the development of technological bridges that include a distributed computer infrastructure, each project joins computer scientists and entrepreneurial users from a scientific discipline who aim to use e-Research technologies to transform established practices within multiple communities of practice. The envisioned result typically also includes the generation of an entirely new field of science.

While the bridging of the systemic gap is the core vision of e-Research, accomplishing this objective is predicated on the ability to bridge the gaps that precede it: the collaboration and entrepreneurial gaps. In the following sections, I use data collected on an e-Research project to elaborate how these two gaps influence technological developments, as well as detailing the bridging strategies actors involved in the studied case have pursued to accommodate them.

4 Research Approach

To study challenges and strategies surrounding knowledge integration in the context of e-Research projects and as a part of a larger study on knowledge transfer in e-Research, I collected interview and archival data on ComDEV (a pseudonym), an e-Research project in the social and behavioral sciences. As recently noted, while engaging users from the social and behavioral sciences in e-Research is of considerable interest to funding agencies and computer science innovators, this engagement is likely to be more challenging, in comparison to other communities, such as engineering or high-energy physics (Barjak et al. 2009; Berman et al. 2005). Some of the identified differences are that the vast majority of social and behavioral scientists do not appear to have a need for a high-end distributed computer infrastructure, because they are less technologically literate, or because the research structure typically consists of a single investigator or a handful of collaborators. The collaboration of entrepreneurial users from the social sciences with computer science innovators in ComDEV, is therefore an extreme example. A study of such an example serves to highlight challenges and strategies that may be more nuanced in other contexts where the epistemic gaps between innovators and the targeted user community are narrower.

Semi-structured interviews with seven core ComDEV participants were carried out during the spring of 2007. The interviews lasted an hour, on average, were tape recorded and fully transcribed. To ensure the accuracy of the interview data, follow up email exchanges and interviews were conducted with three of the informants. Data from interviews were corroborated with extensive analysis of primary and secondary archival materials that were generated by the project – including publications, conference presentations, reports, and email exchanges in the various mailing lists.

5 COMDEV

COMDEV is a prototypical e-Research project. It features an interdisciplinary collaboration among computer scientists, software developers and domain scientists – in this case, social and behavioral scientists from three research organizations. Like many other e-Research collaborations, this was an exploratory 2-year project to which most of the contributors allocated only a part of their time, while also working on other, loosely related efforts. Despite these relatively modest contributions, the aim of ComDEV was ambitious: to generate a systemic bridge that can combine the various communities associated with the study of human communication. Presently, most students of human communication specialize in a single aspect of the studied phenomena; they are divided into communities of practice that separate experts of eye gaze, from speech scientists, from analysts of hand gestures. Each sub field has its own unique epistemic culture, with specialized instruments, types of data and theories. Operating under these specialized cultures obscures prospects of broader knowledge integration, because, as Ben explained:

> You can't translate across [these] domains. If you are sitting here and say 'aha', I understand speech. What if I am merely looking at eye gaze and that was my metaphor? I know nothing about speech, but I know about eye gaze. And then you are sitting in the same room with the person measuring hand gestures.

This cultural divergence has led a number of scientists to argue that the next major development should be a return to the cradle of the field in which theory was based on a consideration of a communicative system – the study of all physical, neurological and social cues involved in communication. Although, these ideas surfaced in the 1950s, because they were not linked to any methodology or technology they gradually faded.

Observing e-Research technological developments in other fields of science has prompted several advocates of the "system" approach to the study of human communication to join computer scientists who specialize in e-Research technologies in an effort to transform the research paradigm in their communities bottom-up. Synchronizing video, voice, image, text and numerical data from different sensors that measure both observable and "under the skin" activity, such as EEG and heart rate, into a publicly available online database, was the specific technological aim of the project. Access to various data on human communications that are harmonized in new ways would enable to "put the puzzle back together, sort of tearing apart all these individual measures, and see how they all fit back together", reasoned Eric. Or as Ben has put it, providing a systemic bridge would "literally create a new discipline". In this new discipline, scientists would be able to analyze large volume of diverse multimodal data on human communication. ComDEV used a distributed computer infrastructure and portal technology to generate a systemic bridge between different communities. Scientists were envisioned to log into the portal, deposit their data, run remote queries on large volumes of other types of data, identify new patterns across data and then collectively interpret results with the help of colleagues who specialize in different areas of human communication.

6 Collaboration Gaps and Bridges

To fulfill this vision, the first gap that needed to be bridged concerned the collaboration between "entrepreneur" social and behavior scientists with computer science innovators, two communities that did not previously interact, or shared knowledge. As a result, even the most rudimentary terms collaborators used had markedly different meanings. For example, social scientists regarded the word "coding" to mean some form of annotation of both quantitative and qualitative data, while the computer scientists used the same term as related to digital tagging of data and the creation of "ontologies" – a relational representation of frequently used concepts in a lexical system. Likewise, a "schema" that to computer scientists was a part of database design, was to social scientists more about a general description of research data.

At the same time, the problem of culturally-specific jargon cannot be attributed only to the lack of mutual collaborative experience of the communities involved in ComDEV. Moses, a computer scientist who was also affiliated with other e-Research projects in the hard sciences noted that while these communities are more "computer savvy then the social scientists that we've been working with… [they, too] have their own unique terms and whatnot, that sometimes overlap with our terms in computer science. They'll say something meaning one thing, and we'll hear it thinking it means something else".

The first collaborative bridge, then, has to enable the basic coordination platform. In his research on collaboration of physicists and engineers, Galison (1997) has identified one such bridging strategy to include a "trading zone", the exchange of rudimentary pidgins among interdisciplinary collaborators to convey abstract ideas and specialized jargons. However, attempts to establish a trading zone in ComDEV were not successful because elusive terms also related to divergent understandings of technology and were associated with different research objectives. Social and bio-behavioral scientists wished to develop e-Research technology that would enable them to integrate and analyze various types of data, and eventually advance a radically new paradigm for the study of human communication. Computer scientists, on the other hand, wanted something else entirely: to foster the adoption of their technology in a community that was not traditionally associated with distributed high-end computer technology, as well as further develop this infrastructure. Ben, a social scientist, summarized the difference: "their vision of the world and their goal is to proselytize and proliferate bigger and faster machines... They are not in [our] world. They have to be brought in".

6.1 Collaboration Bridges

ComDEV scientists devised human and technological bridges to overcome the epistemic gaps they experienced in their collaboration. What is interesting about both types of bridges is that they do not require participants to take the time to personally learn the unique perspective of their colleagues, or to generate a basic trading zone. After experiencing considerable communication difficulties, collaborators turned to the help of "translators" (Callon 1986; Latour 1987), in this case, individuals who were trained in both computer and socio-behavioral sciences. Knowing the language, technological perspective, work styles and the objectives of each community enabled these individuals to serve as "somebody that kind of understands both sides… working with people, trying to distill that handout from the scientists to [the developers of] ComDEV", explained Moses.

ComDEV was not the first time computer scientist innovators have used epistemic adapters to translate field-specific particularities of their entrepreneurial collaborators. Various informants have indicated that they have used people who fulfilled this role in other projects. Jason, another computer scientist who has worked in many e-Research projects – but was not directly involved in ComDEV – suggested that these individuals are crucial to the success of the interdisciplinary project because "they really are different cultures that one of the things we had to do was to try . . . to translate things". Even when working with more computer literate social and behavioral science entrepreneurs it is useful to include epistemic bridges. Informants have suggested that while developers were able to better understand and accommodate their requirements, "it would be nice if there was somebody in between them, that integrated functionality requirements feedback into one person that then could articulate it to the development team – and they can think of it in the more abstract sense". Without an intermediary, developers provided the users who were able to directly communicate with them a particular feature that was not necessarily a part of the broader aim of the project, or to the targeted scientific community.

People who are trained in multiple participating fields can serve as epistemic bridges that facilitate interdisciplinary communication, but they are limited in their ability to broker technologies and associated practices. Technology that is used to bridge systemic gaps, may also serve to bridge collaboration barriers. For example, some ComDEV social scientists have considered the development of algorithms and new tools that would capture multimodal physiological and social cues. Ben explained that once this technology is developed "then you have a database that you can develop with the ComDAT mentality". In other words, the development of these technologies that are specific to the scientific communities that study human communication were expected to ultimately broker social and behavioral sciences and high-end distributed computing, the core technological infrastructure of e-Research. With data streaming from different detectors and with appropriate algorithms to synchronize them, massive amounts of data may be analyzed. With the right infrastructure, informants believed, scientists will deposit their data, and will all benefit from the distributed data tools and high-end computational infrastructure their computer science collaborators were developing.

7 Entrepreneurial Gaps

The second epistemic gap that clouded development prospects has been the ability of collaborators, especially entrepreneurial users, to reach out and solicit mainstream users to adopt their innovation. As noted above, the aim of entrepreneurial users, such as the social and behavioral scientists in ComDEV, was to break long established cognitive molds, to transform the practices and paradigms of their community; they engage in what Kuhn (1970) has described as "revolutionary science". As such, they have a looser affiliation with their community. The users interviewed for this study characterized themselves accordingly. For example, in response to a question about his disciplinary orientation, Ben has portrayed it to be "across disciplines, or trans-disciplinary; it is looking at processes that unfortunately fall into many disciplines".

Being less grounded in a particular social and behavioral science niche proved to be challenging for these Young Turks when trying to solicit their peers to adopt ComDEV technology. Charlie, a social scientist in ComDEV considered this gap to a common one, he said:

> This is a classical problem in the development of any technology. People have certain knowledge and expertise but the development is sometimes a bit opaque to the end user. Sometimes it takes a huge number of iterations before it could be really accessible. The problem is just finding users who are willing to participate.

Charlie suggested that one reason that has led to this entrepreneurial gap was his colleagues' conservative approach to the technology they use, their research practices and the research paradigm they have cultivated over the years. (After all, they were not the ones pursuing paradigm change). For instance, compared to the more sophisticated computational tools he and his colleagues were using, he explained that some of his colleagues were still using paper forms to code observations, then copying these data to generic software, such as Microsoft Excel, for analysis.

A second set of the entrepreneurial epistemic gaps relate to the internal structure of the community and the social institutions that support these structures. As a part of the e-Research vision, the aspiration ComDEV scientists promoted was predicated on a more collaborative organization of scientific research that would lead to cross-fertilization of knowledge among experts in different areas of research on human communication. However, the practices and structure of an academic field dictate the degree to which such collaboration is feasible. There are fundamental institutional differences in the structure of high energy physics, where an experiment can involve hundreds or thousands of scientists from different countries (Knorr-Cetina 1999), as opposed to a sole researcher, up to a small team of scientists in a small lab – the dominant organizational model of social science research. The large collaborative structure of high-energy physics is supported by rewards to academic output, such as authorship, where all contributing scientists to an experiment are often listed alphabetically, across several pages (Knorr-Cetina 1999; Galison and Hevly 1992). In contrast, institutional rewards, including authorship, in the social sciences are tied to the traditionally small research structure.

Or consider data sharing practices. Whereas high energy physics experiments are based on collective gathering of data, ComDEV, as well as many of the other e-Research projects that targeted a community that was not used to sharing data among scientists, embody the classic free rider problem (Olson 1965). All members of the community gain when scientists contribute their data. But without mechanisms to foster or coerce the sharing of data, it is easier for scientists to use available repositories, without reciprocating by contributing their own collected data. Several other reasons make this practice more than sheer selfishness. Aside from the occasional funding grants that specify a requirement for data sharing, no formal negative or positive sanctions are established to facilitate data sharing.

Furthermore, the burden to provide this service to the community is high for an individual researcher or for a small lab because it requires them to provide adequate documentation and to conform to the common data standards that the databank supports, efforts that they do not typically need to advance their own research. In addition, sharing of data prior to publication of results is likely to work against the interest of contributors as they may suffer from researchers using these products to gain competitive publication advantage, with considerably less effort. Given that there are little, if any institutional rewards to foster data sharing in the social and behavioral sciences – no tenure evaluations are based on number of shared datasets – it is no surprise that this is a relatively uncommon practice in these fields (Wouters and Schröder 2003).

Without appropriate institutional mechanisms to support data sharing, it is hard to engage even those scientists who have the technological knowledge and a willingness to contribute data or experiment with ComDEV technology. Furthermore, community-specific rules and research procedures limit these explorations. Social and behavioral science research data typically contain information that may be linked to individuals and violate their privacy. Similar to the privacy regulation concerning medical records, specific rules and regulations surrounding social science data limit the ability of investigators to deposit their research data into a collective repository. Since ComDEV was based on the idea that deposited data will support collaborative, cross-disciplinary community of researchers of human interaction who together will advance a new paradigm, project participants have found the data sharing practices particularly troublesome. Eric, a social scientist, expressed his frustration: "data sharing is the biggest [impediment]; there are also issues like users, usability, manuals and documentation – but really, data sharing is the biggest one".

8 Entrepreneurial Bridges

Entrepreneurial gaps are hard to bridge because, as opposed to collaboration gaps, entrepreneurial users and innovators have little control over them. Nevertheless, applying similar bridging strategies to those used internally may facilitate innovation uptake beyond an internal collaboration. For instance, innovators recognized that they cannot solicit the adoption of their technology by using technologies or software interfaces that were developed in other projects because they required a considerable amount of learning from end-users. Instead, ComDEV developers have turned to open source solutions that provided them with flexibility to translate elements of the mainstream user work environment – through specialized "wrappers" that were connected at the backend to a distributed computer infrastructure, a technology that was considerably more technologically complex for social scientists to approach directly. In fact, according to computer scientists who devised these bridges, they have been the project's true innovation.

To develop bridging technologies, entrepreneurs still need to find ways to understand the epistemic cultures of their potential users, and to engage them in a technology that defies established practices (i.e., the sharing of data). Eric who worked with ComDEV has described the experience of enrolling scientists in a similar collaborative project as a grass roots effort.

> You call up people, you send them e-mails, your write chapters, you try to fix datasets, make the software that people can use it. You know, you just do stuff. You just keep on trying to do the best you can... It is really a few people working bottom-up to try to get this done.

Prior to enrolling these people many of whom were from related sub-fields of human communication, Eric had to spend time learning the cultural particulars of these communities. It is possible that, like in internal collaborations, the use of human bridges could have yielded similar results, but taken less time.

9 Conclusion

Culminating to date with dozens of projects around the world, e-Research is one of the largest and most diverse laboratories of interdisciplinary knowledge integration. By design, and as illustrated with the example of ComDEV, a common objective of these projects is not just to transfer novel technologies from innovators to users, but to bring systemic transformation to fields of science through close knowledge integration between innovators and entrepreneurial users. Specifically, these technologies are envisioned to serve as a conduit of new research practices that include the sharing of and access to distributed data, as well as collaboration across the boundaries of different epistemic cultures.

The experience of ComDEV participants demonstrates the fundamental gaps that impede e-Research from serving as a systemic bridge. It shows that collaborators experience communication barriers because the language they use relates to divergent practices and objectives. It further suggests that there are considerable challenges to engaging more mainstream users, as these users did not have the needed intrinsic or extrinsic incentives to adopt a new technology to dislodge them from entrenched practices. Although the recognition that gaps exist in interdisciplinary collaborations is not new, and that the enrollment of mainstream users is difficult is not surprising, placing these gaps in a conceptual framework has served to identify their dynamics more clearly.

As summarized in Table 1, perhaps the more significant contribution of this chapter is the characterization of the bridges actors employ when faced with epistemic gaps. Findings from the ComDEV project do not suggest that social and technological bridges enabled collaborators to fully overcome epistemic gaps; rather, they let them carry on with developments and enhance the adoption potential of their innovation. Nor are social and technical bridges the only way to address gaps. The use of coercion that leads to institutional change (DiMaggio and Powell

Table 1 Summary of epistemic gaps and bridges

	Gaps between	Reason for gaps	Bridges
Collaboration	Collaborators from different communities of practice	Specialized disciplinary knowledge, unique jargon and particular research objectives pose a challenge to knowledge integration within the collaboration	Human translators who are embedded in both communities bridge specialized knowledge across collaborators, offer a coordination platform that lubricates the internal flow of ideas
		Divergent agendas, idiosyncratic perception of technology amount to “different worlds” that are hard to accommodate	Technological bridges, such as specialized algorithms, may bridge divergent agendas and perceptions of technology
Entrepreneurial	Entrepreneur users who collaborate with innovators and mainstream users	Level of technological knowledge and interest in exploring new technologies separates entrepreneur users from their mainstream peers, posing a considerable challenge to accomplish systemic transformation	The use of technological bridges, including open source solutions that offer more flexible adaptation to mainstream technical environment, reduces the cost of adoption to mainstream users
		As opposed to mainstream users, entrepreneurs are willing to break away from institutionalized practices associated with the technological innovation, such as data sharing	While coercion – such as funding agencies establishing a requirement for data sharing – is a potent way to change entrenched social institutions, grass roots efforts of human bridges who work with selected mainstream users to change their practices, support gradual transformation within the community
Systemic	Across communities of practice	Communities of practice, even those associated with the same general agenda, foster unique epistemic cultures that hinder large-scale breakthroughs	Technological and organizational bridges, such as distributed computer technology and increased cross-organizational collaborations are used as systemic bridges, support paradigm shifts and the creation of new research fields

1983) – such as when mandating that funding is contingent upon the sharing of research data – can decrease the entrepreneurial gap. Setting up an organization that includes interdisciplinary teams of individuals who regularly collaborate with each other for extended periods of time, may also serve to narrow some of the collaboration gaps found in e-Research projects.

While these alternatives offer certain benefits, particularly their sustainable characteristic, I suggest that the bridging strategy described here offers several important benefits to innovation development. One advantage of the social and technical bridges identified in ComDEV is that they are more suitable to transient, dynamic projects. In a turbulent innovation environment that also includes e-Research projects, establishing a new funding regime, or relying on a single interdisciplinary team with an organization are not desirable options. A more favorable approach is, then, to use interdisciplinary individuals who can translate the culture of both innovators and entrepreneurial users. Without requiring all participants to gain deep understanding of the different cultures involved in the collaboration, bridging strategy can suit nimbler development projects.

Epistemic bridges also have a flexible attribute, compared to longer term solutions that tend to be more rigid, and therefore have limited applicability. The development of simple, relatively inexpensive tools and algorithms that can integrate the different characteristics of data on human communication, could enable a large body of researchers beyond the ComDEV collaboration not only to advance their research but also change their needs – to require access to the distributed computing and data infrastructure computer scientists develop. Similarly, supporting the development of an algorithm that can analyze feeds from the cameras placed in metropolitan areas around the world would turn social scientists who study urban processes into a data intensive community with practices comparable to astronomers or high-energy physicists who rely on e-Research infrastructure to handle petabytes of data (Hey and Trefethen 2005). The same process may be applied when applying these infrastructures to commercial organizations.

By extension, as opposed to the relatively slower strategies that emphasize the closing of epistemic gaps, nimble social and technological bridges can also serve to connect an innovation to other emergent technologies, and thus both increase its adoption potential across different communities, as well as its survival prospects when faced with competition. In the context of e-Research this has already been demonstrated to be curial with the inclusion of Semantic Web technologies. Making a winning bridging proposition, several years ago innovators from the Semantic Web community offered their knowledge and technologies to translate grid technology to additional user communities, chiefly biology (Goble and De Roure 2002, 2004). While the general practice of biologists did not necessitate the use of high-end distributed infrastructure, providing Semantic Web solutions that were undergirded by grid computing and offered biologists a potent solution to their more immediate problem of classifying large volumes of data, aided a considerably wider diffusion of e-Research technologies in this community.

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Building a Conceptual Framework for Creating New Knowledge Through a Virtual Interdisciplinary Environment Process

Lynn A. Wilson

Abstract This chapter illustrates practical and theoretical aspects of constructing a conceptual framework for an interdisciplinary online collaboration designed to co-create new knowledge. Insights are drawn from experience engaging natural and social scientific experts and practitioners in the research Consortium on Climate Change and Population Health. A conceptual framework is a set of broad ideas and principles taken from relevant fields of inquiry that are used to structure a subsequent activity (Reichel and Ramey (Eds.), *Conceptual frameworks for bibliographic education: Theory to practice*. Libraries Unlimited, Inc. Littleton Colorado, 1987). It establishes objectives, provides focus, rationale, integration tools and outlines possible courses of action. The goal of the Consortium framework is to assist in developing awareness, understanding and new ways to consider complex issues across disciplinary parameters while remaining open to new and unexpected occurrences and encouraging creativity. This approach could be applied across other fields and issues to provide conceptual clarity for guiding the process and for developing meaningful indicators and measurements. Key lessons include the need to support all participants in contributing to defining indicators that support successful action, flexibility in process structure and data scale, the value of developing complimentary competencies throughout the process, and the importance of incorporating various values and methods in outputs and outcomes.

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1 Introduction

We are drowning in information but starved for knowledge – John Naisbitt

Adaptation rather than adoption of information and methods are features of knowledge co-creation. Knowledge co-creation is a synergetic process combining content and methods from disciplinary traditions to synthesize new ways of knowing. Co-creating knowledge in a virtual environment necessitates performing the work online. This chapter explores fresh territory in applying online social networking systems, tools, theories of learning adapted to this technology, together with attention to cultural, disciplinary and organizational norms to enable and encourage innovative approaches to developing a guiding framework for complex issues.

The study in this chapter, the e-research Consortium on Climate change and Population Health, demonstrates a particular approach to developing a conceptual framework for creating new knowledge among diverse collaborators in a virtual environment. One purpose of the framework is to help reveal areas of potential agreement among diverse participants through inquiry into culturally influenced values and intentional actions. The value of this inquiry lies in aiding purposeful navigations of intergroup cultural commonalities and differences to improve communications for producing new knowledge on complex topics. It is hoped that the new knowledge will eventually result in better and more durable policy decisions on critical, complex topics.

The Consortium is as an innovative partnership between the NGO (non-governmental organization) SeaTrust Institute and private publisher IGI Global. The publisher provides the e-collaboration tools and a forum for publishing the results of the 2 year process. The research institute guides the discussion, analyses data, manages the process and edits the resulting publication(s). Boundary organizations such as NGOs have shown particular promise as precipitators of trust, a key element in interdisciplinary collaborative efforts (Olaniran 2008). The Consortium's purpose is to facilitate knowledge co-creation by developing an interdisciplinary collaboration of geographically dispersed experts and stakeholders whose members have a strong stake in innovative outcomes for climate change and human health. Collaboration is defined here as *an interactive process that engages two or more participants who work together to achieve outcomes they could not accomplish independently* (Salmons and Wilson 2009, p. xxxivv). Building a conceptual framework to guide this complex interaction of knowledge and actors is a crucial step in building new interdisciplinary knowledge that is both science-based and socially relevant.

Recent studies indicate that the understanding of science-based decision making is limited because "the practice of scientific dialogues has been hampered by the absence of a theoretical framework" (Welp et al. 2006, p. 171). The need for conceptual models to guide this type of complex joint scientific/social project, particularly for new areas of collaborative study, is supported by current literature (Genskow and Prokopy 2010; Smyth 2004). In the Consortium example, the paucity of scientific studies that link "climate change to resultant social, economic, and demographic disruptions and their knock-on health effects" (McMichael et al. 2006, p. 860; Michael et al. 2003) together with the frequent calls for improved ways to integrate natural and social scientific knowledge point to the need for developing new guidelines, indicators and other process aids for these types of collaborations. Highlighting models, theories, practical "reports from the field" in science, communications, technology and e-collaboration, this chapter aims to provide theoretical and practical guidance for structuring similar collaborative efforts. Particular attention is paid to aspects which differentiate e-research from more traditional face-to-face collaborative research efforts.

A good conceptual framework keeps work focused on key objectives and serves as a negotiating space within which to consider potential new objectives or rationales as learning occurs. It informs the research design and provides theoretical and practical reference points to steer potential courses of action collaborators might take. It allows for practical and purposeful integration of intergroup cultural commonalities and differences that apply to the project's goals – in this case knowledge co-creation. The process of building the conceptual framework described in this chapter structures the knowledge co-creation process without bounding innovation too tightly by specifically acknowledging outliers that may represent those marvelous "accidental discoveries" which often represent the most creative and innovative aspects of science (Taleb 2007).

2 A Structure for Knowledge Creation

Semiotics, the study of how meanings are constructed or understood, helps to assemble a bridge between disciplines. This project's knowledge bases include water quality, microbiology, marine and freshwater biology, ecology, public policy, ecological economics, infectious and waterborne diseases, nanotechnology, climate science, human dimensions and engineering. This framework explicitly focuses on values and systems in innovative knowledge co-creation rather than some other form of interdisciplinary collaboration. It uses the Index for Knowledge Co-Creation KC^2-O<™ (Wilson 2008) for interlacing content expertise, values, and relationships of information, people, organizations and ideas to help participants develop the specific research within the e-research collaborative design. This dynamic integrated system:

- Draws upon and integrates expertise from multiple disciplines in health, physical, biological, ecological and social sciences
- Engages stakeholders in creating and sustaining the process to ensure relevance for individuals as well as addressing the larger research goals
- Analyses potential adaptive responses within the process
- Creates new options through interdisciplinary and intercultural synergies
- Considers uncertainties and characterizes their implications for the specific policy decisions
- Identifies future research that identifies and prioritizes key knowledge gaps and creates potential partnerships to address those gaps

3 Theoretical Considerations

> I am always doing that which I can not do, in order that I may learn how to do it – Pablo Picasso

Theories provide sources for a project's rationale. They help inform the choice and implementation of methods. In the conceptual framework designed to provide a mental model for guiding this project's activities, theories are implied by both the strategies and outcomes described by the framework. The chosen theories lay the foundation for the ways in which Consortium actors and elements are connected and interrelated in the framework design.

Recent scholarship on social learning/e-learning and on developing a culture of collaboration (especially in interdisciplinary multicultural virtual settings) provides direction for this conceptual framework. Additional guidance from systems theory, network theories, conflict and discourse theories and lessons from e-research, e-collaboration, adaptive management and interdisciplinary science adds dimensions to the framework to help situate it in the social, cultural and virtual contexts that frame the operation of the collaborative.

4 Discussion

The framework's collaborative learning, both organizational and individual, is subject to a variety of influences as shown in Table 1. Argyris and Schon (1978) argue that individuals learn in the midst of difficult circumstances while contributing to organizational learning. They design action to achieve intended results. Schon (1983) points out that most difficult problems are characterized by different parties holding incompatible "frames" of a situation that affect behavior. Ajzen and Fishbein's theory of reasoned action and planned behavior further explains what influences behavior – intentions – which they contend can be predicted by beliefs when combined with perceptions (Ajzen 1985; Ajzen and Fishbein 1980). Bayesian learning theory, which contributes to a foundational reasoning for considering uncertainties in this framework, specifically identifies beliefs as the core element in predictions about relationships and uncertainty. Values underlie beliefs, influencing both beliefs and behaviors as shown within the cognitive hierarchy model of human behavior (Homer and Kahle 1988); values drive basic beliefs and attitudes, and as a result drive behavior.

The complex system of population health is a mixed scientific and social system that must be seen as more than an aggregation of studies within the fields. Population health has more factors contributing to its complexity than public health which traditionally concentrates on the individual (Minnesota e-Health 2008). Complex systems sometimes produce counterintuitive results which can become clear when examined from a systems perspective. An example of such counterintuitive results

Table 1 Theories applied in conceptual framework design

Theory category	Key features
Collaborative learning and behavior	➢ Learning occurs on multiple levels – individual and organizational ➢ "Frames" help individuals navigate complex situations at both levels ➢ Incompatible frames inhibit communication and affect behavior ➢ Values drive belief systems (subjective norms) and attitudes ➢ Beliefs can be predictors of intentions which influence behavior
Systems and adaptation	➢ Complex systems' contain features that result from interaction among system parts ➢ Relational numerics are used to include considerations of uncertainty ➢ Counterintuitive outcomes of complex systems may impact preferable choices
Discourse, network and communication	➢ Cognitive hierarchy preferences expert knowledge ➢ Expert knowledge primacy may be challenged by information consensus through public discourse ➢ Networks synthesize new knowledge through integration and preservation of norms, methods and factors ➢ Maintaining fairness through public discourse and information consensus instead of communicative rationality
Collaboration and conflict	➢ Collaboration processes can help bridge differences in frames ➢ Power and assumed hierarchies may be managed through collaborative systems ➢ Interdisciplinary processes often require negotiating methods, data and analytic assumptions

related to health comes from findings that macroeconomic fluctuations in unemployment and health have an inverse relationship between unemployment and mortality. This discovery is in direct conflict with individual studies' findings that unemployment is associated with increased mortality. The apparent paradox is resolved with the explanation that lower unemployment is an indicator of a healthy economy which creates social and work stresses that actually manifest in a decrease in general population health at a systems level (Roux 2007). Similar logic guides the systems approach within the Consortium.

Climate change has also proven to be more complex than the sum of models showing decreasing ocean thermohaline circulation and atmospheric chemical changes; not all areas of the world are responding in predictable or similar ways to the process that, when seen as a whole, shows an overall warming pattern of the earth's ocean and atmospheric systems and a mean sea level rise. Systems perspectives as shown in Table 1 are particularly important in considering questions that arise at the nexus of the complex systems such as climate change and population health. Both systems contain high levels of uncertainty. Rapid changes occurring at the nexus of these systems indicates the need for highly adaptive social and scientific expertise which is critical to today's learning especially when innovation is the goal (Bransford 2000).

Expert knowledge, a hallmark of systems that depend upon scientific knowledge bases, often presents inequalities that may impede rather than encourage collaborative knowledge building. Players who are not in equilibrium due to power, position or ability each assumes the primacy of his or her strategy (Camerer 2004). When expert knowledge assumes a power-based hierarchy, significant contributory expertise can be branded as less important. Because hierarchy is also endemic to political systems, this aspect requires conscious attention in a scientific expert/public policy interaction. Climate and population health studies incorporate a number of disciplinary norms which must be recognized and aligned while at the same time integrated into a new whole that preserves the original knowledge contribution.

Intercultural collaboration studies, communication and conflict theories suggest additional elements that need to be considered within the analytical frames through which to assess the contribution of policy actors' values to environmental decisions (Wilson 2007). Collaboration, particularly through information consensus, is often suggested as a positive approach to such differences (Dryzek 1997; Keil and Desfor 2003; Wondolleck and Yaffee 2000). However, care should be taken in equating collaboration with consensus. Instead, engaging differences at the edges of commonalities can provide optimum tension points that are often the most fertile ground for co-creating knowledge. Although potentially counterintuitive, purposefully juxtaposing differences in this way is frequently an "enabling condition" for discovering commonalities in innovative collaborations and allowing the unexpected to emerge.

Applied to complex collaborations, the theoretical concepts above inform the development of the social capital that influences power structures, organizational integrity and synergetic potentials needed to move towards shared goals (Arnold and Fernandez-Gimenez 2007). The impact of social theory on collaborations for co-creating knowledge between scientists and policymakers is evident in sustainability science discussions. Even when stated goals reflect synergetic partnerships among organizations and individuals, social perspectives affect modes and outcomes.

5 Towards A Conceptual Framework

> We have first raised a dust, and then complain we cannot see
> –Berkeley, *The Principles of Human Knowledge* (1710)

Intermingling complex systems of climate change and population health issues may appear somewhat chaotic. Yet as concerns escalate on these topics, they affect all areas of society such that "conversation and exchange of arguments become crucial at the interface of science and society, in particular when dealing with the complex problems related to global environmental change" (Welp et al. 2006, p. 171). Imbedding the tenets of the primary content of sustainability science within an interdisciplinary context will help the Consortium explore potential new solutions to climate change adaptation for population health by identifying vulnerabilities, sensitivities and indicators of adaptive capacities (Polsky et al. 2007) and targets that can be refined through interdisciplinary discourse and mapping in a virtual environment.

Requirements for clear goals and mutual parameters intensify when collaborative partners work across geographic distance and experience organizational, technical and cultural divides. It is particularly imperative that sustainability not only apply to the content outcome of the collaborative, but to the process of including and valuing participants who, whether from lack of resources, funding, power structures or geographic proximity, may perceive themselves as minimized in the discourse. Language and the ability to negotiate professional boundaries are particularly important considerations in integrating knowledge domains in *cyberinfrastructures* (Monteiro and Keating 2009). While a few reports indicate that this type of interdisciplinary negotiation has occurred in face-to-face contexts, this negotiation is occurring in a virtual environment. Knowledge validity, disciplinary assumptions, partial knowledge or understanding, uncertainty, and interpretive representations of data and knowledge over geographic distances and in online contexts all bear upon this process and its outcomes.

While many philosophical precepts influence this framework, it is important to remember that the central concept in designing the e-research collaborative is encouraging interdisciplinary innovation. A praxis approach was used in designing this system in which theory and practice inform one another through reflexive, iterative consideration. Process, degree of integration and outcomes all help to define a collaboration and can be used to define, monitor and evaluate the effort as illustrated in the Collaborative Integration Paradigm (Wilson and Salmons 2009) which describes who collaborates, why, how and to what degree they collaborate especially in virtual environments. Using an adaptation of this general process to elucidate understanding with a focus on electronic collaboration and synergy (Fig. 1), this conceptual framework concentrates on the "innovate" level. It encourages innovation through using a model for developing, maintaining and evaluating an interdisciplinary scientific collaborative – The Index for Knowledge Co-Creation KC^2™ which was developed from research on ocean science/policy interactions conducted from 2003 through 2006 (Wilson 2008).

Another view of the continuum of collaboration expands Bohm's notion of differentiation between discussion (negotiated information and opinions) and dialogue (all viewpoints considered valid)[1] (Bohm 1996) by adding a new category: innovation discourse. Innovation discourse breaks with traditional communicative action and related discourse theories that bind it by external rules – instead it is a vehicle for creations that transcend traditional disciplinary boundaries, methods and

[1]In his 1998 work *On Dialogue,* Bohm considers dialogue to be a reflective and iterative display of thought and meaning in a win–win situation that is essential for creating shared meaning, especially when communicating in small groups. He contrasts dialogue with discussion, defined as breaking to break things up. Discussion emphasizes winning or victory over another, which is counterproductive to exploratory collaborative processes.

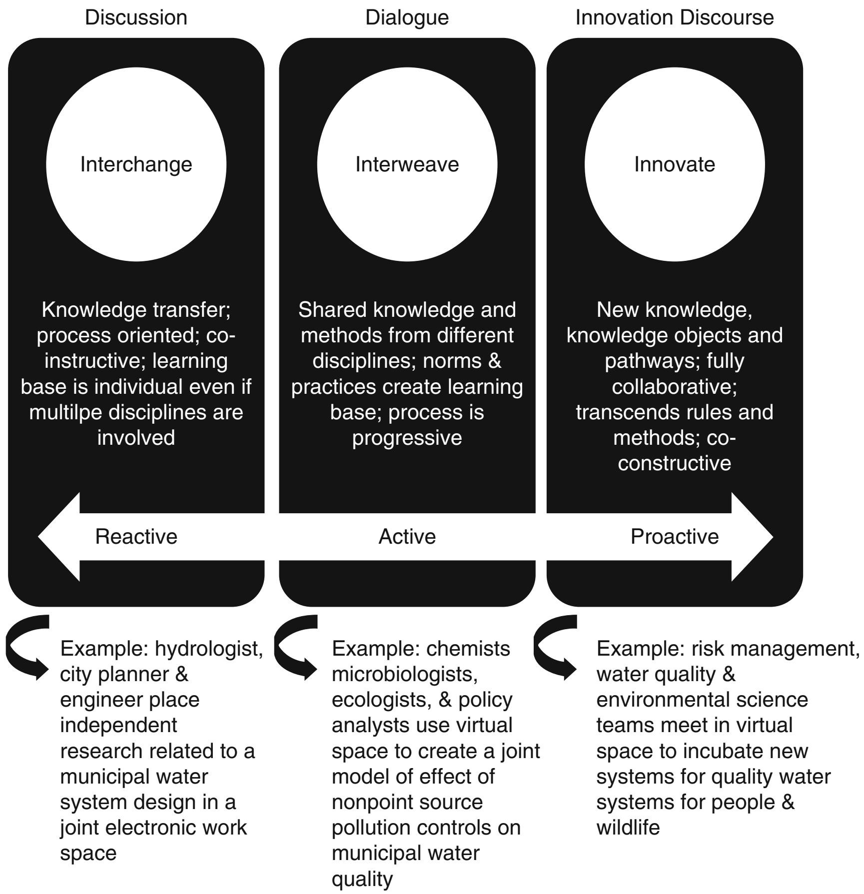

Fig. 1 Characteristics of e-research collaboration in degrees of collaboration appropriate for different outcomes. Adapted from Wilson and Salmons (2009)

power structures. Table 2 illuminates collaborative integration features of conversations as they relate to collaborative integration.

To create a context for the desired levels of collaboration, other conceptual lenses such as "boundary objects" are useful as negotiating spaces between actors. Concept maps and GIS maps serve as boundary objects through which actors can explore new information and potentially create new knowledge if objects can be created that are sufficiently process oriented and dynamic (see Lejano and Ingram (2009) for an ecological concept of interacting objects in policy space known as "Way of Knowing"). If too rigid, these objects may have the unintended effect of dampening innovation through an organization's own regulatory limitations and unequal power structures instead of developing and maintaining sustainable relationships between actors.

Table 2 Bohm's discourse differentiation with additions from the collaborative integration paradigm

Discussion type	Paradigm level (From Fig. 1)	Influence type	Characteristic philosophy	Purpose
Discussion (From Bohm: individual views are presented; positions are negotiated among participants)	Interchange	Convince others; point of view or position is important	Power of the better argument; hierarchical social structure; communicative rationality	Information exchange; structured, independent contributions
Dialogue (From Bohm: all viewpoints are considered valid; meanings and methods are exchanged to gain insights beyond those available individually)	Interweave	Include others; blending approaches	Consensus building, social learning, negotiated power and rules	Information and methods combination; new blended solutions to defined problems
Innovation discourse (Transcends rules and disciplines; methods and information fuse into something new)	Innovate	Contribute to something that is not recognizably "owned" by one party	Systems thinking; leadership synergy; transcends traditional boundaries	Knowledge co-creation; high creativity; climate for outcomes and questions not previously considered

In this framework, boundaries are considered by modifying a metaphor for knowledge building: using the registration of separate images to build a composite scientific image (Monteiro and Keating 2009). In this case, the registration of individual social and scientific models replaces separate images and the composite is new knowledge; the Consortium is tasked with correlating different knowledge domains into common understandings to produce new directions, research and suggestions related to climate change and population health. Conflict in thought processes, representations and priorities will no doubt arise. The challenge is to turn these conflicts into optimum tension points that create better registrations of the represented knowledge domains resulting in clearly articulated new knowledge.

6 Conceptual Framework Application to Process Design

Creating process clarity and identifying desired outcomes helps the designers frame and modify processes appropriately. Disciplinary process differences constitute one characteristic of the Consortium that defines it primarily as a science-based stakeholder activity. Just as registration is the outcome metaphor for considering this framework, a teleidoscope provides the process metaphor. A teleidoscope is a type of kaleidoscope with an internal arrangement of mirror systems. However it differs from a kaleidoscope in that the end piece is a clear leans that turns whatever it is pointed towards into a kaleidoscopic image. As interdisciplinary teams turn their lenses towards the project's issues, a new image is reflected by their composite disciplinary and methodological mirrors.

Structure must support the project's goals and intrinsic values as well as operate as a flexible negotiating space for actors. General criteria established as a rubric through which to create specific criteria for membership selection and guidelines for project administration may require modification. As the Consortium developed, issues of trust and optimum conditions for incubating innovative ideas had to be considered along with other process distinctions between science-based stakeholder dialogues and public participation. In particular, science-based stakeholder dialogues and innovative discourses must address scientists' concerns that involvement in public policy decision making may be at best not unrewarded and at worst could jeopardize their careers. Negotiating degrees of inclusiveness/exclusiveness led to design modifications such as the decision to report progress through web-based public events with opportunities for public comment instead of allowing public participation in open access workgroups.

7 Consortium Activities, Tools and Modifications

Based on the evolving criteria, the partners developed potential participant lists. While content expertise was certainly required, the other most critical factors for initial invitations were the prospective participants' desire to fully participate in a virtual knowledge co-creation process and their willingness to suspend disciplinary and cultural judgments of norms and values of other participants. This required making some difficult decisions about participant selection and necessitated adding steps (and time) in order to build capacity for other participants.

As an additional control, it was decided that an advisory group was needed to refine criteria and preliminary topics that would seed initial conversations. Advisors are part of one form of integrated assessment approach that includes stakeholder involvement as an integrating mechanism. Integrated assessment is "an interdisciplinary process of combining, interpreting, and communicating knowledge from diverse scientific disciplines… it should have added value compared to single disciplinary oriented assessment; and it should provide useful information to decision-makers" (Woodward and Scheraga 2003, p. 17). This approach supported the goal for Consortium members to prioritize the decision-relevant issues and uncertainties associated with climate change and population health. The original topic list for advisory input was designed using resources such as the Environmental Sustainability Index (Socioeconomic Data and Applications Center, SEDAC, 2009) that measures 142 countries' progress toward environmental sustainability using multiple indicators. Advisors and later Consortium members may choose different paths to investigate issues such as incorporating a vulnerability assessment to climate change in a social learning process (Polsky et al. 2007) or they may opt for more in-depth GIS analyses using the baseline resources.

The framework specifies systems for supporting synergy through technology as well as providing online tools and virtual spaces. These systems are designed to catalyze and support electronic collaboration within this group of participants from different institutions, cultures and disciplines through inclusive online processes. Following Welp et al. (2006), a combination of analytical and communications tools were decided upon to facilitate an innovation dialogue between scientists and other stakeholders. These choices were influenced by theories favoring the focus on values and beliefs. For example, a modification to traditional Bayesian Learning Theory was made in the analytical tool KC^2-O<™ by inserting a link representing a numerical "strength quotient" of impact intensities of related nodes to reflect the role of values and beliefs instead of assigning probabilities to the links between nodes. Because collaborative activities and the unforeseen occurrences that are the products of innovation in a dynamic innovative process will necessitate change, some continuity of structure may be sacrificed for the sake of ensuring that the group, process and knowledge objects might morph into new knowledge outcomes.

7.1 Communications Tools

To help keep the participants focused on interim deliverables building towards publication, synchronous and asynchronous working group sessions of the Consortium will be held in monthly synchronous sessions with breakout sessions in a modified learning management system (LMS) space as required during that same month. Quarterly open public web-based forums will engage interested publics. Different types of virtual spaces may lend themselves to certain tasks. For example, social networking sites may be used to recruit, ask questions of other researchers not in the consortium and communicate progress within the group and to the wider community and may range from wikis and blogs to invitation/membership or social and professional networking spaces for scholars in a variety of field and in specialized fields. 3D options like Second Life may be suitable if the activity involves role-playing (Gao et al. 2008) especially since these have been widely used for medical and health education (Boulos et al. 2007) as a place "where learning is achieved by exploration, reflection and collaboration" (Roush et al. 2009).

7.2 Analytical Tools

Consortium members participate in iterative content analysis while project leaders/ researchers simultaneously study processes and methods for encouraging creativity and new knowledge development. Drawing on experiments such as the COAST project in Croatia that used Geographic Information Systems (GIS) as a collaborative support tool (Santoro 2007) this framework considers public participation methods to elicit information about values, data, knowledge and methods from scientists and policy participants. Cognitive mapping and scenario building will help establish causal links between climate change and human health issues, and to reconstruct the discourse. By assigning numerical weighted measures and priorities with statistical linkages, iterative cognitive mapping reiterates aspects of the model that either consciously alters the content with new knowledge or alters the process. These tools will help to provide data for the process of linking climate change with population health issues and potential social adaptations (Fig. 2).

Data generated from the processes outlined above are useful in GIS mapping of the human and natural aspects of the selected issues. Team members can use GIS as a further negotiating space for prioritizing social issues that impact policy decisions as well as creating a spatial representation of the climate change and related health issues under discussion. For example, spatial scales must be negotiated by Consortium members at the beginning of the GIS mapping process because they are not reversible without changing the entire model. GIS users may aggregate data for larger scale but detail and outliers will be maintained so careful consideration and consensus about scale is an early activity. GIS mapping at the workgroup level will be integrated towards the project's conclusion into a composite map to show highlights of co-created knowledge and lead to new questions and/or projects.

Creating "Rules" for Collaboration

- Partners form interdisciplinary questions at a high level using advisors to "seed" discourse
- Group develops the method of "co-constructivism" of the e-research model and evolves step by step instructions
- Agree on time and spatial equivalence scales
- Modify instructions as model is applied to account for new requirements, outliers, uncertainties and unforeseen approaches to knowledge

Benefits: Process allows for the creation of new relationships and hence new social capital in this work and other settings; ideas for future research; and content and teams for the resulting book chapter.

Fig. 2 Preliminary analytical process steps

7.3 Index for Knowledge Co-Creation

A tool specifically considered in this framework to exploit the teleidoscopic potential in this project is the Index for Knowledge Co-Creation KC-O<™. It is used here to create a small number of participant-defined indicators that can be used by all participants and an additional set of supplemental indicators that may be of particular interest to individual projects or may address outliers. Using factor analysis to investigate values that provide metrics for these indicators, the Index links qualitative and mathematical models to allow for innovation within a structure and rigor so that learning is made explicit and new knowledge captured. As an analytical tool used to frame and facilitate the discourse it can also be used to represent interrelated values and other aspects of interdisciplinary relationships as weighted factors that represent participants' interests to give a snapshot in time of the process.

7.4 GIS

GIS is a common method of rendering physical data and is often presented in science and policy briefings and working groups, public meetings and is widely available on the internet. A GIS can depict a database, map or model view of the question under consideration. An increasing number of GIS projects depict human dimensions aspects in relation to geographic or other scientific phenomena such as the Wild Foundation map of the Human Footprint around Mar Banzena, Mali (Deutch and Wall 2006). Despite calls for "interactive GIS" systems with stakeholders (Daniels and Walker 2001) most GIS maps remain static rather than interactive tools partly due to the technical knowledge required for robust GIS mapping. This project aims to use GIS as an analytical tool to purposefully aid in the process of co-creating knowledge as a step towards greater interactivity.

GIS baseline data will be derived from available geographic and health datasets and from project participants' research that specifically relate to climate change and population health. Workgroup level GIS mapping will function as a framing and self-evaluation tool. Some maps may include the topics in Fig. 3 or other health risks. Aggregate consortium-level GIS mapping will help unify the knowledge on different aspects of climate change and population health as well as provide a graphic representation of project outcomes.

8 Evaluation

Because collaborations surrounding complex topics and group composition can be daunting in scope and distracting through the organic nature of the process involving intercultural and interorganizational norms, an effective conceptual framework

Fig. 3 Adapted from the Worldwatch Institute's Climate Change Reference Guide

Sample Health Risks from Climate Change

- Floods, heat and cold waves, storms, fires, and drought causing increased mortality
- Distribution changes of particular infectious diseases, including malaria
- Increased cardiorespiratory diseases
- Increases in diseases spread from contaminated and polluted drinking water supplies
- Rises in diarrheal disease & malnutrition

(McKeown & Gardner, 2009)

for collaborative research should first address general questions to ensure that the goals are consistently pursued:

- What do the conveners want to accomplish?
- What form of collaboration is optimum for the purpose (reactive, active or proactive)?
- What kinds of new knowledge and processes are desired?
- Are unusual integration of knowledge and methods are sought?
- What methods are required and what characterizes the type of system desired?

It should also consider success criteria for the particular collaborative project. Specific factors will depend upon the answers to the questions above. A sample checklist of success factors for the Consortium on Climate Change and Population Health which could be adapted for similar projects appears in Fig. 4.

9 Learning About e-Research

An ancillary goal of this project is to expand knowledge about e-research in communities of knowledge that focus on content other than that directly related to electronic communication or education or to information technology. In this situation, a complex system (the interdisciplinary consortium) incubates knowledge related to another complex system (climate change and population health issues), yielding new information about how e-research processes works to create new knowledge in a virtual environment. Some of the questions about e-research for groups of scientists, policy makers and other experts engaged in co-creating new knowledge are:

- How can technology better support the process of negotiating meaning and foster more open and accessible routes in the context of e-research?

Core Indicators for Consortium on Climate Change and Population Health

By what methods by which and to what extent is the Consortium able to:

- Identify risks and opportunities for adapting to climate change for public health
- Discover or develop complimentary competencies and 'multivocal' capabilities (engaging in different cognitive domains) (Russo & Rossi, 2009)
- Create policy-relevant interdisciplinary knowledge streams and questions
- Identify and prioritize research needs to address those questions
- Communicate results to a wide audience through e-Research dissemination - developing a communications strategy for policy effectiveness
- Inform policy decisions rather than make policy recommendations
- Incorporate others' values and methods into new knowledge products
- Include meaningful contributions from representatives of a wide variety of cultural, organizational, disciplinary, geographic and ideological groups

Fig. 4 Selected success factors for consortium on climate change and population health

- How might digital technologies be applied to optimally support knowledge co-created by geographically dispersed interdisciplinary researchers?
- How can the substance of e-research collaborative learning be transformed by the design of adaptive systems that take account of the social, organizational and cultural embedding of researchers?
- What are the characteristics of digital collaborative spaces that are safe places for researchers to transcend disciplinary, cultural and institutional boundaries?
- What methodologies can be employed for more productive collaborative learning to co-creating new knowledge, i.e. learning which is more successful and efficient in achieving its intended outcomes and transcends barriers which traditionally inhibit creative interweaving of knowledge and methods?
- What are the social and cultural opportunities and constraints for embedding digital technologies in e-research and how can the process be made available to developing nations?

10 Conclusion

> The significant problems we face cannot be solved at the same level of thinking we were at when we created them – Albert Einstein

The metaphor for the knowledge co-creation consortium used in this framework is the concept of registration of social and scientific models. Such registration aids in transcending traditional barriers for knowledge co-creation. The process metaphor for the policy-focused integrated interdisciplinary exploration of issues about climate change and population health of the Consortium is the teleidoscope through which participants weave interdisciplinary knowledge and models to create new knowledge.

The collaborative challenges outlined in this chapter are acute. Scholars and practitioners in climate change and population health call for new and creative interdisciplinary and transdisciplinary "postnormal science" processes (Funtowicz and Ravetz 1992) that blend social scientific and natural scientific principles, methods and findings together with cultural norms, regional perspectives and political realities. Complex collaborative efforts often encounter difficulties such as cultural misunderstanding, organizational or disciplinary hierarchical issues, political power or communications issues that impede if not derail the process. Lessons from the example in this chapter may offer seeds for innovative suggestions for actions to address such deficiencies across a variety of project types. Dialogues may possess different attributes depending upon their aims and participant composition. However, having a clear understanding of the purposes and theories underlying a collaborative effort not only creates a structure for creating, correcting and evaluating a collaborative effort but influences the choice of analytical as well as communications tools to use in the practical application of that framework.

Additional benefits may accrue to participants in processes such as the Consortium. Interdisciplinary teams may propagate into new virtual and inter-organizational partnerships and publications that would not have otherwise developed. These new entities may contribute directly or indirectly to projects that benefit climate and population health issues. Partnerships could include technology, academic, governmental, NGO, scientific or other members and may be face-to-face, hybrid or virtual. The success of this collaborative in achieving these longer-term outcomes is dependent in part on how well the framework provides sufficient definition while maintaining optimum flexibility.

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Part II
e-Research Collaboration: Technologies

Serverless Social Software for Nomadic Collaboration

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Abstract Recent portable devices, from sophisticated mobile phones, to netbooks, thanks to wireless networking and powerful batteries, give hardware support for collaborative work on the go, even when the Internet connection is not available. Yet, current collaboration software requires a dedicated server to synchronize clients, and thus a stable network connection.

In this chapter, we present two tools that use peer-to-peer paradigm to build serverless collaboration networks. PBDMS enables users to share, search and review bibliographic databases. SharedMind provides collaborative document editing to FreeMind, popular, open source mind-mapping software. Both tools handle disconnections and network divisions, enabling users to continue their work and to synchronize with their reachable peers.

Both tools have been implemented and tested in small scale. PBDMS is available for download at http://code.google.com/p/bibliographicsocialinfosys/; SharedMind is available at http://code.google.com/p/sharedmind.

We believe that such seamless, flexible collaboration applications provide the degree of freedom promised by the recent portable devices, yet not fully used by the current applications.

1 Introduction

Collaboration is essential to accomplish complex tasks requiring diverse skill sets. Recent proliferation of portable devices such as netbooks and sophisticated mobile phones emphasizes the need for collaboration on the go, anytime and anywhere,

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even when Internet connectivity is intermittent or not available. To facilitate such user interactions, it is essential to design systems where end users can communicate directly among each other, without having to rely on any dedicated infrastructure. Of course, if the infrastructure is present, it can provide additional services for such systems, such as, for instance, persistent storage. The peer-to-peer paradigm coupled with "rich" client software is particularly suitable in such context, as opposed to web based solutions.

In this chapter, we describe PBDMS and SharedMind, two tools we have recently developed to facilitate e-research collaboration. PBDMS supports social library functionalities, allowing users to share bibliographic content, including personal reviews, summaries and ratings with other (group of) users in a secure way and emulates web based social libraries. The primary challenge of realizing such serverless social software is to support asynchronous communication and access to user generated content in a secure manner. There are other issues like privacy (Buchegger and Datta 2009) in online social networks that can be addressed by adopting a P2P approach. Such issues are also addressed in PBDMS, but are not the core focus in the context of this chapter, and will be glossed over.

SharedMind, the other tool, demonstrates real-time collaborative editing of shared mind maps. A mind map is a form of non-linear note taking, especially useful in creative phases of projects. SharedMind is an extension to FreeMind, the most popular open source mind mapping software. The primary challenge in this work is to support consistency of the collaboratively manipulated objects both in real-time (synchronous) collaboration and asynchronously, thus in presence of intermittent (dis-)connections among the collaborators. Existing versioning systems, like Concurrent Versions System (CVS) or Subversion (SVN), are not directly applicable in the context of note taking, as they focus on asynchronous collaboration, by emphasizing the notion of "committing" larger chunks of work. In contrast, SharedMind supports both the exchange of atomic edit operations in the synchronous collaboration and automatic checkpointing, merging and conflict-resolution assistance on (dis-) connection events.

In the chapter, we describe algorithmic and technical challenges encountered in realization of these tools. We present our solutions and some implementation details.

While the current implementations are purely peer-to-peer and client based, a hybrid solution utilizing infrastructure and adding web-based interactivity can also be easily integrated and is work in progress. We will however focus only on the current implementations of the tools.

2 Background

Software support for collaborative work is probably as diverse as are styles of collaboration themselves. Usually, the resulting collaborative system consists of software deployed directly on users' machines, and software that coordinates all the clients (sometimes deployed on a dedicated server). As users have to coordinate their actions (otherwise, there is no collaboration), such system is inherently distributed.

Depending on needs, constraints, and the methodology during the design, the proportion of effort on the client part and on the server part changes. A typical solution is a centralized, client-server system, in which each client communicates directly with the dedicated server. The server coordinates users' actions and provides a repository with shared data. Systems as diverse as Google Docs, CVS/SVN, or CoWord have client-server architecture. The other possibility is to maintain a fully distributed, peer-to-peer network, in which there is no need for a dedicated infrastructure. In this chapter, we present PBDMS and SharedMind, two programs that follow this pattern.

Collaboration groupware systems can be roughly divided into two groups: commit-based (or off-line) and real-time. Commit-based systems, such as CVS/SVN repositories, use the notion of a user committing larger chunks of work into a shared data store. The data store hosts the current, consistent view of the shared data, periodically updated by users. While working, a user periodically merges his/her local copy with the current data store version, thus half-automatically synchronizing his/her work with others. When the user considers that her work is complete, (s)he commits it to the data store. The main advantage of commit-based systems is that the document in the data store is always consistent (or, should be, as merging depends on users), which is important especially in team programming. In contrast, real-time systems (such as CoWord, or Google Docs) allow the whole group to see each modification of each user almost in a real time. For some tasks, collaboration in such architecture is considerably easier. However, in order to produce a consistent view of the shared data, real-time architecture puts the whole effort of synchronizing users' actions on the system itself, and not on the users – which, as convenient as it sounds to the users, is much harder to realize.

Some collaboration systems (e.g., Google Docs) provide both real-time and off-line collaboration. When a user is online, users' actions are synchronized in real-time. When the user goes off-line, she can still make changes to local copy of the shared document. The changes made will be sent to other users the next time the user goes online.

Another axis of division is the required level of coordination between peers, which depends mostly on the desired result of collaboration. If the group is to produce a single, consistent document (such as a source code of a program, or an academic paper), the goal of the system is mainly to synchronize users' actions. An example of such program is SharedMind, in which users work on a single mind map. When such a tight coordination is not needed, the system can be used mainly as a more convenient way to communicate than the plain e-mail, or chat. There is no notion of a single, consistent document; rather, each user has his/her own view on the matter, but is also seeking other users' opinions, or perspectives. In PBDMS, each user maintains his or her own bibliographic database, but is able to easily share individual entries or the whole database with peers.

2.1 Common Issues in Collaboration Systems

Common issues that should be handled by collaborative systems include most of the problems present in distributed systems (Tanenbaum and Van Steen 2007), such as:

- Data storage: The shared data can be stored only in the central server or replicated on every client's local storage (the whole data or part of it). While replication results in less network traffic on each update, since only the change, and not the complete document is being sent, maintaining consistency in replicated data is more difficult.
- Concurrency control: Since there are multiple users accessing the data at the same time, more than one user might be trying to read or write to the same part of the data. Concurrent read operations are permitted, but concurrent write operations create an unpredictable result. There are two approaches to handle this problem:
  - Conflict avoidance: This approach does not allow concurrent writes. Lock mechanism (on the whole document, or on its well-defined part) is used to ensure exclusive access when writing the data. The advantage of this approach is that there is no need to handle conflict. The downturn is that parallelism is reduced since only one user can write at one time.
  - Conflict detection: In this approach, potentially conflicting write operations are examined. When the changes are indeed conflicting, a user is notified of the conflict and asked to resolve it manually.
- Security and access control: the system must ensure that only the appropriate users can access and change the (appropriate parts of the) data. If the data is particularly sensitive, the system must provide secure communication channels.

2.2 Decentralized, Nomadic Collaboration Systems

The main disadvantage of centralized collaboration systems is that a group of interconnected users cannot collaborate if they are not connected to the server. Example scenarios include a group of users traveling by train, who create a fast, reliable local wireless network, but who don't have an Internet connection; or users working within a university with a fast LAN, but which is temporary disconnected from the rest of the world because of problems with university connection to the Internet. In such scenarios, the only solution is to use decentralized approach, backed up by a pure peer-to-peer communication architecture.

In decentralized systems, the shared data must be fully replicated by each user. The reason is to enable all users to continue working in case of disconnections, or network partitions, as depicted in Fig. 1.

Because of similar problems, for concurrency control, a distributed collaboration system cannot use conflict avoidance. In case of a network partition, if a user from one partitioned group locks an object, the other group cannot access it. Therefore conflict detection approach should be used. The choice of this approach incurs

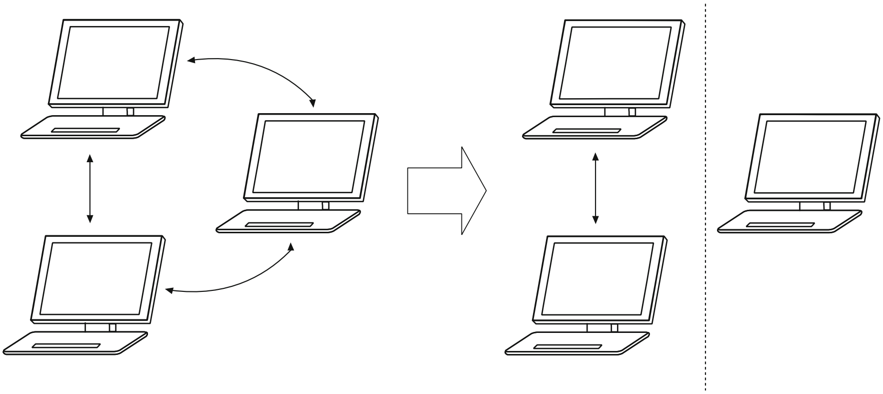

Fig. 1 Partitioned network: one of the peers looses the connection to two other peers; however, the group of two peers should still be able to work together

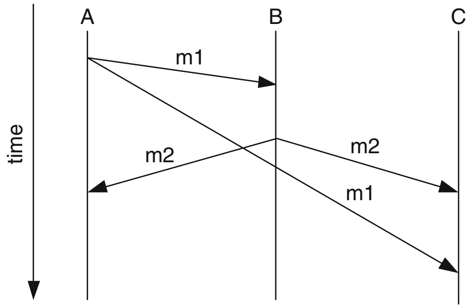

Fig. 2 B's modification (m2) may be logically linked with A's modification (m1), as B received m1 before sending m2. Yet, because of large latency on A–C link, C receives firstly m2, and only after m1. Vector clocks (Raynal and Singhal 1996) can be used to detect such problems

Table 1 Comparison of real-time centralized and decentralized collaboration

	Centralizedcollaboration	Decentralized collaboration
Network architecture	• Client-server	• Pure peer-to-peer
Data storage	• Only on server • Partial replication • Total replication	• Total replication
Concurrency control	• Conflict avoidance • Conflict detection	• Conflict detection
Asynchronous collaboration	• Can be supported	• Must be supported

several inconsistency problems in synchronous collaboration due to network latency and concurrent operations. One of such problems is shown in Fig. 2.

Finally, asynchronous collaboration also must be supported so that a user who remained disconnected for some time, upon connecting back is able to integrate his/her changes with other users.

The overall comparison of centralized and decentralized collaboration systems is shown in Table 1.

3 Social, Collaborative Bibliographies with PBDMS

Science is an incremental effort, in which new ideas are built upon old ones. To keep track of "the old ideas", each scientist usually keeps a bibliography, be it in a form of an annotated bibtex file or a stack of printed articles on their desk, with comments written on margins. When working in a team, a scientist often suggests a colleague to read a paper. Currently, this suggestion is usually sent by email. Then, the colleague's comments are either resend back by email, or kept privately. Thus, a team ends up having as many diverse bibliographies as there are members. Moreover, it is inconvenient to share comments (or informal reviews) on all these papers.

We wanted to provide support with respect to bibliography management for a team of scientists. Our software, Personal Bibliographic Data Management System (PBDMS), is a prototype that solves the most common problems in managing, sharing and annotating bibliographies. PBDMS supports both bibliographic information about a document (meta-information) and the meta-information coupled with an electronic version of the document itself (e.g., a pdf containing a paper). Later on, we will refer to both types of information as "documents".

PBDMS helps users to both to manage their own bibliographic databases locally, and to easily request information from their peers. A user manages documents on his or her local computer. These documents can be shared with other peers. A user can search the network for documents shared by other peers and download them. Moreover, a user can subscribe to other users' bibliographies, and be automatically notified about every change in the subscribed bibliographies. PBDMS also supports basic chat functions, with instant messages and a list of friends currently on-line. In order to connect to other peers, PBDMS has a peer discovery protocol, which, given a peer's ID, finds its current IP address.

In science, some of the papers are protected. For instance, authors share a paper in the process of a review only with their closest collaborators. A published paper, especially when downloaded from publisher's electronic library, can be tightly protected by copyright. Thus, PBDMS must allow its users to control which elements they want to share with whom; and then to enforce these constraints. In order to verify peers' identities, PBDMS implements an authentication protocol, supported by distributed public/private key cryptography ("web of trust" model). Other peers can be then classified into "trusted" and "not trusted" group.

Scientists working in different time zones (or simply having different working style) can miss each other's online presence. In order to support such nomadic collaboration, when a user is off-line, PBDMS delivers messages and files to a "mailbox" of the user. These mailboxes are user-specific spaces in a Distributed Hash Table (DHT) maintained by the collaboration network itself, or backed by a server.

3.1 Architecture and Basic Network Communication in PBDMS

PBDMS is a typical Model-View-Controller application. The view manages the GUI. The model is backed by a database storing all the bibliographic information in a XML format. Finally, the controller responds to local user actions (by changing the model) and handles network communication with other peers. As the model and view part are fairly standard, we will only describe the network part of the controller in more detail.

PBDMS uses two network architectures. Firstly, a fully distributed, unstructured peer-to-peer network handles direct communication between peers (e.g., when searching for a document, or downloading it). Secondly, peers use Distributed Hash Table (DHT)-like functionality for functions that would be cumbersome for an unstructured peer-to-peer network (such as peer discovery, or off-line messaging).

The unstructured peer-to-peer network is created and maintained by PBDMS' network controllers. A PBDMS instance connects directly to a remote PBDMS instance whenever the user's actions require interaction with other users' data (for instance, when searching for a document). Technically, each network controller acts both as a client (when initializing connection) and as a server (when waiting for and accepting other peers' connections).

All messages, excluding search queries, are directly handled by the receiver, and thus do not require routing on the application layer. Search queries are flooded through the network with a limited time to live (TTL), initially set to five hops. Upon receiving a search query, a peer firstly tries to find the appropriate document in its local data store. If the peer doesn't have the requested document, it forwards the query to all its neighbors (except the neighbor who has sent the query), if the query's TTL is positive. When a peer forwards a query, it decreases its TTL by one.

To handle peer discovery and off-line messaging, PBDMS rely on a DHT-like database. A DHT enables peers to store ("put") a data object identified by an ID (a "key"). Then, other peers who know the ID can efficiently find and download the data ("get"). Multiple objects can be stored under the same key. A DHT can be efficiently created and hosted in a decentralized way, by a *structured* peer-to-peer network. Initially, PBDMS used OpenDHT network (Rhea et al. 2005). However, due to OpenDHT instability and its imminent closure, we switched to OpenLookUp. OpenLookUp has the same interface as OpenDHT, yet, technically, it is not a DHT, but a publicly-available key-value data store, operating on a few well-known servers (http://any.openlookup.net:5851/). Note that, in future, PBDMS instances themselves can create and host a DHT, if there are numerous enough to sustain the network.

To support peer discovery and authentication, each PBDMS instance persistently stores a list of known other users ("buddy list"). Each user is uniquely identified by her public key. As we do not assume a central Public Key Infrastructure (PKI), we use a web of trust approach to determine the trustworthiness of each key (see Sect. 3.3). Based on web of trust, known users are divided into the "trusted" and "not trusted" groups.

3.2 Peer Discovery

In order to connect to another peer to, e.g., download a paper from a collaborator, PBDMS must know the peer's current IP address. As we expect that our users will move from one physical location to another, their IP addresses will also change; thus it is not feasible simply to use the same IP for a peer. In order to find the current IP address of a known peer, we implemented a simple peer discovery protocol.

When *userA* starts PBDMS, PBDMS connects to the DHT and stores her current IP address. The key under which the IP is stored is the hash of *userA*'s public key.

When another *userB* wants to connect to *userA*, it gets *userA*'s public key from the local buddy list, computes the hash function and then connects to the DHT and downloads *userA*'s last saved IP. To verify the address, *userB* connects to this address and performs a mutual authentication (described in the next section). If the authentication is successful, the IP address retrieved from the DHT is authentic, and thus it is stored in a local variable in *userB*'s PBDMS instance. *userA* is considered as connected.

To automatically refresh the list of connected peers, PBDMS periodically tries to connect and authenticate with each one of them.

3.3 Peer Authentication

Although the system can locate a peer by retrieving its IP address from the DHT, the system does not know whether that IP address is authentic. In order to perform the authentication of known peers (with known public keys), we use a variant of Needham–Schroeder–Lowe Protocol (Lowe 1995). This protocol mutually authenticates peers by their public key by making sure that both peers have the appropriate private keys. However, in a distributed system we cannot be certain about the authenticity of the public key itself (i.e., whether the key pair has been generated by the person who claims to be the owner). To address this issue, we construct a web of trust.

To ensure the trustworthiness of the public keys stored in the local repository, we use web of trust (Zimmermann 1992). The idea of the web of trust is based on the transitivity of trust relation based on signatures on public keys. For instance, if *userA*'s public key is signed by *userB* and *userC*, and *userD* trusts *userB*'s public key, *userD* can also trust *userA* public key. The trust path is thus *userD*→ *userB*→*userA*. In PBDMS, to find such trust paths, we use a local and network web of trust.

During local web of trust algorithm, PBDMS does a breadth-first search on the signatures of public keys stored in the local list of known users. The algorithm starts with the target public key (*userA* in the above example) and, by examining all the signatures of the key (*userB* and *userC*), proceeds until a key signed by the current user is found.

If PBDMS is unable to establish a trust path using local web of trust, it performs a similar algorithm over the network (network web of trust). Connected, trusted peers are asked to perform local web of trust in order to resolve the unknown key. In a peer, if local web of trust fails, the query is further forwarded to its connected, trusted neighbors, similarly to document search (with a limited TTL).

3.4 Delay-Tolerant Communication for Nomadic Collaboration

If a peer is off-line, PBDMS cannot deliver messages using direct links. Instead, it uses a delay-tolerant mechanism based on a DHT network. The main idea is to decouple network storage problem from the availability of a particular set of peers, by providing a fault tolerant storage. We assume that data in the DHT is sustained (through replication and similar mechanisms), despite individual peers going off- and on-line. Thus, all the messages for an off-line peer can be put in the DHT under a well-known key, called the peer's *inbox* (identified by the hash of a peer's public key and some fixed string, e.g., "inbox"). When a peer goes on-line, it contacts the DHT and downloads all the messages from its inbox. Below, we describe in detail how is the inbox constructed and how to deliver messages larger than the object size limit (usually present in a DHT).

Because a DHT usually limits the size of the objects (e.g., OpenLookUp's objects have to be smaller than 1 kB), in order to construct an "inbox" and a "message", we use a structure similar to directories and files in a filesystem. In a filesystem, a file is composed of its meta-information (such as name, creation date, etc.), and a list of addresses of blocks, that actually store the file's contents. Similarly, a directory is stored as a list of addresses of file meta-information.

Our system divides a message into a list of 1 kB-long blocks. A message is uniquely identified by a timestamp, and a hash of sender's and receiver's public keys. Each block of the message is put into the DHT under a key composed of block's sequential number, and the message ID. In order to let the receiver know about the message, under the key corresponding to receiver's inbox, the sender stores meta-information needed to find the keys describing the message: message's ID and the total number of blocks.

When a receiver goes on-line, it connects to the DHT, downloads the messages' IDs from its inbox (using one "get" operation), and then, for each message ID, downloads its blocks by a loop of "get" operations (requesting a key being a concatenation of a sequential number and the message's ID).

PBDMS allows users to attach whole files to messages (for instance, pdfs with a copy of a paper). The mechanism is the same as in case of messages: a file is divided into blocks, and the meta-information is attached to the message notifying the sender.

3.5 Following Friends' Bibliographies with Subscriptions

In a group of scientists closely working together, information about a new paper found by a member should be disseminated as easily and quickly as possible. We implemented this functionality through RSS-like subscriptions of peer's bibliographies.

A user can specify which peer's bibliographies (s)he wishes to follow. When these peers are on-line, PBDMS periodically contacts them and requests a subscription file, containing information about the recent updates in the local database (pull approach, similar to RSS).

4 Collaborative Mindmapping with Sharedmind

All scientific projects start with a creative phase, during which key contributors meet to brainstorm, to collaboratively formulate rough ideas for problem definition and possible solutions. In subsequent phases of the project, members further specify and develop these ideas; they test them with a proper scientific procedure, and, finally, write and publish research papers. Sometimes, these phases alternate with smaller-scale creative phases, to solve hard problems, or to look back at their definitions, in order to reformulate them. Thus, in a project, creative, non-linear phases alternate with logical, linear development. These logical phases are much better understood (in terms of objectives, procedures, etc.), and, thus, much better supported by existing software, be it (collaborative) text editors, numerical solvers, or best practices for collaborative software development. In contrast, creative phases usually happen when researchers meet face to face, next to a whiteboard and a coffee machine. Our aim was to help researchers in these creativity phases when such face-to-face meetings are not possible. To this end, we developed SharedMind, a program enabling collaborative editing of mind maps.

A mind map (Buzan 2006) is form of non-linear note taking, developed to help creativity and support unusual associations (see Fig. 3). A mind map's center is a problem or a topic. Different aspects of the problem are visualized as branches diverging from the center. To present details and subtleties, these branches are recursively divided into sub-branches. To further help creativity and non-textual expressions, branches can contain pictures, drawings or be annotated with colors.

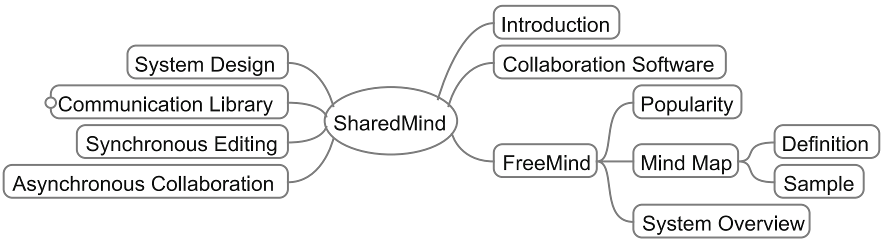

Fig. 3 A mind map in FreeMind. To reduce visual clutter, FreeMind enables to fold branches (denoted by *small circles* next to the branch's name)

Among many mind-mapping software products, FreeMind (http://freemind.sourceforge.net/) stands out as a popular, open source project with avid community of users and developers. It was thus a natural choice as a starting point for our extension.

4.1 Architecture of FreeMind

This section introduces the internal architecture of FreeMind. SharedMind, our extension to FreeMind, mirrors this architecture.

FreeMind is based on a standard, model-view-controller architecture. The model provides an internal API with a common interface to the in-memory representation of a mind map. The view displays the map in a window and keeps references to the current model and the current controller. The Controller sets up all the actions that are used to respond to user input and make changes to the model. One controller object is associated with the whole system and one mode controller object is associated with each opened mind map.

In FreeMind every change to the map is represented as a pair of *actions* (*do* and *undo*), that carry information about the required changes to the model. The controller serializes actions into an internal XML representation and then invokes the model, which finally applies the "do" action on the current mind-map. There are several subclasses of XML actions. Each subclass represents one particular kind of action, for instance creating a new node, or changing the node's attributes (such as the font, or the background). The action that needed special attention in our project is the edit action (the action of changing node label). Edit action is not generated on every key press; instead, only after focus is lost from the edited node.

FreeMind stores its mind-maps as XML documents, that closely follow the hierarchical structure of the mind-map itself. Each node in the document corresponds to a (sub-) branch in the mind-map. A node has a unique ID. Apart from nodes, user or various plug-ins can define attributes, either for the whole mind map, or for each of the nodes.

FreeMind provides a comprehensive plug-in API. Plug-ins are hooked to the main program using an XML file.

4.2 SharedMind: Use Cases and Architecture

SharedMind, our collaboration plug-in for FreeMind, provides the following functions:

- *Start collaborating*: A user can create a new group and share a new map or join an existing group and request the map that is shared by that group.
- *Stop collaborating*: A user stops collaborating either explicitly (by a log-off), or implicitly, when the network connection is lost.

- *Modify the shared map by:*
  - *Synchronous Collaboration*: when a user is connected to the group, modifications to the map made by the user will be propagated to other users; the user will be notified on conflicting changes as soon as the conflict is detected.
  - *Asynchronous Collaboration*: When a user is not connected to the group, modifications to the map will be stored locally. When the user reconnects to the group, the versions are automatically merged.
- *Provide a consistent version of the document by detecting conflicts:*
  - *Real time conflict detection* happens when user is connected to the group. User will be notified when there is conflict between the node currently edited locally and a received, remote modification.
  - *Manual conflict resolution* happens when a user goes on-line again after making some off-line modifications. The user's latest local map version will be merged automatically with the current on-line version of the map. If there are conflicting changes, they will be shown to the user, who is then asked to resolve these conflicts manually.

Following the architecture of FreeMind, model-view-controller architecture is also used in the collaboration plug-in. SharedMind defines its own controller that handles incoming messages about remote modifications and creates local actions, then applied on the local data model. The controller also intercepts local modifications and multicasts them to other collaborators. The view and the model are handled by FreeMind. SharedMind uses their existing functions for its purposes (e.g., arrows to display conflicts or map attributes to store version information).

SharedMind is loaded using FreeMind's plug-in API.

4.3 Communication Layer: Real-Time P2P Messaging

Real-time collaborative editing requires fast communication between collaborators. Unfortunately, most of the existing P2P communication protocols and libraries focus on database-like communication pattern, in which data objects are stored in a network, and later searched for and retrieved by other peers.

The basic communication primitive in SharedMind is a multicast message: an action describing a user's local change that must be disseminated to all other collaborators. After a failure to introduce multicast on the network level (IP Multicast (Deering and Cheriton 1990), multicast is nowadays implemented in the application layer of the Internet protocol stack).

SharedMind is able to switch between Peer-to-Peer Protocol (P2PP), and MoMo communication library. P2PP is an emerging standard API for peer-to-peer communication. The implementation we used (P2PP Wrapper), had an additional support for publishing and subscribing to so-called "topics", that provide basic filtering of messages received by each peer. Basically, each shared map defined its own topic. All the contributors subscribe to the topic; and the changes are published as updates to this topic. The communication library guarantees that the order of the received messages is the same in each client.

MoMo is our local implementation of application-level multicast, in which peers form a logical spanning tree to minimize the number of messages. The tree structure is also optimized to minimize observed latencies and connection costs, taking into account the frequencies of updates by each peer. Unlike P2PP, MoMo does not provide publish-subscribe functionality. All the messages are multicasted to everyone in the network. In other words, MoMo only provides one default topic and each user is automatically subscribed to that topic upon joining the network.

SharedMind assumes that all the security is handled by the communication layer (similarly to, e.g., an application that uses secure sockets). Although currently the security is not implemented in any of the used libraries, P2PP will provide it in one of the future versions.

4.4 Synchronous Editing By Action Exchanges

In synchronous editing, all users are interconnected, thus local changes are propagated to other users as soon as they are applied on the local data model. Below, we explain how local changes are propagated to other users, how to detect potentially conflicting changes between local changes and remote changes and how to re-order messages to keep the order of edit operations.

In FreeMind, every time a change is made to the map, a pair of actions describing the modification (do action) and possible undo (undo action) is generated. To enable synchronous editing, changes made by the user (local changes) and changes received from other collaborators (remote changes) must be handled differently. Local changes must be applied to the local map and propagated to other collaborators. Remote changes only need to be applied to the local map.

We modified the FreeMind component that applies changes locally, so that the action is also send to the SharedMind network controller, which, in turn, passes the action to the communication library. Similarly, SharedMind controller listens to the incoming messages describing remote actions and converts them to "quasi"-local actions that are later send to the local model.

In synchronous collaboration, it is usual that two (or more) users edit and change the mind map concurrently. Concurrent changes are depicted in Fig. 4. If different nodes are modified, no conflict will occur. Conflict occurs when more than one change is applied to the same node (or, in case of deleting a node, also to the node's ancestor). For example, in the picture below, if *m1* and *m2* are applied to the same node, *m1* will be executed first in client *B* whereas in client *A*, *m2* will be executed first. It is important to detect such conflicts, as they might lead to inconsistent state of the collaborative document. Note that a conflict is not an artifact of the application, or the communication library. In contrast, a conflict represents a clash between two users' different visions of the problem. For instance, if two users want to label a node differently, only they (and not the application) can agree upon the "right" label

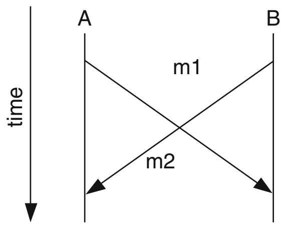

Fig. 4 Concurrent changes: A modifies its local file and sends notification (m1). Approximately at the same time, B also modifies its local copy and sends notification (m2)

and thus produce a common version. SharedMind detects such conflicts (by comparing vector clocks of the message and the history of recent modifications), produces a rough, consistent version (by reordering conflicting actions in a globally-consistent manner) and then notifies users.

Two classes of real-time conflicts are, firstly, a remote change applied to a node that is currently edited by the user; and, secondly, a concurrent change of the same node by more than one user (or some of the modifications of the tree in which the node is in like, e.g., deleting the node's parent).

Another problem that can occur in decentralized collaboration systems is the inconsistent order of arrival of messages. To handle it, we attach vector clocks to all the messages. By examining a message's vector clock, a peer is able to detect that there is a missing message that logically precedes the received message; and thus, enforce causal ordering by either waiting or requesting the retransmission of the lost message, before applying the message's action.

4.5 Asynchronous, Nomadic Mind-Mapping

In asynchronous collaboration, a part of the group is disconnected, and thus the group cannot agree on a common state of the document just by sending update actions, as in the previous section. The idea is that as soon as the connectivity is restored, SharedMind should automatically merge the versions of the documents and mark possible conflicts. Below, we describe how to detect which part of the group is currently reachable (*presence detection*); how to make consistent backups of the state of the mind map, so that it is easier to merge the changes (*checkpointing*); and, finally, how to *merge* the maps by computing differences between maps, detecting and visualizing conflicting changes, and applying the non-conflicting changes.

Presence protocol is used to find out which part of the team is currently reachable. The protocol is based on time-outs. The idea is that, periodically, a peer will initialize presence session. During the session, the peer requests a response from all the other peers (using a multicast message). Other peers respond by sending "I'm alive" messages, also by multicast. After another timeout (a few times larger than the group's maximal point-to-point latency), the peer analyzes all the responses. Peers who haven't replied are considered as disconnected (absent).

Note that, as all the messages are multicasted, after the protocol completes, all the connected peers have the same view over the group.

Continuous checkpointing is a process of creating a series of snap-shots of the shared mind map. Each snap-shot is a consistent view of the document among the collaborators who are reachable (present) when the snap-shot was taken. An example scenario of how the versioning is done is shown in Fig. 5.

Continuous checkpointing uses presence protocol to find out which part of the team is reachable and what the common version of the document is. As the protocol is complex, we present only a sketch below. A version number is a random number, initialized by a bully selection algorithm. When a presence session is initiated, the current state of the map is copied into a "checkpointed" map. The checkpointed map will eventually contain the common version of the document from the time moment just before the checkpointing started. Thus, while checkpointing is not completed, local changes are not propagated and applied only on the current map. As all the peers know about the on-going checkpointing procedure (and, thus, do not propagate their local changes), all the incoming, remote changes have been send before checkpointing started. They have to be thus applied both to the checkpointed map (to have a consistent version of the document), and to the local map (so that the local map reflects all the changes).

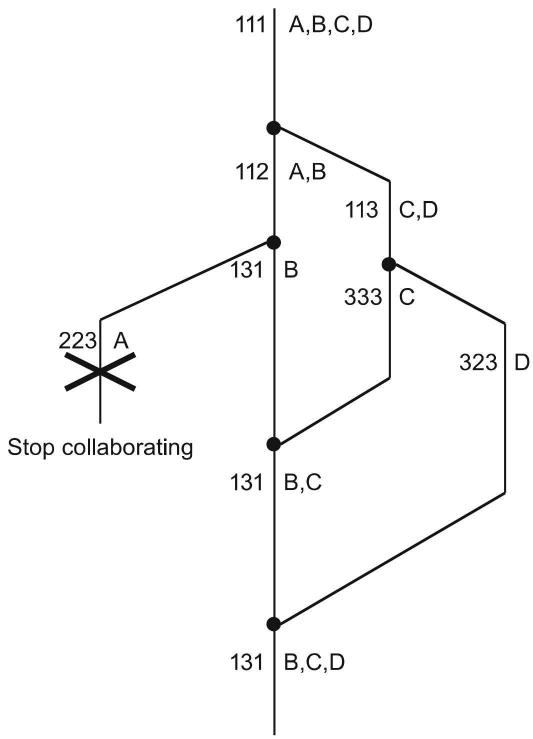

Fig. 5 A history of collaboration with attached version numbers. *Dots* indicate events when the state of the group changes. For instance, the first dot is the division of group (A, B, C, D) into two groups: (A, B) and (C, D)

After the presence session is completed, if there are any users who disconnected between the previous and the current session, a new, random version number is generated for this checkpoint (e.g., first dot in Fig. 5, in which group A, B generates version 222; approximately in the same time, group C,D, who is disconnected from A,B, generates version 555); otherwise the current version number is still used (which reflects “refreshing” the last checkpoint).

During checkpointing, each peer applies remote actions, until its message queue is empty. It then issues a “checkpoint complete” message. Note that other, remote modifications can arrive later, thus the vector clock (reflecting the number of consumed messages of the peer) has to be analyzed. When the number of “checkpoint complete” messages *with the same value of the vector clocks* is equal to the number of peer in the current group, each peer has the same version of “checkpointed” map, and thus the checkpoint is consistent. Finally, each peer persistently stores the checkpointed map, along with the version number.

In order to merge maps, when a peer or a group of peers re-joins the network, we start with finding the last common version of the map. It can be easily obtained, by comparing the list of version numbers in the maps being merged. For instance, the last common version between B and C is 111.

Afterwards, two maps are merged automatically as much as possible, using a three-way-merge algorithm. Below, we present the sketch of the algorithm (the details of this process are beyond the scope of this paper). The algorithm starts by producing two lists of actions that transform the last common version into the version of each group. Then, the algorithm analyses both list to detect conflicts (for instance, both list have actions that change the label of the same node). If there are any conflicts, one user is elected to resolve them manually. This user is presented with a mind map that shows three versions of the map (Fig. 6): the last versions of each group (V1 and V2), and the merged map that has all the non-conflicting

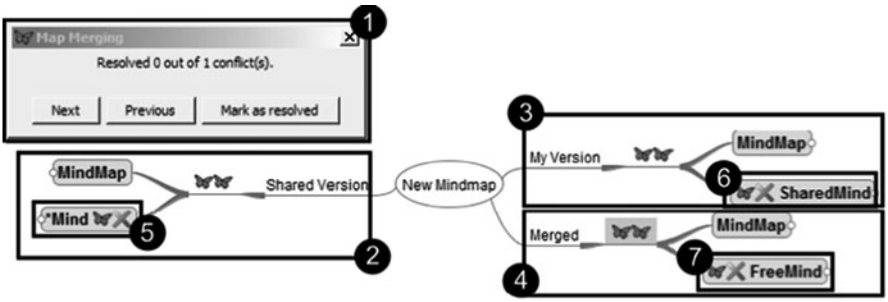

Fig. 6 Interface for conflict resolution (*numbers* added for description). As there may be multiple conflicts, the window (1) enables to switch between them. Two conflicting maps are presented as (2) Shared Version (group’s version of the map) and (3) My Version. The Merged branch (4) contains all the non-conflicting changes (and last common version of the conflicting nodes). Cross icons (5, 6 and 7) denote conflicting versions of a node. In this case, a node labeled “FreeMind” (7) in the last common version of the map has been renamed to “*Mind” (5) by the group, and to “SharedMind” (6) by the user

changes. The user edits this mind map as a usual mind map; afterwards, when the user decides that all the conflicts have been resolved, the merged map becomes the new common version.

5 Related Tools for Research Collaboration

In this chapter, we have presented two applications that help to maintain collaborative, annotated bibliographies of scientific papers (PBDMS) and to take notes and brainstorm (SHAREMIND). The unique feature of these two tools is that they do not require a central server, or documentary repository. Users can work both off-line and on-line. Their work is automatically merged with the group version whenever a connection with the rest of the group can be established. We believe that this feature gives our users much more freedom than the conventional, server based solutions: The possibility to work anytime and from anywhere, even without a stable internet connection.

Recently, many other programs enhancing collaboration has appeared. Based on the function, they can be roughly divided into three broad areas: generic software for data synchronization (such as SVN, CSV, or databases); collaboration portals (such as MyNetResearch, SourceForge or wiki pages); and specialized editors for real-time, collaborative work on a particular document type (e.g., CoWord, or GoogleDocs). Below, we briefly describe what we consider as most important approaches, with example applications:

- Version control systems (SVN, CVS, git): motivated mostly by collaborative software development, but successfully used also in collaborative authoring. They allow reviewing the changes made by different collaborators; storing previous versions of the work; and developing in parallel different versions of the document (*forking*) that can be later *merged* into one, common version. They integrate well with text-based formats (e.g., LaTeX source files).
- Collaboration portals (generic: MyNetResearch; source code: SourceForge, gForge; bibliography: http://www.bibsonomy.org): enhance intra-group communication by providing discussion boards, blogs, wiki pages (for simple collaborative authoring of documents) and, sometimes, an interface to version control systems.
- Web-based real-time editors (office documents: Google Docs; rich text: http://etherpad.com; mind maps: http://www.mindmeister.com, http://bubbl.us;) Do not require software installation. Data is stored on the server, which can raise some security concerns. Requires stable, broadband Internet connection.
- Client-side real-time editors (office documents: CoWord, CoPowerPoint; text and source code: Eclipse DocShare plugin): usually require complex setup (a server part has to be installed and accessible by all the clients). Some approaches rely on stable client-server connections and do not allow off-line editing.

To select an appropriate tool among so many possibilities, a group of researchers has to consider a few factors. Of course, different groups can have entirely different needs: modern astronomy, for instance, is revolutionized by the Sloan Digital Sky Survey (http://www.sdss.org/), essentially an annotated database, thus nothing really novel for the CS community; in contrast, a group of social scientist would rather require a real-time document editor to enhance collaborative authoring. Therefore, the first question a group should ask is: which part of the collaborative scientific process should we enhance? For instance, if it is raw data gathering or sharing (as in astronomy or molecular biology), the easiest solution is a specialized database. Depending on the domain, such databases either exist (like SVN for storing and versioning source code), or have to be developed. If the main problem is the intra-group communication, wiki pages or collaboration portals (such as MyNetResearch) would be appropriate. Some collaboration portals are integrated with versioned document repositories; for instance, gForge (http://gforge.org) provides a separate SVN repository for each project.

If the group wishes to enhance collaborative editing capabilities, the choice of tools depends on the kind of documents that should be produced. In general, off-line, commit-based collaboration is well supported by generic source code repositories – as long as there is an appropriate user interface for merging and conflict resolution (well-understood for text-based formats, such as LaTeX source, somewhat harder for more complex data, such as figures).

As we argue in this chapter, real-time editing can give the team additional creativity and synergy in the collaborative work. For real-time editing, the choice of the tool depends mostly on the type of the document (we list some of the possibilities in the list above). The existing tools, however, rely on a centralized server for synchronization and acting as a document repository. If this server is not controlled by the team (as it is the case in the web-based tools), there are some security and availability concerns, such as what happens with the data if the service provider goes bankrupt? On the other hand, if the server is hosted locally, it is usually not trivial to setup and maintain. For instance, the server usually requires an open TCP port at the firewall, which is not welcomed by any organization's IT staff. Another problem with these approaches is that, usually, they implicitly require a stable, broadband connection between the server and each of the clients; they are thus not very well suited for more nomadic style of work.

6 Conclusions and Perspectives

Although there are quite a lot of tools and techniques used nowadays for scientific collaboration, we believe that there is still a place for a more flexible approach supporting different phases of the scientific process. Decentralized, nomadic collaboration enables researchers to work together even when Internet access is not available. When a user is off-line, or the group gets separated because of connectivity problems, people can still work on their local copies of the documents, which get synchronized as soon as the connectivity is restored.

In this chapter, we have described two tools that employ these collaboration paradigms for vastly different tasks. PBDMS enables researchers to share their bibliographies, together with reviews and electronic documents. Here, the collaboration pattern is very flexible, as each user maintains his or her version of the data. PBDMS enables users to store messages for other off-line users (providing delay-tolerant networking), and to control which content they want to share with which users (through distributed public key cryptography).

The second program, SharedMind, adds real-time collaboration to FreeMind, open source mind-mapping software. Here, the whole group works on a single document. A change made by one user is propagated as soon as possible to the rest of the group. SharedMind provides consistency by detecting conflicting changes made in parallel by many users. When the group disconnects into sub-groups, or single users, they can still work on their local copies. When they reconnect, ShareDMind determines the last common version of the file; automatically merges the non-conflicting changes; and assists an elected user in solving the conflicts (by marking the smallest-possible conflicts in the versions being merged).

Both tools have been implemented as a part of final year undergraduate projects at NTU, and have been tested in small scales. PBDMS is available for download at http://code.google.com/p/bibliographicsocialinfosys/; SharedMind is available at http://code.google.com/p/sharedmind/.

Although SharedMind and PBDMS are just two examples, we believe that many other applications can gain by enabling multi-user collaboration. And, the more flexible is the collaboration, the more eager will be users to actually use it in their daily scientific activities.

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A Taxonomy of e-Research Collaboration Tools: Using Web 2.0 to Connect, Collaborate and Create with Research Partners

Stein Brunvand and Mesut Duran

Abstract The proliferation of Web 2.0 technologies in recent years has resulted in a wide array of tools designed to help researchers connect with one another and collaborate around a shared agenda of study. This chapter looks at the variety of tools currently available to support researchers in e-research collaborative efforts. In addition, recommendations are provided for developers and designers of collaborative research environments to consider as they create and refine these tools.

1 Introduction

The proliferation of Web 2.0 technologies in recent years has resulted in a wide array of tools designed to help researchers connect with one another and collaborate around a shared agenda of study. Governmental agencies have taken note of the power of these technologies and created initiatives designed to make electronic resources and computational processing power available to individuals engaged in scientific research. In 2001, the United Kingdom created the e-Science Programme (http://www.rcuk.ac.uk/escience/default.htm) to provide researchers access to "data collections, very large-scale computing resources, scientific instruments and high performance visualization" (Research Councils UK 2009). These resources are provided through a powerful infrastructure of computers and technology, or Grid (Foster and Kesselman 2004), that can be accessed remotely and made available on individual desktop workstations. Likewise, the National Science Foundation has created an Office of Cyberinfrastructure (National Science Foundation 2003) and funded the development of TeraGrid (http://teragrid.org/about/), which provides many of the same kinds of resources and computational infrastructure to researchers and scientists in the states. The Australian government in

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conjunction with the Department of Education has funded the DART Project (http://dart.edu.au/) in order to provide researchers with a resource rich infrastructure of technology (Paterson et al. 2007). The goal of these initiatives is to provide access to crucial resources and technologies that would otherwise be cost prohibitive for individual institutions and support the evolution of research practices that emerge as a result of this access and collaboration (Jirotka et al. 2006).

In addition to the creation of grid technologies that allow multiple users to access a common set of data and tools, there has been an emphasis on creating virtual research environments designed to facilitate and support the various stages of a research project. These environments allow colleagues to come together around shared interests regardless of geographic proximity and participate in the formation of a community of learners (Lave and Wenger 1991) intent on conducting meaningful and productive research. Working within these virtual environments, where comments and contributions are shared, and having access to the vast amount of data that is available online, creates a rich collection of organically cultivated information. This also necessitates that the researcher be ever more vigilant about checking the authenticity of the data and resources to be used in collaborative e-research projects (Anderson and Kamuka 2002).

Conducting research with the use of virtual environments and a distributed network of resources and stakeholders is still in it's infancy and presents a fertile area for research to be conducted in order to better understand how research in the digital age can, and will, be different. One area in need of further investigation deals with matters of trust both with regards to trust of the technology and trust in the expertise and intent of the researchers with whom we collaborate (Jirotka et al. 2005). Participating in a virtual research environment where files and resources are shared, conversations take place, and data is analyzed means trusting that the technology will work properly to safeguard all of that information and make it available when necessary. When a system goes offline or suffers unforeseen glitches in functionality the collective confidence of the community starts to erode. If the technology cannot be relied upon to work it presents an insurmountable obstacle to conducting e-research. In addition, being able to develop a trust of the other members of the online research community is imperative to achieving success in any research project. This trust can be difficult to cultivate in the absence of face-to-face interactions and presents a significant dilemma in the field of e-research. To promote the development of trust, virtual environments and other e-research collaborative tools can provide multiple opportunities for researchers to interact through chat tools that support text, audio and video so that individuals can get to know each other by more than just a screen name. In addition, these technologies can incorporate asynchronous avenues of communication such as discussion forums and blogs where colleagues can engage in conversations and share opinions as a way to get to know each other better and develop a shared understanding of different theories and concepts.

Before continuing with the discussion of the different types of tools available for conducting e-research it is important to make a few points of clarification. First of all, the Internet is littered with Web 2.0 technologies and companies that have come to the marketplace with a great range of services and features only to see their business fail in a fairly short period of time. While certain names may seem dominant today, think Google in the area of search, there is no guarantee that these same companies will survive and continue to provide the services they offer indefinitely. We acknowledge that some of the specific tools we highlight in this chapter may not be available in the near future for any number of reasons, but we do believe that the features and capabilities they provide will continue to be sought after by researchers so these *types* of tools will persist even if the individual names change. Therefore, we encourage the reader to focus on the *capabilities* of the different tools and consider how they can help facilitate e-research rather than concentrating solely on the specific names that are shared. In other words, the *process* is more important than the *product* in e-research initiatives.

The second point of clarification deals with the selection of tools to be covered in this chapter. With each category discussed in the following pages, whether it is an e-research collaborative tool or add-on tool that can be integrated with the different e-research environments, there are numerous options available to the researcher. Because of obvious restrictions of space, and to keep this chapter from becoming unwieldy, it is impossible to expect that we would be able to cover all of these options. Therefore, tools were included that had established a track record of reliability and represented a full featured alternative in their respective categories. Priority was also given to those tools that were accessible with a wide range of operating systems and browsers. The authors do not have a financial stake in any of the tools discussed in this chapter and no decisions were made about what to include based on perceived or actual monetary gain as a result of their inclusion.

Finally, this chapter is not intended to serve as an evaluation or ranking of the tools discussed. The different sites and applications shared are not presented in any particular order of preference and while comments may be included at times about the specific features or functionality of a tool, those comments are included to inform the reader and not as a way to render judgment on the merits of the tool itself.

2 e-Research Collaborative Environments

There are a variety of online environments designed to help researchers connect with others so that they may work collaboratively to conduct research with colleagues regardless of geographic location. These different environments help to facilitate the research process in multiple ways by providing access to a rich set of features, many of which are outlined below.

2.1 Connecting with Colleagues

Most of the online research environments currently available take a cue from popular social-networking sites and allow users to create profiles. In these profiles, researchers can indicate what they are interested in studying and the research questions they are looking to explore. In addition, users can "tag" their profile with other information that identifies them by discipline, publications, grants awarded, geographic location and other parameters as well. Researchers can then search the directory of participants in a given environment based on any number of these identifiers in order to find others with whom they would like to work. This helps to formalize the process of connecting with colleagues who share similar interests and goals or who may possess a sought after set of skills or expertise. Being able to identify colleagues by these different parameters also facilitates the process of establishing a trust as it allows researchers to narrow their focus to colleagues whose work they respect and whose interests are in alignment with their own.

2.2 Communication with Research Partners

The ability to communicate effectively is an integral component of any research project. Many of the online research environments available today provide a variety of options for both synchronous and asynchronous communication, which allow teams of researchers to stay in touch and create a shared archive of the different discussions that take place. The communication tools available in most online research environments include real-time chat, forum discussions, blogs and internal e-mail systems where users can leave messages for one another. These tools not only allow researchers to keep in touch regardless of location, they also provide a shared permanent record of conversations, and decisions made during those conversations, that users can refer back to for clarification at any time.

2.3 Creating Collaborative Research

With most research projects there is a fairly regular need to be able to share resources such as links, data files, drafts, articles and a host of other files. Sending these files back and forth through e-mail can become cumbersome and time-consuming so to alleviate this burden online research environments provide storage space for files and other resources to be shared with the group. This promotes the collaborative nature of e-research by storing files in a shared space where they are owned, and can be accessed, by the group rather than having them reside on individual computers where they are only accessible by specific users.

One benefit of working in a face-to-face research group is the ability to organize regular meetings where colleagues can hold each other accountable for making timely progress. Maintaining deadlines and keeping track of assigned tasks can help to keep a research project on schedule and online research environments should provide project management tools that help automate this process and allow colleagues to easily track the progress of other group members. These project management tools may include a group calendar, task manager or "to do" list and possibly a reminder system that can send out regular messages to group members alerting them of approaching deadlines.

There are a variety of online tools that allow researchers to create surveys, questionnaires and other types of data collection items. Many online research environments provide access to similar types of tools making it possible for colleagues to collaborate around the creation of these items. Researchers can work together to create data collection tools that reflect the input and expertise of the entire group. In addition, many of these tools also facilitate the collection and organization of data by sorting responses into a spreadsheet or similar data file for further analysis.

The act of writing is often a solitary experience regardless of whether the research is being conducted by colleagues who work in the same building or are spread across the globe. A group of researchers may develop a shared outline to follow or divide up different sections of a particular article or publication, but the actual process of writing those individual sections usually consists of each person working independently on his or her assigned section. This can be problematic as each author working on his or her section may not know what the other people in the group are writing and often results in the article being spread across multiple files rather than being contained in a single document that is accessible by the entire group. There are a variety of tools that are designed to make the writing process more collaborative. These tools facilitate multiple authors working on the same document by hosting the document online rather than having it be stored on individual computers. In addition, there are online graphic organizers where colleagues can create outlines and other visual representations of their ideas as a way to brainstorm collectively. Web-based bibliographic tools allow researchers to contribute to, and access, a shared library of references to cite while writing. Each of these tools helps to promote the creation of a collaborative document and facilitates authors working together during the writing process.

3 e-Research Collaborative Tools

This list of features discussed above represents the common functionalities of online research environments but is by no means all-inclusive of the capabilities of these environments. Additional available features are highlighted below in the discussion of specific e-research collaborative tools.

3.1 MyNetResearch *(http://www.mynetresearch.com/Application.aspx)*

One of the most comprehensive e-research environments currently available is MyNetResearch. MyNetResearch is web-based and does not require any software downloads. With the free membership users can create and share projects, files and online resources as well as connect and communicate with colleagues. However, the free account only allows you to be the owner of one active project at a time while upgrading to the premium membership means that you can have up to 50 concurrent projects actively running. Some of the other benefits of the premium account include being able to create and administer online surveys, a bibliography creator and access to a host of services designed to provide information and advice to the individual user. For instance, there is a grant program locator that facilitates the process of finding funding for different projects. In addition, there is a research methods advisor tool and a literature search and citation analyzer that can be used to increase the overall efficacy of the researcher. Once your research project is completed, you can use the journal selection guide to pinpoint the publication that is best suited for submission of your work or the conference selection guide to find the perfect place to present your findings.

3.2 Sakai *(http://www.sakaiproject.org/portal)*

The Sakai community is made up of various educational institutions that have developed a range of open source applications around a course-management system. Since these products are open source they are freely available but do need to be hosted on a local server or servers and it would be necessary to have individuals on site that could administer and troubleshoot the entire system. The various tools developed as part of the Sakai project are largely geared towards course management but they can also be adapted for use in e-research. As with MyNetResearch, the Sakai suite of tools provides access to an array of communication technologies, allows for the sharing of uploaded and online resources and facilitates project management. However, since Sakai is intended to run as more of a "closed" system, there is not the same opportunity to search for and find colleagues from within the Sakai environment. In order to get all the functionality desired it would be necessary to download and integrate the individual tools with one another. Another option would be to purchase the commercial version of the Sakai learning management system (http://www.rsmart.com/), which includes a fully functioning collaborative environment without the need of additional coding or programming. However, it does require a server running on either a Linux or Windows platform.

3.3 OMII-UK *(http://www.omii.ac.uk/index.jhtml)*

OMII-UK is another open-source option for creating an e-research collaborative environment. This suite of tools was developed in conjunction with the United Kingdom (UK) National Grid Service (http://www.grid-support.ac.uk/), which provides access to resources and tools for UK researchers. The software is much like the Sakai tools in that institutions would be required to download individual applications and integrate them in order to create a comprehensive environment. There is a development kit (http://www.omii.ac.uk/wiki/DevelopmentKit) that can be downloaded that facilitates the process of linking different applications together and allows you to customize the installation of different tools in order to tailor the environment to your needs. OMII-UK allows users to submit jobs that require computational processing of data and provides access to pre-made workflows that can be modified for different uses. The focus of this environment is more on the processing of data and providing access to computational tools rather than facilitating avenues of communication for researchers.

3.4 Ning *(http://www.ning.com/)*

At the core of e-research collaborative environments is the ability to establish powerful networks with colleagues across the globe and this is not unlike the process that takes place in many of the popular social networking sites such as Ning. With these sites, users seek out each other on the basis of a shared interest in a particular topic, hobby, cause, organizational affiliation or any number of other factors. While the name "social network" lacks an educational or professional connotation, these networks can be used to facilitate collaborative e-research. The strength in sites like Ning is the ability to foster communication among users through the use of forums, blogs, chat tools and comment "walls" that allow users to leave targeted messages for specific individuals. Ning also allows for the sharing of files and online resources through the forum tool as well as the integration of a group calendar that could be used to set deadlines and establish individual tasks. Since Ning was not built from the start to be used for e-research it does not boast the same range of specific tools that MyNetResearch has but it is still worth considering as an online space where researchers can come together to collaborate.

3.5 VERA *(http://vera.rdg.ac.uk/index.php)*

In addition to the environments highlighted above, which could be used across a broad array of disciplines, there are online research environments that have been developed for use with certain subject areas and for specific purposes. The Virtual Environments for Research in Archaeology (VERA) project is an online environment designed to help the archaeological community collaborate and share information on effective research practices relevant to the field. This project also provides support to archaeologists who may be unfamiliar with working and learning in virtual environments.

3.6 MyExperiment *(http://www.myexperiment.org/)*

MyExperiment is a tool designed to help researchers find and develop scientific workflows. This particular e-research environment would be most suitable for individuals creating workflows to do such things as extract data, perform an automated computation or complete some other task related to a particular research project. While it may not be designed for a specific discipline, it is certainly focused on a very specific purpose and objective.

4 e-Research Add-on Tools

There are a host of add-on tools that can be integrated with the different e-research collaborative environments in order to further promote collaboration among colleagues and researchers. These include tools that facilitate the collection and categorization of online information, promote collaborative writing and allow researchers to create shared artifacts.

4.1 RSS Feed Readers

- Sample tools
  - Pageflakes (http://www.pageflakes.com/)
  - Netvibes (http://www.netvibes.com/#General)
  - Google Reader (http://www.google.com/reader/view/#welcome-page)

Many popular websites and blogs generate an RSS feed making it possible to subscribe to them so that users can receive regular updates when new content is added. Using an RSS feed reader makes it much easier to follow multiple sites and stay abreast of the most current conversations and topics being discussed in a particular field. Following a range of sites and blogs related to a specific area of interest can be an effective way to generate ideas and make initial connections with other colleagues who may be maintaining or contributing to the targeted blogs or websites.

4.2 Social Bookmarking Tools

- Sample tools
  - 2collab (http://www.2collab.com/nonLoggedInHomePage)
  - Diigo (http://www.diigo.com/)
  - Delicious (http://delicious.com/)

The host of social bookmarking tools available allow users to save sites to a web archive rather than to an individual machine. This makes it possible to access these saved sites from any computer with Internet capability rather than storing them on a specific machine. In addition to being able to save sites for their own use, individuals can view sites saved by other users in order to see what resources they are uncovering on the web. Groups can be created around different subjects or areas of interest, which allow users to share specific sites with members of the group. Some of the social bookmarking tools even allow users to annotate the pages they save by highlighting text and adding electronic sticky notes as a way to point out specific information. Sites can also be tagged with keywords and classified into different categories making it possible to search through a series of sites based on this metadata. Social bookmarking sites can be an effective way to meet other researchers with common interests, locate online resources and create a web archive of sites accessible for reference by all members of a particular research group.

4.3 Collaborative Writing Tools

- Sample tools
  - Google Docs (http://www.google.com/educators/p_docs.html)
  - Zoho Writer (http://writer.zoho.com/index.do)
  - WriteWith (http://www.writewith.com/)

The ability to write collaboratively on a document can be a huge time saver since it allows all contributors to have immediate access to the same version of a draft. Word processing tools such as Microsoft Word allow the tracking of changes in a document so that fellow authors can quickly see co-author's edits, but using a desktop application such as Word means that only one person can be working on a draft at a time. Online collaborative writing tools make it possible to store drafts online where all users can access and contribute to the writing process either simultaneously or independently. These writing tools also provide a history of the document making it possible to see past versions and revert back to a previous draft if necessary. Edits are attributed to the individual author as a way to track the contributions each person is making and built-in chat capabilities make it possible for researchers to discuss ideas and pose questions in real-time as they write.

4.4 Survey Creation Tools

- Sample tools
  - Google Docs (http://docs.google.com/)
  - Survey Monkey (http://www.surveymonkey.com/)
  - Zoomerang (http://www.zoomerang.com/)

Online survey creation tools make it possible to create a comprehensive survey that can be distributed either by e-mail, a direct link, or by embedding the survey into a blog or website. These tools automate the process of collecting and organizing data by placing responses into a spreadsheet where they can easily be viewed and accessed for further analysis. This makes the entire process of certain types of data collection much more efficient and cost effective since it negates the need to print and copy surveys, mail them to research subjects, retrieve the responses, and enter them manually into a computer or statistical software application. It also allows colleagues to collaborate on the creation of surveys and the different questions contained within those instruments before they are disseminated.

4.5 Bibliographic Tools

- Sample tools
  - Endnote (http://www.endnote.com/)
  - Mendeley (http://www.mendeley.com/)
  - Zotero (http://www.zotero.org/)

Web-based bibliographic tools share many of the same features and benefits as social bookmarking sites in that they allow researchers to archive and share resources and references online. These references could be websites but can also include journal articles, books, reports, blogs, conference proceedings, and any number of other reference items that may be cited in a research publication or proposal. Bibliographic tools automate the process of citing references within a text by allowing the author to insert a reference directly into a document with a simple mouse click. The software applies the correct citation style based on preferences set by the author and the bibliography is automatically built as the draft is written. These features alone make this type of software invaluable to researchers engaged in the writing process, but the real benefit of these tools is the fact that colleagues can create a shared library of references online that can be accessed by multiple authors. Once again, this type of technology moves the focus away from viewing resources and information as being individually owned and managed on a single computer and positions it firmly in the online realm where information and ideas are shared, managed, and owned by the group.

5 Conclusion

The availability of tools to support e-research presents a broad range of possibilities for colleagues to collaborate around different areas of study. No longer is it necessary to rely on traditional face-to-face events such as conferences or annual meetings in order to meet like-minded researchers. Nor are we restricted to just the data, resources and references we can collect individually and analyze on a personal computer. The way we conduct research will evolve as these new technologies are further developed and modified, much like the way we communicate has evolved with the advent of e-mail, text-messaging, cell phones and social networking. But regardless of what new tools will be created in the future, the needs of the researchers will remain the same and they include the ability to connect with other colleagues in order to collaborate around different topics of study and engage in the creation of knowledge.

6 Recommendations for the Future of e-Research Environments

It remains to be seen exactly how e-research technologies and virtual environments will change the way research is conducted but we offer some recommendations to consider for the future of e-research collaborative environments and for our colleagues who endeavor to both use and create e-research tools. First of all, the various web-based research environments outlined in this chapter all share one commonality and that is their dependence on contributions from their respective community of members. Searching through a directory of colleagues to collaborate with is only effective if that directory is populated by a varied and qualified group of researchers. Likewise, accessing a public repository of data and files is only useful if the repository contains a credible selection of resources. The tool itself provides the infrastructure to support the sharing of information and facilitate colleagues connecting with one another but these virtual research environments rely heavily on the active contribution of content and ideas from the community in order to be fully useful.

There are several things that can be done to encourage the use of these collaborative e-research technologies. As indicated in the introduction of this chapter, government organizations from many industrialized nations have initiated projects designed to support and promote a cyberinfrastructure for e-research. These institutions, as well as private companies who design similar tools, can help to attract researchers by providing tools and technologies that are robust and reliable. Researchers need to feel confident that the resources, files, and conversations they share online are secure and will remain accessible indefinitely. As a way to provide extra assurance, virtual research environments should be designed to allow individuals to archive different components of a research project and download those elements for back-up purposes. This archival feature may include being able to save the contents of a discussion forum, files and resources from a project repository and multiple drafts or collaborative notes written by the group. Having the ability to save entire sections of a project will provide important peace of mind that these vital representations of knowledge constructed online can be exported and saved for future reference.

In addition to establishing a sense of trust in the "grid" as a repository of knowledge and data, it is paramount that researchers start to move beyond the mindset of working with individual files stored on a single computer and instead embrace the concept of accessing shared files and data stored online in the "cloud". This does not require that all research be conducted online or that individual researchers can only contribute to the research process when seated at a web-enabled computer. It does mean, however, that we make a more concentrated effort to share our work, thoughts and resources with colleagues more openly in these virtual environments rather than operating as islands separated from the whole. With the proliferation of Web 2.0 technologies that make it possible to easily share photos, videos, podcasts and multiple other forms of expression it is not hard to imagine the field of scientific research being able to move in this direction of socially created ideas and investigations.

This brings us to our final point, which deals with the need to rethink our concept of authorship. As the field of e-research grows and evolves it may become more and more difficult to attribute ownership of ideas and thoughts to a particular individual especially when those thoughts and ideas were shaped and honed through online interactions within a community of learners and thinkers. In a sense, ideas will easily get "re-mixed" much like the vast array of video and audio content that is shared online regularly and this can make it difficult to think about authorship being attributed to a single individual. Instead, we may want to view articles, books and online publications as different versions of topics and ideas that are open for revision and waiting to be modified by the community once more information is gathered. The popular online reference site Wikipedia (http://www.wikipedia.org/) serves as a perfect example of this kind of evolving body of knowledge that is authored by a very large community of contributors. We do not hold Wikipedia up as an example for it's accuracy of information, but rather because it represents a source of information that has been crafted through ongoing revisions and contributions from a multitude of authors. It seems quite possible that the field of e-research may follow this same model and, if it does, our focus may need to turn more towards the social construction of knowledge and away from the individual authorship of text.

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Blogging to Accelerate Peer Review of Doctoral Dissertations

Marcy Willard and Dean Leffingwell

Abstract In this chapter, the authors describe how to use internet blogging tools to accelerate peer review of academic and scientific research. Blogging provides the ability to reach out to geographically dispersed experts, and others – such as the students often difficult to reach advisors, professors, and professional colleagues- to express and solicit research opinions and input in either public or private forums. In so doing, the student's work gains the benefit of cumulative ideation from experts in the field, resulting in a more thoroughly vetted, tested and peer-reviewed content, prior to even the first draft publication of the work. In this chapter, the authors describe the growth of blogging in general, and provide specific and practical recommendations for setting up a blog to solicit and obtain peer review of a PhD student's in process dissertation.

1 The Wisdom of Crowds

The simplest way to get reliably good answers is to ask the group each time

– James Suroweiki, The Wisdom of Crowds

In evaluating the peer review process, a tale about a researcher in 19th century England, provides an excellent illustration. This story was retold in The Wisdom of Crowds (Surowiecki, 2005). Francis Galton was a British Scientist well known for his work in the science of heredity. Galton was a eugenicist who believed that intelligence was hereditary, and that the decisions and judgment of scientists and educated people would be superior to that of a large crowd of "commoners". In order to prove this, he set up a unique experiment.

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He intended to show that a crowd of regular folks could never match the scientific approximations of just a few, hereditarily-gifted experts. The ox weight estimating contest at The Annual West of England Fat Stock and Poultry Exhibition provided the perfect opportunity. The participants in the contest would pay a sixpence to try their hand at judging the weight of the ox. After the ox was weighed, those with the best estimates could receive a prize. There were over 800 people from all walks of life who participated in the contest. They were not experts in livestock, per se, although there were farmers and butchers in the crowd. As Galton explained it, "Many non-experts competed...the average competitor was probably as well fitted for making a just estimate of [the weight of an ox] as the average voter in judging the merits of most political issues on which he votes . . ." (Galton as cited in Surowiecki, 2005, p. xii).

After the contest was complete, Galton borrowed the ballots of all of the participants in order to run some statistical tests. He added the estimates and calculated the mean in order to determine the average intelligence of the crowd. His assumption, of course, was that the crowd's average estimate would be dead wrong; thus, clearly demonstrating "the stupidity and wrong-headedness of many men and women" (Surowieki, 2005).

What happened? Galton and the expert guessers were the ones who were dead wrong. The crowd's estimate was 1,197 pounds. The actual weight: 1,198 pounds; essentially, an exact estimate. Galton was forced to conclude that the crowd was much smarter than he previously thought.

Of course, researchers are not generally estimating the weight of oxen in academic research, nor can they realistically gather large crowds of which they can ask difficult questions, but this simple experiment, and many more facts that Suroweiki develops in his work, conclusively demonstrate that individual expertise alone is not a formula for solid decision-making. In fact, the best results are achieved by obtaining diverse and independent opinions of the topic. In developing research manuscripts and similar treatises, these diverse perspectives can be effectively integrated and taken advantage of only when the peer review process is effectively utilized.

2 Peer Review in the 21st Century

Peer review is critical to the development of quality academic research. Indeed, the general advancement of science and intellectual property often rests on an author's effective utilization of this process. Peer review is "the evaluation of creative work or performance by other people in the same field in order to maintain or enhance the quality of the work or performance in that field" (The Linux Information Project 2005).

In graduate school, students and professors are constantly striving to gain recognition through published research. For every doctoral paper or dissertation, the use of scholarly articles and papers is foundational to the quality of one's research. In order to determine if each article is worthy of being cited as background material for one's dissertation, the author needs to ensure that the work has been peer reviewed. Peer review implies that the work can be considered well-constructed science, rather than an individual's ideological opinion piece. Fortunately, peer review can be accelerated and simplified and in the Web 2.0 era. This chapter provides an overview of the benefits of peer review, describes the utility of using blogs to garner peer review, and finally, provides a step-by-step process for establishing a peer review blog.

3 E-Research Collaboration in Doctoral Studies

Thomas L. Friedman, a leading expert on how advances in technology have changed the world economy, has weighed in on the importance of research collaboration at the university level. In his hallmark book *The World is Flat*, Friedman explains that collaboration (in the advancement of science, technology, and business) is one of the key skills necessary for the advancement of innovation, research, and commerce in today's competitive marketplace. With respect to collaborative research efforts, he quotes Bill Gates in saying, "There are one hundred universities [in the U.S.] making contributions. . . . Each one is saying that the other is doing it all wrong, or my piece actually fits together with theirs. It is a chaotic system, but it is a great engine of innovation in the world. . . . if we are smart we can increase it faster by embracing this stuff " (Gates as cited in Friedman 2007).

The other significant aspect of e-collaboration in a doctoral dissertation is that the peer review community often requires a wide net, including geographically distributed reviewers who will never meet in person. For example, one expert reviewer may work in the community, another at the hospital; another may be a doctoral student, another a professional colleague. . . the list goes on. Rather than arranging individual meetings with each of these reviewers, the peer review process can be rapidly accelerated with the use of Web 2.0 technologies.

4 Peer Review in the Web 2.0 Internet Age

In the last decade, the growth of the World Wide Web has dramatically altered and accelerated the peer review process. As such, effective utilization of the Internet to accelerate peer review, and thereby, more rapid advancement of science in general, is a phenomenon that should be understood by every doctoral student interested in advancing his or her particular field of endeavor.

Even earlier, the advents of the Internet and the World Wide Web have had a dramatic impact on the development of quality academic and scientific research. During the earlier years of the web, authors were restricted to what we now think of as the 'push web' (or Web 1.0), which involved the use of static websites and sideband email communication for publication and review of research. Now, doctoral students and professionals have entered the era of Web 2.0, the far more collaborative 'push/pull web' which allows readers and authors to collaborate fluidly and continuously. In the article, "*Why Web 2.0 is good for Learning and for Research: Principles and Prototypes*", Ullirch and others note, "the Web changed from a medium to a platform, from a read-web to a read-write-web". They continue, "This stimulation of active participation distinguishes Web 2.0 based learning from traditional Web 1.0 learning" (Ullrich, Borau, Luo, Tan, Shen, & Shen, 2008). Web 2.0 technologies have taken a significant role in enhancing education and pedagogical research paradigms. The writing of research and peer review can now become widely parallel, simultaneous processes. Authors enjoy accelerated and instantly critiqued reviews of their work in process. The final result is research content that is richer, more thoroughly tested, and more quickly integrative of many expert perspectives.

5 Blogging for Massively Parallel Peer Review in Doctoral Work

A blog, short for "weblog", is similar to a webpage in that content is posted for wide Internet viewing. However, blogs are different from websites in that readers can provide feedback and comments in a fluid and constantly evolving forum. Blogging utilities are one of the primary Web 2.0 collaborative Internet tools of our time. At present, there are known to be around 1.3 million active blogs (Nardi & Gumbrecht, 2004). Blogs have become powerful tools for a wide range of on-line collaboration projects of social, business, entrepreneurial, and more recently, academic endeavors. This finding was illuminated and acknowledged in a report of the 2008 World Scientific and Engineering Academy Society conference, entitled, "*The application of Blog and Benchmarking-Digital Divide in Education and Future Strategies,*" The authors refer to a blog as a 'new star' in the field of education and digital learning (Fang, Yang, Lee, Tsai, & Li, 2008)

Blogs have become powerful tools for a wide range of on-line collaboration projects of social, business, entrepreneurial, or academic endeavors.

Blogs also add depth and personalization to on-line research communities with archives, discussion threads, and expanded information storage capacity. The growth of the blogosphere is allowing for more rapid advancement of intellectual property. Blogging within the context of research in doctoral work allows for accelerated, wideband, parallel peer review. Doctoral students can write while they are being peer reviewed. This is an entirely new and exciting way of approaching doctoral dissertations and collaborative research projects.

Doctoral students can leverage these blogging technologies to enhance the quality of their work and improve the quality of their research. The peer review process can be included from the beginning of dissertation work. While it is still commonplace for students to write a large body of their dissertation without subjecting to peer review, this approach is becoming quickly outdated and less effective. The problem with this write ... submit ... wait ... re-work process is that the original work does not share the perspectives and scrutiny of an educated body of peer reviewers in the community.

These research collaboration tools in the peer review process are especially useful for doctoral students because reviewers are distributed around the community, and in some cases, around the globe. Professors, who often are part of the peer review community, are rarely available for face-to-face meetings. On-line collaboration has become the preferred means to work with professors on a variety of projects. In this way, expert faculty can make comments on a student's work within the context of their unique schedules, priorities, and deadlines without any interruption to their work day. Similarly, a student might be on-line at 2:00 AM when she realizes the need to check a professor's feedback on a certain piece of research. This is easily done in an on-line format.

6 Privacy, Originality, and Other Concerns in the Web 2.0 Era

Some might argue that utilizing an open forum for peer review violates some of the conventions of doctoral research. Researchers may be concerned about protecting the privacy of their unique bodies of research. Fortunately, blogs can be set up for full public or restricted access.

While restricted access has the advantage of privacy, it is harder to create a broader community of interest around the topic. In a controlled setting, the researcher may not get the benefit of a wider body of experts to help rally support for a topic and to gather suggestions for additional research. A public blog facilitates a research community more efficiently. A mix of publicly available and restricted access content may also be appropriate. For example, if the researcher would like to maintain privacy, he or she can choose to only post generic materials to a public blog and then require a log-in to access proprietary materials. In this case, the author would make his contact information available and he could choose community members on a case-by-case basis. This process is more laborious and requires more administration; however, this need to maintain privacy has long been a concern of researchers and businesspeople in the Web 2.0 era.

Another concern about this process is that doctoral dissertations are intended to be original, unique, proprietary works – rather than the "wisdom of crowds". The fear is that the dissertation author might unknowingly dilute their message and sacrifice originality through this open forum. While this is a legitimate concern, the author can overcome any of these challenges by taking one precaution. The author, while weighing her opinions against the advice of other experts, must maintain her voice and original thesis, throughout the process. Yes, the author is choosing not to write in a vacuum, so ideas may be re-evaluated and adjusted continually (as, indeed, all good scientists must diligently consider the accuracy of their theses and conclusions); however, the resultant content remains the sole responsibility of the author.

7 A Prescriptive Blogging Method for the Development of Collaborative, Accelerated, Peer Reviewed Content

The discussion that follows provides a prescriptive recipe for initially setting up a peer review blog, using the blog to build a community of peer reviewers, engaging an interactive dialog by soliciting comments, and using the results of that process to create a peer-reviewed dissertation.

7.1 Selecting the Blogging Platform

Once the student has decided on a general topic for the dissertation and made the decision to use a blogging model for accelerating peer review, the next choice is the specific blogging service to be utilized. Fortunately, there are a number of choices of free or fee-based blogging service providers. Since this is, after all, a student who is leveraging this service, we will assume that the student picks a free service, one with the general utility needed to solicit and coordinate reviewer's feedback, but without the extensive extras that come with a paid service. As of this writing, the student's choices fall into two main categories.

(1) Private, member-based communities with collaboration platforms designed for research purposes; these include platforms such as MyNetResearch (www.mynetresearch.com) and 2collab.com. (www.2collab.com). Each provides a set of on line collaboration tools for researchers that enable researchers to share, connect, and discuss research projects. MyNetResearch is one such hosted collaboration environment, which also embodies an embedded community of registered member researchers covering a broad spectrum of research topics.

One advantage to this research-specific platform approach is that if there is sufficient existing membership in the domain of interest, the student may have tapped a rich vein of actual subject matter experts who are already interested in the topic. Additionally, if the student needs to protect future intellectual property or particularly sensitive ideas, this "gated" community might be an attractive feature. However, a disadvantage to the approach is that such sites require a log in subscription, which even when free, presents a barrier to reaching out to a wider community of potential contributors.

(2) Public-facing blogging services – The rapid growth of the blogosphere (there may be as many as 100 million bloggers worldwide today) (Friedman 2007) has created a ready commercial market for companies who provide hosted blogging

facilities, which are available for free to anyone. Two such services include WordPress.org (www.WordPress.org) (see Table 1) and Google's Blogger (www.Blogger.com), but there are many others as well. Each of these platforms provides basic blog hosting and publishing utilities as well as startup templates, access controls, and individual profiles. An example of Dean Leffingwell's WordPress blog follows:

Advantages to this public facing platform approach include the fact that the blog content is available to users of the Internet at large (assuming the student provides such access permission) as well as the general usability features of these blogs, which have been designed to serve a wide public audience.

Our personal experiences are based on the application of the WordPress.com blogging service, so examples of usage and feature sets are based on these experiences. However, the basic utilities of all such services are advanced to the point that the functionality we will describe is likely available on any reasonably popular blogging platform.

7.2 *Creating the Blog*

Once the platform is selected, the user registers on the site and creates a name for the blog. The name of the blog will be captured in the URL (the Internet address of the blog). This will be the name the readers use to access the blog, so a careful selection may be important. However, the blog title may not be able to capture the essence of the blog, so a generic name may be suitable. Once registered, the user

Table 1 Example of Wordpress

can pick a style template for the blog, which controls the way the blog is presented to the users. The student should select based on personal style and suitability to the academic work ahead.

The student should also create a special blog page, typically titled “About this Blog” which describes the author’s background and the nature and purpose of the blog.

The student then creates an initial first post, which typically announces the blog and describes the purpose and intent, along with a pointer to the “About this Blog” page and any other special pages (for example: a Resource or Contact Me).

Thereafter, the student is ready to begin the more serious activities of posting content and garnering peer review.

7.3 Publishing Initial Subject Content

The next step in the process is to create some initial content of interest to those potential collaborators on the Internet. In the case of a student’s dissertation, the first step may be to publish the dissertation proposal itself. Standard practices for dissertation content vary, but it typically incorporates a number of specific elements that constitute the initial dissertation proposal. These may include (Kilbourn, 2006):

- **Problem** – a clear statement of the problem to be addressed must express the intent of the dissertation and blog.
- **Theoretical Perspective** – The theoretical perspective of a proposed study orients the research in a specific direction.
- **Inquiry Proposal** – This section of the proposal describes the inquiry strategy, which begins the process of examining the problem from a general perspective, and then moves to a specific subset of interest.
- **Literature Review** – This section describes the student’s plan for literature review, which identifies the strategies and sources of potential published input for the dissertation.
- **Proposed Methods** – This section provides discussion of the specific research methods that will be applied in developing the content for the dissertation.
- **The Plan** – The proposal may also include a plan that provides the student’s procedural approach to content development; the steps that will be taken to achieve the intended result.

Pushing the research proposal to the blog and soliciting feedback immediately is a highly leveraged step that works substantially to the benefit of the student. Even if the proposal has been reviewed and approved by the student’s academic advisor, others may comment on elements of the proposal and provide meaningful additional direction. This feedback can be used by the student to adapt or adjust the problem statement or the methods that will be used to research the subject matter. In turn, this can help the student avoid missteps, blind alleys, and unproductive delays.

7.4 Building a Community of Interest and Soliciting Feedback

The next "step" is not really a single step, but rather is a long-term continuous process whereby the student actively solicits feedback to the initial thesis proposal and subsequent blog content. This must be an active, not passive, effort on the part of the student. The blog will be indexed by Google and other search engines in as little as a few hours and, therefore, may be discovered via search queries. However, simply being indexed is not likely to generate enough visits to the site, as people may or may not be actively searching on the topics and the search results may not be adequate to drive a sufficient number of visitors to the site.

So the student cannot leave this part to chance and must take an active and ongoing role in driving potential reviewers to the site. Mechanisms to drive visits include:

(1) Identifying and contacting people known to the student who have an interest in the topic. This can include other students, mentors and advisors, research peers, and subject matter experts; whether previously known to the student or discovered via the student's research. Once identified, the student should point these potential reviewers to the blog, actively "ping" them via email and ask them to contribute comments. The student should also ask the potential reviewers to subscribe to the site with their RSS reader which allows readers to subscribe to automated updates from favored websites or to aggregate feeds from many sites into one place for their convenience. In this way, they will be notified automatically of new posts or newly posted comments.

(2) Use the blog's link facility to provide links to other blogs and websites on the topics of interest. This allows the student to provide value to the reader and extends the community by providing pointers to additional content that may be of interest. Thereafter, the student should contact those blog owners and webmasters and ask that they build reciprocal links to the student's site in return. In this way, a small, linked "community of special interest" can be quickly organized around the subject matter.

(3) The blog author can also use the blog's tagging (or keyword) function to ascribe tags to the various posts. Tags provide additional metadata (the tags themselves) to the search engines, which helps searchers find the blog of interest using their most likely search terms.

All of these techniques will help build a community of special interest around the blog, but the most important point is that it is the student who must actively build this community. If the blog is ultimately successful and it is of sufficient interest to the community, the process will take on a life of its own over time as others link to the blog, syndicated blog content, and new potential contributors find their way to the blog via independent keyword searches.

In addition, to truly unleash the Wisdom of the Crowds of the intelligence gathering process, the conscientious student should be careful to facilitate input from independent and diverse schools of thought. As Surowiecki (2005) notes:

> Ultimately, diversity contributes not just by adding different perspectives to the group but also by making it easier for individuals to say what they really think. . . . Independence of opinion is a crucial ingredient in collectively wise decisions. . .. Diversity helps preserve that independence; it is hard to have a collectively wise group without it.

By seeding and encouraging independence of thought and diversity of opinion in the initial community of interest, the student will have taken an important first step in the development of scientifically peer-reviewed, new, and beneficial intellectual property.

7.5 Developing New Content

After this initial setup work and time investment, the next part of the process delivers on the primary objective of the endeavor, using the active community to review the students incremental content as the research progresses and the conclusions of the research are tentatively formed and pushed to the blog. This is based on the student publishing a continuing series of new blog posts, which are short writings on relevant topics. A recommended standard format is as follows:

- A post title which communicates content and intent. The title is important, as it will be concatenated into the URL for the post. The title of the post will appear in search results, and the post itself becomes a searchable page on the Internet
- Introductory context to put the content in perspective
- The content
- A short summary or conclusion
- A look-ahead (tells the reader what to expect next and hopefully compels them to revisit or subscribe to the blog)

The number and timing of these posts is based on the velocity at which new content is being developed. The serious student will be careful to post only meaningful content, no idle or lateral chatter, and to do so routinely – not so often as to frustrate the readers because there is always something new they have to read – but not so far apart as to lose the reader's attention to the thread. As a general rule of thumb, one or two posts per week is a good cadence to capture and keep an interested readers intention.

Also, with respect to the thesis, since each post is just a few hundred words, it will likely take a significant number of posts to develop a meaningful body of content. This highlights the iterative and incremental nature of building research content via blogging and is one of the main advantages of blogs, i.e. a student can push content – even if not well developed – out in short snippets and get immediate feedback. This cadence also helps force the student into a pace that forces the rate of research to be aligned with the committed schedule for the manuscript.

7.6 Comments and Comments on Comments

Of course, the goal of the entire process in peer review is to get readers to comment on the content that has been posted. Typically, this will happen on-line in an attributed comment field provided by the blogging platform. In this manner, all readers can see all content on all posts, know who commented, and build on each other's comments as well.

However, the student has discretionary control of all posted comments and can prevent or allow potential comments, edit, and respond to comments. This process is under the complete control of the students so there should be no concern about the potential for inappropriate comments or materials to appear on the student's site. Individual posts can also be public or private (password protected) as the author so chooses so that a private post or thread might be made available only to a specific sub-community. This access mechanism can also be used to protect (hide for private use only) new intellectual property where appropriate.

However, generally, the blogger should permissively allow all comments, whether they are critical, supportive, or simply elaborative to appear on the site, so long as they add value to the readers and the subject of interest.

This cumulative commenting process is the prime area where peer-review value is received and the open, community nature of the process builds intellectual property in new and fascinating ways. As one researcher (Wardrip-Fruin 2009) commented on her experimentation with blogging peer review process notes:

> But with this blog-based review it's been a quite different experience. . . . faced with just this one (reviewers) comment, in anonymous form, I might have made only a small change. . . . However, once they started the conversation rolling, others agreed with their points and expanded beyond (the initial) focus — and people also engaged me as I started thinking aloud about how to fix things — and the results made it clear that the larger discussion . . . was problematic, not just my treatment of one example.

In other words, the blog-based review form not only brings in more voices (which may identify more potential issues), and not only provides some "review of the reviewers" (with reviewers weighing in on the issues raised by others), but is also, crucially, a conversation (my proposals for a quick fix to the discussion of one example helped unearth the breadth and seriousness of the larger issues with the section) (Wardrip-Fruin 2009).

The writer goes on to note her new perspective on the issue of relative trust in the two methods – traditional, anonymous manuscript review vs. blog based review – as follows:

> On some level, all this might be seen as implied with the initial proposal of bringing together (traditional) manuscript review and blog. But, personally, I didn't foresee it. I expected to compare the recommendation(s) of commenters on the blog and the anonymous, press-solicited reviewers – treating the two basically the same way. But it turns out that the blog commentaries will have been through a social process that, in some ways, will probably make me trust them more.

From these comments it is clear that properly executed blog-based peer review can bring the Wisdom of Crowds to bear in building new information. Indeed the evolution of intellectual property via this process evolves in ways that cannot be readily anticipated by the author/researcher. As a result, innovation and science is advanced and accelerated in ways not available from the traditional peer review process. Traditionally, this process typically happened at the end, was blind (anonymous), and was often too late for meaningful new research initiative or intellectual advancement.

7.7 Special Posts – Publishing Aggregated Work in Process – Blogging for Massively Parallel Review

When it comes to growing a new body of knowledge, as we have described, blogging has many advantages over traditional manuscript development, but it has some inherent disadvantages as well. Not the least of these is a degree of difficulty in understanding the gestalt of the information that is being created as a work in process. Even with blog categories, tags, and embedded search capabilities, it can be difficult for the author or reader to get an "all-at-one-time understanding" of the intellectual property being developed in these short blog post snippets. Plus, we must remember that while the blog is written sequentially in time, it will be presented to the readers as last entry first. Reading the blog from front to back (or back to front) requires some work and context switching on behalf of the reader.

To address this, the student should put together comprehensive working drafts of research in process and publish those as separate documents on the blog. Typically, this will be done at one or two seminal points in the development process; those points at which a reasonable body of knowledge is being formed and tentative conclusions can start to be reached.

Each of these special posts will likely spawn additional comment threads relative to structure, presentation, readability, and tentative conclusions being drawn. These posts serve as the first "manuscript level" reviews and also help the student evolve a far more worthy work – one whose critical content and near final form have already been extensively reviewed prior to even the first drafts publication.

7.8 *Optimizing Peer Review with Blog Statistics*

So far, we have just touched the surface by applying only the most basic blogging constructs to drive readership and peer review. However, as the information science aspects of blogging are rapidly accelerating, blogs are being used to perform broadband market research, influence public opinion, and even build entire businesses. In support of this sophistication, current blogging utilities provide rich capabilities in support of knowledge gathering with respect to readership, special interests, common search criteria, etc. For example, the student likely has access to the following types of information:

- Views per day and daily post traffic summaries highlight activity in aggregate, as well as per individual post
- Top posts statistics highlight the posts that achieve the most views over time
- Most active posts statistics tell the student what topics are generating the most interest
- Incoming links illustrate what blogs and web sites refer to the subject blog
- Referrals delineate the websites, blogs and search engines where visitors are coming from
- Common search terms highlight the search terms of interest that are being used to find your blog and also imply related topics of interest

The more experienced blogger will use these tools to optimize their information presentation and presence, capture additional readership and reviewers, and otherwise extend the community of interest.

7.9 *Finalizing and Publishing the Draft Thesis*

As the deadline nears, the content and state of the work must near completion. Hopefully, by this point in the process, the student/blogger will have published many dozens of posts and received many dozens of comments in return. Early manuscript drafts have been posted and reviewed and the student has arrived at conclusions reflecting the findings of the research. Reviewer's comments have been incorporated in the work and the reviewer's added value has been attributed where appropriate.

While the student may be tempted to abandon the overhead of the blog process as the deadline approaches, he or she owes it to the active reviewers and other readers to see the final result of all their combined hard work, and to give credit for the intellectual and emotional investment of others. To this end, the student/blogger should publish the final working draft in another special post and then perhaps conclude the series with a thankful acknowledgement to all who contributed to the blog.

8 Summary

In this chapter, we've described how the peer review process, even in its traditional form, is critical to the development of meaningful and unbiased new knowledge. We've also introduced blogging for peer review as a means to harness the broader wisdom of crowds, resulting in better and more definitive research and improved decision-making. In the context of a student drafting a doctoral thesis, we have also described how a student can utilize current, free commercial blogging platforms to find potential reviewers, actively instigate reviewer comments, aggregate comments into new forms, and publish initial and final draft manuscripts.

Perhaps most importantly we have seen how the growth of real and meaningful knowledge is enhanced and accelerated in ways not available prior to the advent of e-collaboration via blogging tools. We've seen that the combination of real-time comments, reviewer's comments on comments, and the social network that evolves in direct pursuit of this new intellectual knowledge, produces results that were not achievable via traditional methods. Therefore, we conclude that the simple approach of accelerating peer review via blogging and other such collaboration utilities substantially accelerates the development of new and more scientifically-based knowledge in academic, research, and commercial business settings. To ensure the best decisions possible, ask the crowd every time.

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The Butterfly Effect: An Approach to Web-Based Scientific Data Distribution and Management with Linkages to Climate Data and the Semantic Web

David P. Waetjen, James H. Thorne, Allan D. Hollander, Arthur M. Shapiro, and James F. Quinn

Abstract Environmental scientists generating longitudinal data that reliably track changes in biodiversity face additional challenges of data management and dissemination. An open source web framework can be used effectively to manage datasets while making research available at different levels of expertise, including for public environmental education. This chapter discusses the development of a web framework which links long-term butterfly presence/absence data with regional weather data, allowing researchers to investigate the relationship between butterfly populations and climate change, over time. The chapter concludes with a discussion of the semantic web, and how observational and monitoring data can become part of the growing Linked Data project.

1 Introduction

Researchers in many fields apply long term trend data to examine whether temporal patterns can be used to predict outcomes. A central challenge, especially in environmental sciences, is that observational data are closely linked to other data types, such as investigators, methods, semantic usages, calibration, maps, and images, which evolve over time. These must be tracked simultaneously, posing challenges to the construction of information systems and web resources. In this chapter, we present a model data portal that can provide access to event based time series data and mixed types of linked data objects. The portal uses open source tools to address the needs of both expert and educational audiences and the general public. In particular, we draw from semantic web concepts and the Linked Data initiative to show how unstructured ancillary data types, as defined by a research community,

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can be attached to trend datasets to allow interpretation of temporal change. We illustrate the approach using multi-decade butterfly population records from California, linked in a web portal to regional weather data, maps, photographs, identification guides, and taxonomic materials. The model permits previously impractical assessments of the impacts of climate change on regional biotas.

As environmental scientists and other scholars generate longitudinal data to track changes in biodiversity, they face the twin challenges of data management and dissemination. In creating research interpretations, the challenge is to interpret research findings for communities of experts and specialists but also – increasingly – to the public at large. The rise in global environmental awareness and the politics of climate change are emerging motives for developing interchange between scientific and scholarly studies and public environmental education. Whereas data management and research dissemination were once separated by a gap between specialized scholarly language and general public understanding, the Internet has brought together these two realms into an interactive domain of knowledge networks.

Consistently recorded long term (>20 years) ecological datasets from the same locations are rare, despite the reality that such datasets are essential for understanding patterns that emerge across time due to global-scale environmental change. Because there are so few, these datasets are used not only for understanding environmental influences on populations of target species, but also as surrogates for estimating impacts on the vast majority of species and ecosystems for which we have little direct data. Moreover, the lack of on-line access to species occurrence data is an impediment to advancing biodiversity knowledge (Guralnick et al. 2007).

Many of the most pressing environmental challenges, such as the effects of climate change on natural populations, ecosystems, and the ecological processes that support human wellbeing, require analysts to integrate long-term data series from disparate sources. Typically, these were gathered by investigators in different professions, using very different language, concepts, methods, and sampling frequencies. While these data can often be overlaid, cross-correlated, and viewed graphically by time and location, it is a challenge to data architects to structure data in a way that can be readily used for novel analyses not anticipated by the data collectors. Structuring data as a series of point events, which include the observer, constituent, time, and space, ("who", "what", "where", and "when") is a good way to maintain flexibility for future processing needs.

In summary, this chapter explores a generalized framework for constructing web-based event information systems capable of using long term ecological records to understand the impacts of climate change on populations. The purpose is to enable new analyses, but at the same time, to build a standards-based, modular system that uses free and open source software, and that may be re-used for simple ecological "who–what–where–when" data in general. The goal is also to use a single system, viewable in expert, public/school, and machine interfaces, to publish time series data to multiple audiences and provide professional rewards to data collectors for doing so.

Butterfly research at the University of California at Davis (UCD) has produced one of the world's largest datasets of site-specific data on butterfly populations collected by the same experts, following consistent and rigorous scientific protocols, visited systematically over several decades. As such, it provides an important source of information about biodiversity and change over time and offers an excellent case study through which to prototype semantically-enabled methods for management and dissemination of multi-year ecological time-series.

The challenges of data management in a collaborative system can be reduced by using the web as a central access point for those resources. This chapter presents a model for building a data portal that provides access to event-based time series and monitoring data, as well as their related content, including photographs, site descriptions, educational modules, and transect maps. The processes and tools used to build an effective site are discussed in relation to the case of ongoing butterfly research conducted at UCD by entomologist Arthur Shapiro, who has been monitoring butterflies across central California continuously since 1972 (see http://butterfly.ucdavis.edu).

2 Case Study: California Butterflies in a Shifting Climate

Shapiro collects butterfly occurrence data in central California to understand the influence of topography, vegetation, and weather patterns on the biodiversity of butterfly species present in this region, and to document year-to-year and long-term changes in occurrence and abundance that ultimately link to global environmental conditions (Forister and Shapiro 2003; Thorne et al. 2006).

There are ten field sites that transect California, from the western terminus at Suisun Marsh east across California's Central Valley, up and over the Sierra Nevada and into the Great Basin. Each site is visited at approximately two week intervals, although the mountain sites are not visited when they are snowed in. Sites were selected to encompass California's full spectrum of elevation, ranging from sea level (at Suisun Marsh) to 2,775 m at Castle Peak. A total of 160 butterfly species have been observed and are monitored by the project (Fig. 1).

The associated butterfly website, developed under a grant from the National Science Foundation (NSF) provides over 1,100 unique textual web pages, including 10 collection site pages, 40 database queries, 160 pages detailing each butterfly species, and 878 pages describing their phenologies. The butterfly website hosts over 450 interpretable photographs of the individual taxa and the study sites. The monitoring database is updated annually from hand-transcribed field notes. These data then become accessible through the website interface. This website is accessible from the National Biological Information Infrastructure (NBII) California Information Node (CAIN) (http://cain.nbii.gov/).

The weather data for this project comes from the Western Regional Climate Center (http://www.wrcc.dri.edu/). Meteorological data are collected and quality tested, then published in various formats for public and private use. The butterfly website uses data from ten of these stations, and tracks minimum and maximum temperature, precipitation, snow fall, and snow depth. These data cover the same

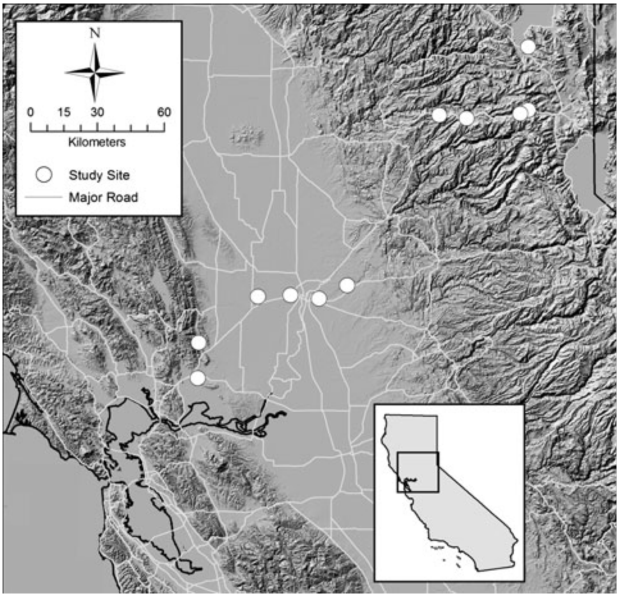

Fig. 1 This map shows the butterfly collection sites across central California

temporal period as the butterfly project, so questions comparing butterfly populations and changing climate can be addressed.

2.1 Field Site: The Butterfly Web Interface

There are two main processes that should be present in all scientific research: discovery and dissemination. Traditionally, biogeographic knowledge has been disseminated through journal articles, resulting in a fragmented literature little read outside the immediate technical community. For educational purposes and the interested public, these texts are difficult to locate and interpret. Yet working scientists are rarely rewarded for re-presenting their data for alternative audiences. With the web, it is possible to design multiple user-specific entryways to the same data, and direct the content to various levels of expertise. Because most schools and residences now have connections to the Internet, the web becomes an effective method of conveying this message to the general public.

2.2 The Public Interface: Education and Citizen Science

Designed for junior and senior high school students, the website offers educational modules that teach research methods in biodiversity and statistics. One module, entitled the "Lepidopteran Detective" promotes research on the web, both on the butterfly site and elsewhere. A butterfly image is selected and the student must identify the species and answer a series of taxonomic and life-history related questions. Another module teaches regression analysis by using life data from the database, allowing the student to select a species and produce a linear regression in Excel. A basic statistics module is planned that focuses on measures of central tendency, normality, visualization, and the production of scientific graphs. These education modules conform to State of California high school education standards and allow students to learn these research techniques with "real-world" data.

The Butterfly web portal has also received butterfly observations from the public, an activity referred to as "citizen science". During the Spring 2009 migration of the Painted Lady butterfly (*Vanessa cardui*), people who observed the great number of migrating butterflies provided valuable information to the website. This information included where in California the migration was dense, and how many butterflies per second were observed at given locations.

Dr. Shapiro posted regular updates on the status of the migration, based on his own observations as well as those sent to him through the website. The public observations were compiled into a second web page and posted on the site. Local news agencies took interest in this migration, and the website provided details and graphic elements which were included in many news stories. This community effort has been a remarkable example of citizen science, and enabled the tracking of this migration from Southern California northward through Davis and other collection sites which Dr. Shapiro visits regularly.

2.3 Trust and Access Rights

A major challenge is defining and implementing appropriate vocabularies for each class of users. At the level of data generation, some vocabularies, such as the Latin names of species, are fairly well defined, although even those typically offer some complexity. For example, the majority of the Latin names in the database may also be referenced in other standard online taxonomic databases, such as ITIS (http://www.itis.gov/) and, more importantly, refer to exactly the same collection of species. However, several names differ, and a data system suitable for expert or machine-to-machine queries must specify the specific and unambiguous meaning of all of the names used. On the other hand, a common name, accompanied by a photograph, will be much more useful to non-technical users. Similarly, entomologists use unambiguous language for ecological, morphological and life history traits that would be unfamiliar to a middle school class or tourist in a national park. Ideally, data should be self-describing, so it can be interpreted according to multiple vocabularies or languages.

An important goal of this project is to make butterfly and climate data accessible and readily interpretable to a wide variety of clients, including field biologists, climate researchers, butterfly researchers and enthusiasts, users seeking help with identification or natural history of butterflies, schools, automated machine agents, and distributed biodiversity information systems. Access to the data will be different, depending on who you are and what your purpose is.

Web-based information systems have become an integral tool in the facilitation of research and the management of monitoring data (Mitreski et al. 2004). Web based frameworks, specifically, Content Management System (CMS), are designed to organize and structure content, and provide a permission system that grants individuals the rights to access (restricted) information and perform tasks.

2.4 Publishing Data

If you are going to provide access to monitoring data, those who collected the data, or who build a model to analyze the data, should receive professional credit if these data are reused for additional analysis. The data portal should provide the necessary references so that those who access the data and use it for their own projects can easily determine how to cite this resource in their own work. It may be desirable to require, as a condition of making intellectual property freely available, that those who create derivative works also make those available on the same terms (Lessig 2001).

Some journals (e.g., Nature and Science) have recognized the importance of publishing the data, and require such with article publication. The Ecological Society of America (ESA) publishes *Ecological Archives*, designed to publish data, which can then be referenced by other articles that use this dataset. Often, these data can be summarized or transformed slightly, and then used as input into new analyses. However, these types of data repositories frequently lack the needed metadata and a self describing format which is inherent in some data formatting models.

The butterfly website makes all data available to registered collaborators. Subsets of the data are made available to other users through the use of on-line queries. These queries permit summaries of trends, and can be used by scientists and others to develop further work.

3 Data Management and System Architecture

Many of the challenges of management and access associated with the Shapiro butterfly dataset are shared by other scientific endeavors. Scientific data management is concerned with the reliable storage and retrieval of data. The parameters or constituents that make up individual data values, the relationships between these data elements, and the actions that can be triggered based on particular values, are all represented in a data model and are designed to support the underlying disciplinary knowledge, be it geography, chemistry, or biology (Ludäscher et al. 2006). Using a collaborative web-based framework to promote an underlying data model and research methodology has helped resolve some of these challenges (Schweik et al. 2005). In this section, the components of the Open Source butterfly system architecture are described.

3.1 Common Sense: Using an Open Source Toolkit to provide Open Content

Free and open source software (FOSS) licenses grant people the right to use and modify computer programs freely. For a software product to be considered open source, the source code must be available to be viewed and modified, the license must not discriminate usage between different groups or users and fields of endeavor, the product must respect the neutrality of the computing environment, and there must be assurance that credit is given to the creators (http://www.opensource.org/docs/osd). Such a license lends itself well to academic and research use (Schweik et al. 2005), as the tools are ubiquitous and available to anyone who wishes to utilize similar architectures.

For data contributors, it is equally important that provenance information always be carried, so that they receive appropriate professional credit for their contributions, and so the data are not misused or misappropriated. A formal "commons" framework, such as the Creative Commons (http://creativecommons.org) is likely to be essential to ensure participation of experts – and would be highly desirable in making environmental and conservation data more accessible and readily applied to effective policy (Hoorn 2005; Samuelson 2003).

3.2 System Architecture and Overview

A major goal of this project was construction of a flexible database and web portal framework that could be adapted to other long-term datasets of species occurrences, and could present them entirely using FOSS, structured so that they would be accessible and interpretable to machine and human users, and be readily synthesized with data streams from other disciplines.

The following diagram shows the basic components that constitute a web-based information system. The specific tool used for implementing the Butterfly website is listed below each component name. Architectures will vary, both in the tools and components, and it is good practice to diagram the architecture for inclusion in the system documentation (Fig. 2).

The butterfly website architecture consists of two data sources (MySQL databases), a content management system (CMS) (Drupal), and a web server (Apache), all running within a server operating environment (Ubuntu Linux), with a connection to the world wide web. The components grouped together by the large rectangle, represent a single server. To improve efficiency or management of the individual components, some computing environments will split these services across several servers. For this overview, the various components are

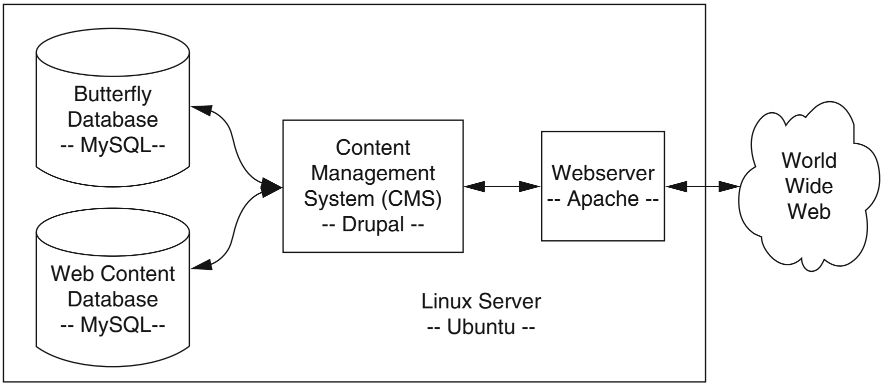

Fig. 2 This web architecture shows the components and software tools that constitute the butterfly web framework

running on a single server. The world wide web is represented as a cloud, which is linked to the network. Users interact with the system through the web by using a web browser.

3.3 Managing Website Content and Research Data

Data is the core content of this website, but data alone would make for a sterile and incomplete experience. Creating a fuller contextual environment within which to access the data is paramount, hence the need to use a CMS to host other related resources. The term "resources" is a generic designation for digital imagery, related websites links, news articles and blogs, documents and reports, monitoring and geospatial data, and other web-based content. This associated qualitative content should not be separated from the raw data itself, because combined, it creates a frame of reference for the subject matter. Without metadata, textual descriptions, maps, and imagery, the website would only service a small subset of its potential audience, and omit public comprehension and understanding. Thus, a full set of resources should accompany the data on the website to provide the context for the research (Johnson 2007). Ideally, these resources are tied together ontologically, and connect to the Linked Data cloud (Fig. 3).

A web-based CMS can be an essential tool for hosting a research project where one of the goals is to convey its findings to the public. Many CMSs provide a web-based administrative interface to manage the content of the site as well as content permissions which provide mechanisms to secure content based on authoritative roles. The permission system can be designed to support access to the content based on the needs of the research group. The ability to add, edit, and delete content can be managed through a permission system and applied to various users on the system.

Since management of the CMS is done through the web framework, one only needs access to the Internet to control the website. It becomes easy to update the

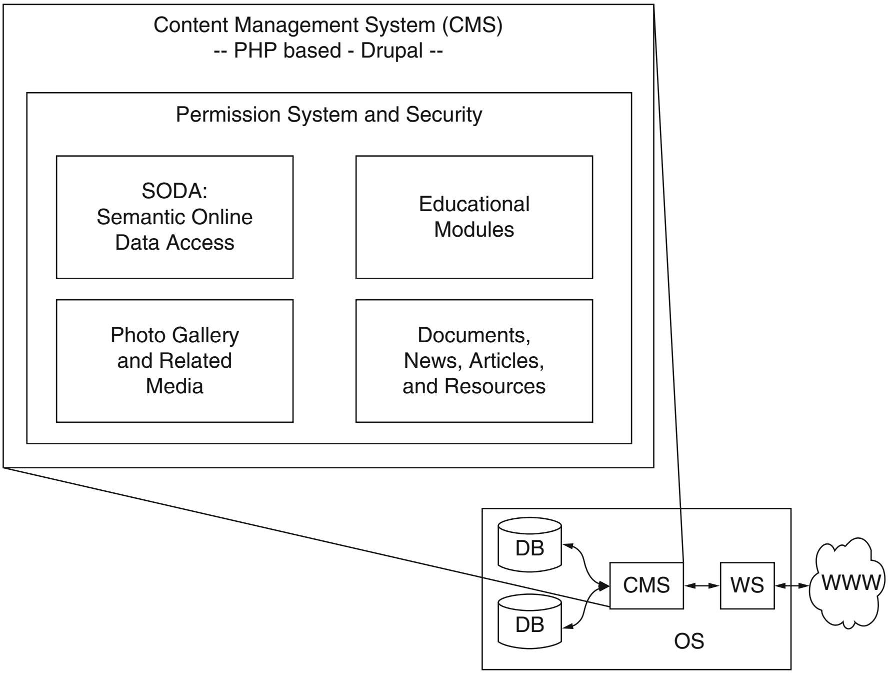

Fig. 3 The Content Management System (CMS) handles authentication and security, and provides a web-based administration interface for system management. This component provides the web framework and services requests to the various content provided

site, and anyone who has the necessary rights can participate in adding and editing content. The CMS also provides revision tracking, so changes to a web page can be tracked and reverted back to a previous state if necessary.

The CMS chosen for the Butterfly Project was Drupal (http://www.drupal.org), a popular PHP-based web framework. The core of Drupal provides a rudimentary framework allowing the web developer to customize the "types" of content that the website serves to its visitors. The community that supports Drupal is large and active, producing many specialized modules which plug into the core framework. This allows web developers to create sites that do precisely what they want with minimal coding. For example, there is an excellent user contributed module for managing bibliographic references, allowing one to download the references in a variety of formats. Such modules can greatly enhance a website.

3.4 Accessing Data

Accessibility refers to availability and user friendliness. Requiring researchers to understand a website's data model or query language favors those individuals who have an information technology background. It can take years to develop an understanding of a species' biological processes and environmental habitat: requiring researchers to learn the intricacies of a data query language should not be requisite for their job. But almost everyone has learned how to use the Internet: to enter a website into the address field, click on a hyperlink, select an option from a drop-down menu, and click on a submit button. The website permits multiple levels of engagement, from scientific queries to high school homework assignments, all without having to understand the implementation detail.

When developing a web-friendly user interface, rapid data extraction is desired. For example, the butterfly website allows the user to choose from a set of vocabularies (such as the list of collection sites), then click the submit button to receive those data. Through a database query language, such as SQL (Structured Query Language), *questions* can be asked of the data, with the resulting dataset being the *answer*. In a Relational Database Management System (RDBMS), a query can utilize the relationships created within the data model, to span database tables (or research concepts) to return the correct result. Aggregate functions can be applied to the resulting set, creating summaries of the data, such as mean, minimum, and maximum values. Such questions as: How many sighting of a given species have occurred at a given site? and What sites have a particular butterfly species been seen? can be translated into SQL, and sent to the database engine for the result.

A goal of the overall design was to have the format of query outputs accessible to humans and computers. When a query is performed against a relational database, the result is returned in a tabular format that can be parsed and output using various standard formats, including Comma Separated Values (CSV), Extensible Markup Language (XML), or Hypertext Transfer Protocol (HTML). Applications are designed to utilize data based on a particular format, and it often does not require much work to transform the web-based query return data into such a format (Gertz and Sattler 2003) (Fig. 4).

From a management perspective, the reliability of storage and ease of retrieval are the chief considerations for data storage format. Because new applications and analytical processing techniques continuously evolve, data storage must be flexible so it can be rectified with new methods . As new trends emerge, data must be able to "transform" into a format that lends itself to a particular application or analysis. Fortunately, there exist established standards to ensure that data can achieve this flexibility and, therefore, accessibility.

3.5 Linking Data Relationally

Storing data in a RDBMS, as opposed to another format (such as a spreadsheet), allows for optimal storage while preserving relationships inherent in the data. A good database design requires understanding concepts in database theory. In many instances, data are organized by *concepts* meaningful to humans, and associated research variables are grouped with each concept.

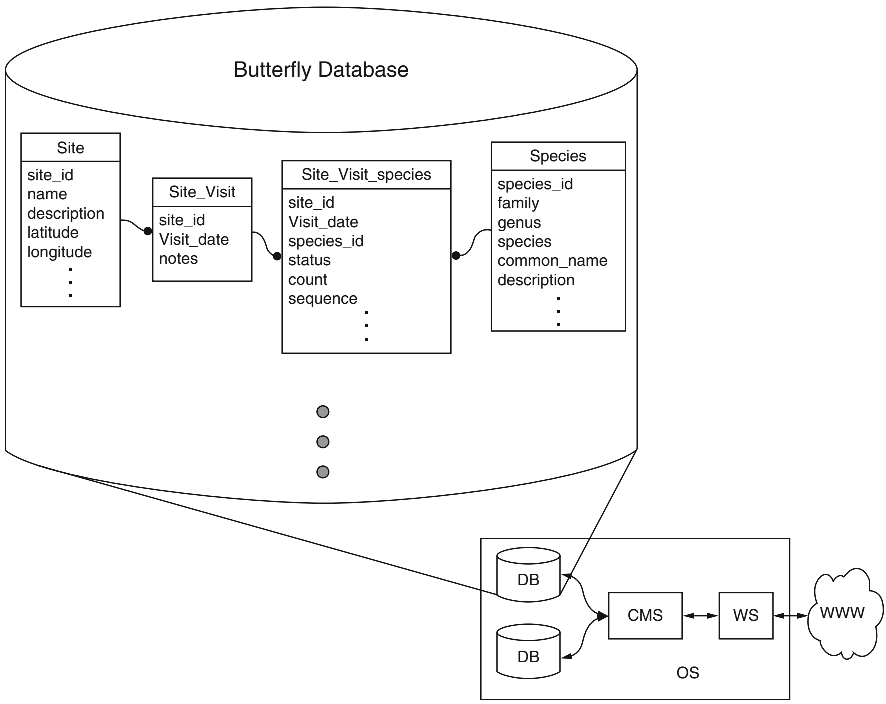

Fig. 4 The butterfly database has its own relational model, with additional data inserting new records to the existing tables. A few of these conceptual relationships are shown in this diagram

For example, to understand how weather might affect the distribution and frequency of butterflies, weather data from the Western Regional Climate Center (http://www.wrcc.dri.edu/) have been linked with the butterfly monitoring data collected. The permits website users to access the combined biodiversity and meteorological datasets. Each collection site is joined to the weather station by their *primary key*, so once can select a collection site and have the data from the weather station returned. Since these datasets span over 35 years, the recent effects of global climate change can be studied.

3.6 Other Database Best Practices

When managing data, storage space reliability is based on timely backups to an external storage unit, the maturity of the database engine, and the continual monitoring and maintenance of the databases as they are being used. Backups are crucial, and should be an integral part of all computer use, not just scientific data. Keeping a copy off site, in the event of a catastrophe, is an important step to ensure a fully reliable backup. Use of a mature database engine will help ensure that the database does not become corrupt. Before selecting a database program, it is good practice to see who else is using that database engine, and what sort of data it contains. The butterfly database uses MySQL, an open source database used on websites such as *Wikipedia* and *Flickr*. When such large and prominent sites use this platform, its reliability and scalability have likely been well tested.

3.7 Linked Data and the Semantic Web

The semantic web is built on top of the Internet. It is a way of expressing information resources so that knowledge and meaning can be derived, allowing Internet-wide searches to be more precise by providing structural linkages between resources. As a result, knowledge discovery becomes easier and more accurate (Kashyap 2001).

While there are specialized tools for processing information coded for the semantic web, the formats themselves are text based. The Resource Description Framework (RDF) is a standard data structure for encoding knowledge based on subjects, predicates, and objects, often serialized as XML though other formats are widely used. RDF is the method used to publish information and data on the semantic web. This subject, predicate, object structure is often referred to as triples, in which each is it own authoritative vocabulary. This triple structure specifically encodes the relationship between the subject and object and provides an authoritative source. Meaning is derived based on the authoritative vocabularies, which are called ontologies. These ontologies provide a domain of knowledge and structure, which other datasets can reference to derive relationships and meaning. Often ontologies will link to other ontologies, so a few steps may be necessary to resolve ambiguity.

To provide a simple example of RDF, let us take a butterfly observation as an example:

Subject	Predicate	Object
Painted Lady Butterfly (*Vanessa cardui*)	observed at	site: Rancho Cordova
Painted Lady Butterfly (*Vanessa cardui*)	observed on	date: April 25, 2009 at 2:30 pm
Painted Lady Butterfly (*Vanessa cardui*)	observed by	person: Arthur M. Shapiro

This detail can be encoded in RDF as follows in the Turtle format (Beckett 2007):

```
@prefix taxa: <http://ecoinfo.ice.ucdavis.edu/taxa/>.
@prefix ex: <http://www.example.com/observe/>.
taxa:Vanessa_cardui
ex:observedAt "Rancho Cordova";
ex:observedOn "2009-04-25:T14:30-07:00";
ex:observedBy "Arthur M. Shapiro".
```

The butterfly monitoring data follows the "who", "what", "where", and "when" event model which some systems use to express the metadata of an observational or monitoring event. The relationship between these objects is the observation itself, so the predicates in this case are variations and attributes of the observation.

Who: Arthur M. Shapiro
What: Painted Lady Butterfly (*Vanessa cardui*)
Where: Rancho Cordova
When: April 25, 2009 at 2:30 pm

Each of these elements will be a more complex data element that may specify attributes (adult female), methods (location determined by a hiker's GPS), validation (a photo was taken and is available at URI) or authority for the term used (Geographic Names Information System).

Encoding these observations into RDF is a good first step in readying the data for the semantic web, but there are some additional steps to add to allow the data to be part of the semantic web's *Linked Data* project. Linked Data is a fairly new method of exposing data on the semantic web. The goal is to make gathering data on the web as accessible as reading documents and web pages (Bizer et al. 2007).

Humans are good at reading and interpreting a text web page, but this is more difficult for machines, which require the text to be structured in a suitable format. A computer can identify keywords and start to make some associations and educated guesses about the topic, but keyword matching can be fairly imprecise.

If a web page is encoded in RDF, then a machine can understand the meaning of the text, and can extrapolate the context of the web page down to a very fine level of detail. RDF is a language designed for machine interpretation. The Web is highly successful because it provides information which humans can read and readily interpret. Web pages are designed to streamline knowledge transfer, and this aspect of the Internet is continuing to improve. There needs to be a way in which same web page can service both human users and machines.

The Linked Data model incorporates the human aspect of reading HTML with a machine readable RDF version of the same data by using a standard feature of the webserver called *dereferencing*. Before the webserver issues a page across the network, it checks who is making the request and what format they want the data returned. If the request is in HTML, then a standard HTML page is returned, but if the request is RDF/XML, then a different web address is returned which points to the structured data. This is an important distinction between Linked Data on the Semantic Web, and other online data resources on the Internet. Another important feature of the Linked Data model is that providers of Linked Data are encouraged to reference vocabularies and resources that have already been published on the Linked Data web. Re-use of vocabularies on a Web-sized scale is a major mechanism by which diverse datasets can be combined to yield novel insights.

As the *linked data* cloud continues to grow, with more and more specialized data being exposed in both in HTML and in RDF, the power to combine disparate sources becomes possible.

If the WRCC were to have their climate data provided as *linked data*, querying for location and time could be easier. Such queries as the following would become possible: What butterfly species, above 3,000 ft, emerge when the minimum temperature is below 15°C for the previous two weeks, and the previous year's snowfall was below average for the last 10 years?

3.8 Semantic Online Data Access (SODA)

The purpose of SODA is to make scientific monitoring data more accessible across the Internet. Because the code base is Open Source, it provides a free, modular, scalable, and re-usable tool set for academic institutions or research laboratories to release data to the scientific community, providing a greater opportunity for this data to be utilized, in perhaps global contexts.

The SODA module is a "plug-in" component that provides a web-based query interface and access to distributed scientific monitoring data. SODA resides behind a web portal (e.g., Drupal) and is a mediator to disparate data sources, providing access to the data for viewing or download purposes. SODA accesses information through the use of controlled vocabulary (the who, what where, when) and therefore permits context-driven queries of the underlying data. New data sources are registered both through an interactive web interface, and by an automated harvester. The SODA central registration database is a repository of metadata about the distributed data sources. Subsequently, multiple sources can be queried and the results combined when the data have similar semantics, and measure phenomena that can be meaningfully combined. By default, SODA is accessible to everyone. It is the responsibility of the CMS to limit access to certain data, if that is desirable.

4 Best Practices and Recommendations for Academic Research Teams

Producing a collaborative research portal, is a straightforward task, especially if you use off-the-shelf tools. This section highlights some considerations for portal construction. Be sure to consult any software documentation, as this section is not a definitive guide. Also, if a research team already has a technical staff and computing infrastructure, some of these steps can be omitted.

Building a research-based website is easier than one might imagine. It is quite possible to setup a working system, end to end, without a lot of experience with these components. Getting a system up and working enables one to start developing a web portal, and provides a working environment to learn more about each of the components before the website goes to production. You will have a chance to learn more about it as the system is being developed.

4.1 System Hardware Considerations

Making general recommendations about hardware is difficult. Computing needs will depend on the overall project goals as well as the anticipated audience. If you expect a high traffic website, you will need a faster computer processor and more memory; if the website is designed for a project team and a few interested web surfers, then a high-end server is not necessary to run the website. Often, more important than a fast server is a fast connection to the Internet since the network is more often the bottleneck. In many research environments, computer infrastructure is already in place, so many of these hardware and network related questions are predetermined.

4.2 Development and Production Environments

It is important to create an environment to develop and test the website before it goes live on the web. Ideally, development and production environments are identical, ensuring that changes made to the development website are a true test before they are put into production.

The Butterfly website architecture is described earlier in this chapter (Fig. 2) and shows how components can fit together. Many of the tools shown provide mechanisms to install, maintain, and configure themselves to the specific hardware and computing environment which they will run on.

4.3 Download, Install, and Configure Applications and Modules

4.3.1 Installing a LAMP Server

Visit the Ubuntu Linux website (http://www.ubuntu.com) and download the latest Server Edition with Long Term Support (LTS). The download size is fairly large (around 600 MB), so a fast connection is essential. Select the 64-bit version is your computer processor supports 64-bit operations. Downloading the file using BitTorrent is a preferred method because bandwidth requirements are lessened for everyone. Be sure to check the downloaded file for consistency using MD5 checksum, and verify that it matches the file size posted on the Ubuntu Linux website. Burn the file to a CD to make the installation disk.

Follow the directions posted on the Ubuntu Linux website to install a LAMP installation, which then installs the Linux operation system, Apache webserver, MySQL database, and the PHP and Python scripting languages.

4.3.2 Download Drupal Web Framework

Drupal is provided as a single download file (http://www.drupal.org) which, when installed, provides the core functionality for managing a website. This includes user administration, authentication and system permissions, content creation and management, website configuration, various core utilities for tracking website usage, and some basic themes to brand your website. To create a full featured website, it is necessary to download and add some user contributed modules which greatly enhance the core framework. Some important modules include Views and the Content Construction Kit. The addition of these two modules greatly enhance Drupal and provide lots of flexibility which can be adapted to most research environments.

Please consult the Drupal documentation for installation and configuration. Since Drupal has a web-based installation and administrative interfaces, they are generally fairly easy to manipulate and configure to your site's specification.

4.3.3 Configuring Web Environment

When the operating system is installed, you must provide an IP address to enable a network connection. This IP address can be used to connect to the default website that is installed. On the production environment, you will likely want to use a meaningful domain name to represent your website. For the development environment, you can use an IP address, or find a temporary name to use.

A webserver can host multiple websites, and Apache needs to be configured to recognize them all. The document root for each domain needs to be set in the Apache configuration, and if you are using Drupal, you will want to set this to the Drupal home directory.

4.4 Design and Build Website

A well designed website will see a lot more use during its lifespan than a poorly designed one. But while design is important, content and progress toward your ultimate goals for the website are equally so. We have found that an iterative-based implementation plan works best, and that completing minor versions of the web portal, and having them go live to the world, are important milestones. Do not make the first version of the website have all of the desired features at once, add them more slowly and be comfortable in this process, allowing the overall design, and look and feel to change as the site improves. This iterative-based plan allows the site to become available earlier in the project lifecycle, enable you to start collecting important content which can follow the upgrades to the site, and gives you more time to perfect the design because you have a chance to work with the site. Collecting content can often be the most time consuming, yet most important, task in a website's development, and an iterative-based approach will help maximize this effort.

Do not construct the website in a vacuum. Look at other data portals which provide similar functionality and mimic certain features. For example, perhaps it is important to have a list of the project team, showing a photo and a brief summary of their duties. Look how other websites display their project participants, and copy design aspects you like from these pages. If you wish, you can link to these sites in your acknowledgements page as design references.

4.5 Data and Content Management

Much of this chapter focuses on the management of the content and data. A regular backup program is essential to assuring that the website and research can be reproduced in the event of a problem. Ask the question: if the server crashed, how long would it take to restore it to the point where it is today. The answer will help you decide the frequency and importance of backups.

4.6 Maintenance and Security Concerns

There is a responsibility that goes with building a website. While certain design aspects to a website might be considered "finished", it is unlikely that the site will ever be at a point where it can be neglected. CMS's which allow participants to login with a username and password will always have a certain degree of security risk associated. It is therefore necessary to maintain the website and apply security patches and module upgrades to assure it is not compromised and data exploited.

Keeping a system up to date requires updates to the operating system, the webserver software, the database software, and the web framework. The update frequency of these components varies, but one can expect to upgrade the individual components at least every three months, with some at a higher frequency if a security issue is discovered.

4.7 Making Knowledge Accessible

The next generation of web computing will be based on the semantic web. Encoding content and data into a framework that intelligent software agents can utilize is important in taking that next step toward precise searching for online scientific data, informed decision making and process workflows, and using the Internet as a true knowledge resource rather than a cornucopia of data bites. Exposing your data to be utilized by the semantic web community will help propel science into the future. But how does one support semantic web technologies?

Drupal plans to support RDF and RDFa as part of the core installation in the future, and there is currently a RDF module which can be used to encode your data.

You can also expose your data as a Linked Data, which uses Apache to redirect requests to various formats of your data, such as HTML or RDF, base on the data request. It is a good idea to read the Linked Data Tutorial (Bizer et al. 2007) to understand how to expose your data with this methodology.

4.8 Customizations

It is possible to build a content based web portal without any custom programming. One of the best reasons to use open source software is the option to incorporate modules that other people have written into your system. Drupal, for example, has hundreds of user contributed modules available, which all provide useful functionality and save time. However, not all user contributed modules work as well as others, so test them in the development environment before use in production.

5 Conclusions

The methods prototyped in the butterfly project are designed to be standards-based, to address long-term biological species-occurrence monitoring, with scientist, public, educational, and machine interfaces, and to contribute directly and automatically to national and international global change assessments.

If there is to be wide participation, it is important that the resulting information services:

- Be easy to understand for a broad range of data collectors and users
- Be based on simple but robust data models
- Make maximal use of readily available software (e.g., widely supported FOSS software)
- Be configurable for multiple audiences
- Be compliant with emerging data standards such that the records are readily accessed at the level of machine-to-machine queries from other biodiversity, climate change, and conservation applications

The usefulness and credibility of such efforts requires that the data be of high quality and represent the professional standards of practicing scientists. Finally, we urge biological records web-builders to include the time, location, data collector, species, and method be unambiguously documented for all records.

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Collaboration Among e-Research Projects in the UK: An Analysis Using Online Research Methods

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Abstract In this chapter, we investigate the use of web-based data for mapping the collaboration dynamics of e-research at the project level. We focus on the web presences of projects that were part of the UK e-Science and e-Social Science programmes, cyberinfrastructure-like efforts that aimed to foster the development of collaboration infrastructure, initially in the sciences and latterly in the social sciences. We explore two different analytic approaches for mapping levels and orientation towards collaboration amongst projects that constitute the UK e-Science and e-Social Science programmes: Content Analysis and Hyperlink Analysis. In addition to presenting results of these analyses, we also discuss the effectiveness of unobtrusive research techniques such as web content analysis and hyperlink analysis for mapping collaboration dynamics, not only at the project level but also in terms of sensitivity to broader contexts e.g., institutional. We compare these approaches with obtrusive research techniques such as surveys of individuals participating in e-Research.

1 Introduction

Over the past decade there have been considerable efforts to develop digital tools and resources, and to establish an infrastructure to support scholars in their daily research. Undertakings such as the UK e-Science programme and the establishment of the office for cyberinfrastructure at the National Science Foundation (NSF) are examples of these. Both grew out of a recognition that the Internet had become integral to research (Kling and McKim 2000; Nentwich 2006) and that research was becoming more and more collaborative (Wuchty et al. 2007) and have sought to

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support and encourage these trends. In addition, there are specific methods and tools that take advantage of networked computing facilities that have the potential to benefit the social sciences. The application of these tools in social science research is what is roughly meant by the term e-Social Science, and the UK e-Social Science programme was established with the primary goal of promoting the uptake of e-Research tools in the social sciences.

In this chapter, we explore the use of web data for measuring and understanding collaboration between e-Research projects. The web is becoming a major medium for scientific communication. One of the first things a newly-established project in any field of scientific endeavour does is to create a website, which is then used during the life of the project for communicating the nature of the project and its progress and outcomes. Broadly speaking, project websites provide two sources of data relevant to our concerns – text-based content and hyperlinks (the in-bound and out-bound links to a web page or set of pages). Taken together these sources of data can represent the characteristics of a project, and the positioning of that project in the overall field both in terms of how project leaders represent the project as fitting in and contributing and ways in which other projects position it through their web presences. Thus, one could argue that project websites provide indirect information on the level of regarding collaborative relationships in a research field.

In this chapter we quantitatively analyse the web presences of projects supported by the UK e-Science and e-Social Science programmes, focusing on content analysis of project descriptions and hyperlink analysis. First, we present some background on the UK e-Science and e-Social Science programmes. We then present an analysis of tag clouds mined from project descriptions, followed by an analysis of the hyperlink networks created by projects funded under these programmes. Our chapter concludes with a discussion of the advantages and disadvantages of unobtrusive online research methods such as those presented here and we also suggest avenues for future research.

2 e-Research

Delimiting the boundaries of e-Research is problematic as individual projects do not necessarily map onto pre-existing disciplinary or institutional formations very well. e-Research efforts appear to be part of a network of interrelated phenomena including existing communities, interdisciplinarity, open access and research assessment. Yet the positioning of e-Research in this network seems to vary considerably from one funding agency, developer, or researcher to another – and even more so across geographic boundaries (see Schroeder and Fry 2007 and Meyer, Park and Schroeder 2009 for an overview). Consequently, choosing appropriate conceptualizations and forms of representation is not without difficulties.

The most prominent representation of e-Research across funding bodies, national efforts and centralized development efforts has been the notion of the “Grid”, derived from the computer science community, which is associated with sharing high-performance computing resources via high-speed networks (Berman et al. 2003). In the US, the label "cyberinfrastructure" is commonly used to convey the concept of advanced computing in science (Atkins et al. 2003), though another label, "collaboratories", has been in use for longer and continues to have currency (Finholt 2003). The infrastructure metaphor also has an echo in the terminology mainly used in the EU of an "e-infrastructure" (see Hine 2006). Nentwich (2006) has used the term "cyberscience" for all research that is enabled by the internet, including the humanities. The labels and metaphors employed to convey the concept of e-Research (and e-Research could of course be regarded as a metaphor itself) in multiple discourses relating to e-Research will also have implications for how the use of advanced computing in the sciences and engineering, arts, humanities, and social sciences will come to be regarded. The complexity of labelling particular areas of research as e-Research points to the potential issue of privileging certain kinds of "science" over others.

In this chapter, we restrict ourselves to the projects that have been initiated within the UK's e-Science and e-Social Science programmes, as represented by the databases of the National Centres for e-Science (NeSC) and e-Social Science (NCeSS) that are publicly accessible through www.nesc.ac.uk and www.ncess.ac.uk, respectively. Henceforth we will use "e-Research" to include fields across all disciplinary groups (but e-Science or e-Social Science when referring to the specific funded programmes).[1] This cut-off has obvious limitations, but it has the advantage that it includes all the projects that come under the rubric of the UK funding councils' efforts to promote e-Research.

One of the aims of e-Research is to foster collaboration, another is to cope with the "data deluge" (Hey and Trefethen 2003) and national research funding bodies have played a large part defining these aims. In the US, the vision of the so-called Atkins report (Atkins et al. 2003) described a potential "revolution" in science and called for one billion dollars of funding per year. This has led to a number of initiatives in creating large-scale facilities and projects under several programmes of funding. The vision of the Aktins report has since been extended to the social sciences in the report by Berman and Brady (2005), who have outlined an ambitious series of challenges for various social science disciplines that can be addressed by means of an enhanced "cyberinfrastructure". More recently, the US funding programmes have come under the umbrella of a central Office of Cyberinfrastructure, which is housed within the NSF. There are a number of other efforts in Europe and further afield to promote the development of computing tools for research in a similar way.

In the UK, the Engineering and Physical Sciences Research Council (EPSRC) and the government's Office of Science and Technology took the lead in establishing a programme of funding, though subsequently several other funding councils have also contributed funding. Among them, the Economic and Social Research

[1] Projects in the arts and humanities are also now labelled e-Research, but these are outside the purview of this paper.

Council (ESRC) initiated a programme of research of its own. Both the e-Science and e-Social Science programmes in the UK have come to operate under a hub and spokes (master-feeder) model, with a national centre or hub (NeSC and NCeSS) coordinating the efforts of a number of nodes. These nodes, in turn, have taken the form of collaborative research projects drawing on a number of sources of disciplinary expertise which, although they may be based in a single institution, have an implicit aim to contribute to a larger collective effort to foster inter-institutional and inter-disciplinary collaboration in relation to new computing tools and resources.

In this context it is important to note that many of the technologies on which researchers have come to rely for collaboration in recent years have come into existence relatively independently of these efforts to foster e-Research – be it tools such as wikis or voice-over-IP, or resources such as SSRN (the Social Science Research Network) and arXiv.org.

3 Online Research into e-Research

Online research methods can be split into two broad categories: obtrusive and unobtrusive research methods. Obtrusive online research methods involve the use of the Internet to elicit primary research data, where the individuals under study are aware of their participation in the research project. Examples of obtrusive online research are online surveys, focus groups, or participant observation. In contrast, unobtrusive online research involves the construction of primary research data from web trace data that is generated from the online activities of individuals and organisations, for example archived discussions on websites or in newsgroups, hyperlinks between websites and website access logs.

In the UK, the term *webometrics* (Thelwall 2009) has been used to refer to the large variety of methods, tools and technologies that are available for conducting unobtrusive online research. However, as argued by Ackland (2009) and Lusher and Ackland (2010), there are in fact several different disciplinary approaches to unobtrusive online research. For example, approaches for hyperlink analysis fundamentally differ across applied physics, computer science, information science, and it is perhaps problematic to group these approaches together.

In the present chapter, we focus on unobtrusive online research using text content and hyperlink data from websites.

3.1 Content Analysis Using Tag Clouds

Content analysis (Krippendorff 2004) is a research method for sociology that has been used since the 1940s to study written communication. Initially, analysis was limited to determining the frequency of key terms in texts, but over time more complex notions such as concepts represented by multiple words and turns of phrase have been taken into account as well. The bodies of text to which content analysis is applied tend to be relatively small, allowing for manual coding. However, that is not to say that content analysis on a large scale is impossible: for instance, Feinerer and Wild (2007) managed to automatically code a large set of qualitative interviews with help of techniques that were developed to carry out what in computer science is known as *text mining* (Manning and Schütze 1999). Even without advanced computer science techniques it is often possible to carry out content analysis on a large scale. An example of this is the study of MySpace profiles by Hinduja and Patchin (2008). This study took advantage of the structural elements that are the same across MySpace profiles in order to construct a database of the personal information that is contained within these constructs.

Similarly to MySpace, e-Research environments and even just websites devoted to e-Research are likely to contain profile-like information as part of their content. For example, the NeSC maintains a web site with the project descriptions of over a hundred projects that were funded through the UK e-Science programme.[2] In addition to the free-text project descriptions, each profile also contains fields with structured information concerning the size of the project, its collaborators and its funders. Unfortunately, in this particular dataset many of the fields with structured information have been left blank and so a statistical analysis like the one of Hinduja and Patchin on MySpace would have to find a way to deal with a large proportion of missing data.

In contrast, nearly all the projects in the dataset have a short description of the project aims associated with them and den Besten and David (2008) show that the analysis of these descriptions readily yields interesting results. The tag clouds that have been created on web sites like Flickr in recent years represent a very basic text mining technique in which the relative frequency of labels associated with a topic is visualized. The dynamics of folksonomy tagging are a good topic for research on collaboration (cf. Ding et al. 2008). As a tool for data visualization, tag clouds also lend themselves to the analysis of other collections of words. That is, in a way similar to these tag clouds, it is possible to derive a picture of the e-Science projects on the basis of the project descriptions alone.

Figure 1 shows the result of such an exercise. In order to obtain this figure, a tool called ManyEyes[3] was used (Viegas et al. 2007). This web-service provides easy access to several modes of visualization for collections of words and other kinds of data. After creating an account at ManyEyes and uploading a data item by copy-pasting project descriptions from the NeSC web-site into the appropriate field at this web-site, the figure was created by hitting the button "visualize" and selecting one of the modes available for visualization. In this case the "wordle" was selected as mode as it provides a more visually pleasing image than traditional tag clouds and allows for automatic removal of stop-words such as articles and conjunctions.

[2] http://www.nesc.ac.uk/projects/

[3] http://manyeyes.alphaworks.ibm.com

Fig. 1 Wordle generated cloud based on descriptions of UK e-Science projects between 2001 and 2005 (source: http://manyeyes.alphaworks.ibm.com/manyeyes//manyeyes/visualizations/uk-e-science-project-descriptions-20)

The latter, in particular, can often be very useful as stop-words would otherwise tend to dominate an analysis based on word-frequency.

Figure 1 reflects the message that many e-Science projects in the UK were concerned about "data" and the Grid, and comparatively few were concerned with "community" or even with "collaboration" (compare this with an initial scoping of UK e-Science undertaken by David and Spence 2003). More detailed analysis would be needed to confirm whether or not that actually was the case, and whether that conclusion also holds if one considered not just the numbers of projects, but the relative magnitudes of the resources they deployed as well. Such analysis would be interesting as it has been argued that the most difficult challenges for multi-national and multi-disciplinary distributed research collaboration lie in greater administrative complexities (Cummings and Kiesler 2005). The focus on "data" and the lack of interest in "collaboration" in the project proposals could suggest that the UK e-Science programme has shied away from promoting projects that choose to tackle these administrative complexities head-on. If that were indeed the case, then it is no surprise that these difficulties remain.

Figure 2 takes the analysis of the project descriptions a small step further by comparing two parts of the corpus. The figure was obtained by defining the project descriptions from 2002 as fragment one and the project descriptions from 2004 as fragment two and selecting a tag cloud of word pairs as mode of visualization in ManyEyes. At the top of the figure are the pairs of words that appear only in 2002 and at the bottom the pairs that only appear in 2004. In the middle pairs that are frequent in both collections of descriptions are displayed while the size indicates

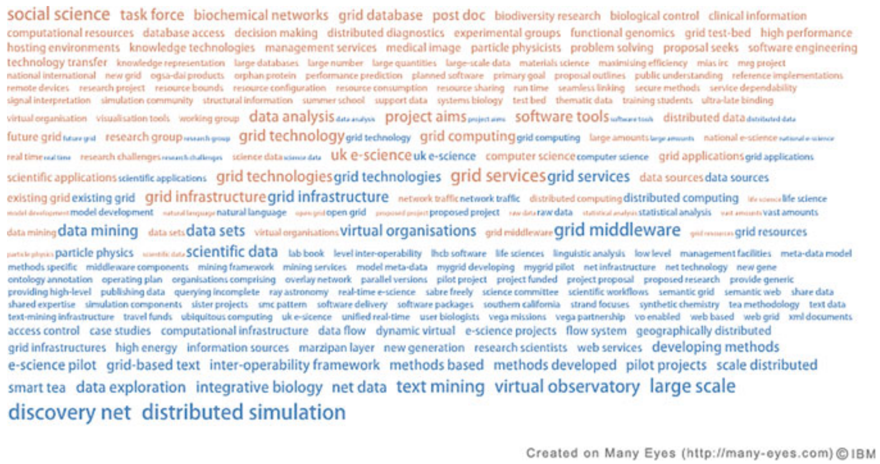

Fig. 2 Cloud of word pairs contrasting word combinations prevalent in 2002 project descriptions with combinations prevalent in 2004 among UK e-Science projects (source: http://manyeyes.alphaworks.ibm.com/manyeyes//manyeyes/visualizations/uk-e-science-project-descriptions-in)

relative frequency. Looking carefully at this figure one can detect suggestions of changes in scope and focus of the projects. Of course, further analysis would be needed to statistically corroborate these trends; ManyEyes does not allow for such analysis but other tools do (Lebart and Salem 1994).

In terms of content analysis, tag cloud visualization ranks among the most basic techniques. More advanced methods for the study of e-research are being explored at the moment (e.g., Lin 2009) and even more advanced methods have already been applied to the Web (Segaran, 2007; Ackland and O'Neil 2009). Yet, as we have seen, even basic techniques can yield valuable results.

3.2 *Hyperlink Analysis*

Ackland et al. (2007) used the VOSON e-Research tool[4] to conduct a dynamic hyperlink analysis of UK e-Research projects. The NeSC and NCeSS websites were used to identify projects that were recipients of UK e-Research funding, and the sample consisted of 51 projects: 42 projects identified from the NeSC website, 7 projects from the NCeSS website (the NCeSS nodes), and NeSC and NCeSS themselves are also included.

Some projects are not represented by a single project site. In such cases the authors searched for websites that best represented the web presence of the project (in some cases, this included academic homepages of the researchers most closely

[4]http://voson.anu.edu.au

identified with the project). In accordance with terminology commonly used in hyperlink analysis, the 51 projects are referred to as “seed sites” or “seed URLs”, but it is important to note that the approach used by Ackland et al. (2007) allows for a given project to be represented by any number of websites.

The Internet Archive’s (IA) Wayback Machine,[5] which has been archiving the web since 1996, was then used to collect historical data on hyperlinks and text content for the sample of e-Science and e-Social Science project web sites. For each project, data was collected at yearly intervals (there was an attempt to collect the data for the middle of each year, although the exact date of data collection was dependent on the date of the IA crawl). The archived pages had to be manually accessed using web browsers (the IA currently does not allow web crawler access) and in order to limit the data collection process only the archived top-level (or index) pages, and those (internal) pages linked to directly from the top-level pages were accessed.

The data collection resulted in a time series of web networks (from 2002 to 2007) where the nodes represent websites (the 51 projects in the sample and the websites that they hyperlink to) and the edges represent hyperlinks between the project websites. Note that not all projects in the sample were present in the web network for each of the 6 years of the study: the first year of inclusion was the year the project was first funded (or 2002, if that was later), while the last year of inclusion was determined using information on duration of grants and also by checking for project activity on the websites.

As noted by Ackland et al. (2007), there are several distinctive patterns that emerge, namely, the steady growth of the network from 2002 to 2006 both in terms of the number of projects and the links between them, and a decline in the number of seed projects in 2007 (perhaps reflecting of the short-term nature of UK e-Research funding initiatives), and the continued separate evolution of e-Science and (arriving later) e-Social Science. In 2002, UK e-Science was represented by the NeSC hub and a few projects in early adopting disciplines such as physics and astronomy. By 2007, this disciplinary core had not changed, despite the addition of many projects and a sizable proportion of life science projects. A high proportion of projects within the engineering and physical sciences are concerned with the development of generic tools and services, whereas a greater number of the life science projects are concerned with developing domain-specific tools within the context of research problems.

By 2007, the e-Science and e-Social Science programmes form two separate clusters, implying that the generic tools and infrastructure developed under the e-Science programme had not yet diffused to the social sciences (Fig. 3). The central position of NeSC and NCeSS in the hyperlink networks suggests the central role that these organizations have played – rather than any other form of “infrastructure” that might have done so – in the evolution of e-Research in the UK. However, it should be noted that the structure of the web network is bound to

[5] www.archive.org

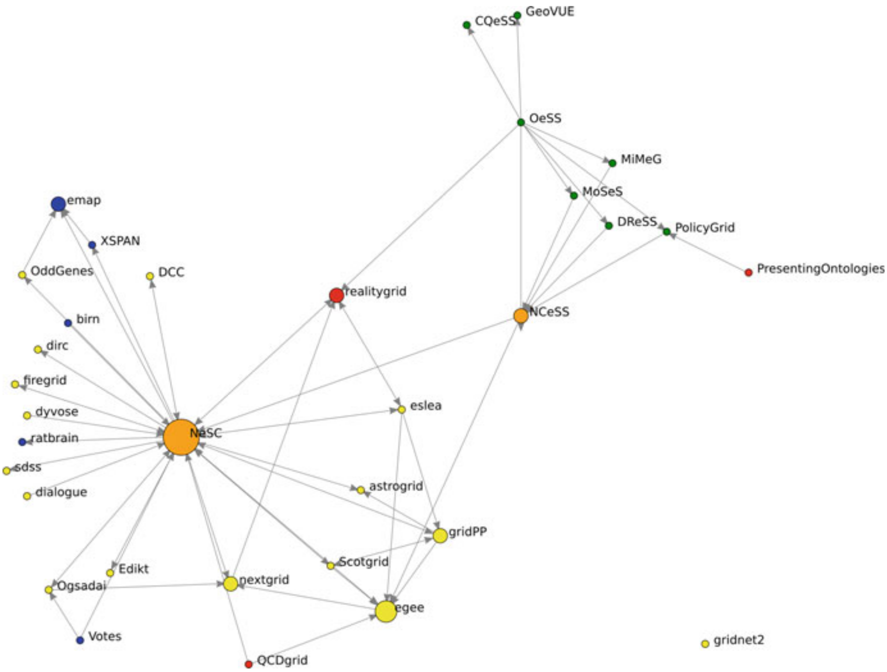

Fig. 3 UK e-Research Network 2007: Seed projects plus URLs. (source: Ackland et al. 2007)

change when we include other seed sites outside of the funded projects analyzed here as the central role of the two umbrella organizations is in part due to sample selection. Further, it remains for further research to establish how the structure of the network responds to major new initiatives, and how the evolution of the web presence of UK e-Research compares with that of the "cyberinfrastructure" initiative in the US and other similar programmes in the rest of world.

4 Discussion

It is interesting to consider how content and hyperlink analysis of the UK e-Research effort differs from the more traditional social science methods that have been used to study e-Research. Perhaps the most common methods used are obtrusive techniques such as surveys, in some cases combined with interviews, and more recently online surveys (Cummings and Kiesler 2005). These methods are useful for obtaining specific information about e-Research projects, such as the nature of collaboration, differences across disciplines, and the types of tools for overcoming distance and how they are used. Online surveys can be revealing in terms of the uptake of certain tools, who uses them, and attitudes towards their uses (and non-uses), as Dutton and Meyer (2009) have done for UK and international e-Social Science and Barjak et al. (2008) with regards to e-infrastructure in Europe. More in-depth interviews can be revealing about changing practices in e-Research, such as the degree of openness in collaborative projects (Fry et al. 2009).

The unobtrusive online research methods that we have presented in this chapter have several particular strengths. First, such automated methods are not dependent on obtaining information directly from respondents or interviewees, which saves effort on the part of researchers and research participants (the latter being particularly important, given the anecdotal evidence regarding the increasing prevalence of survey fatigue). Second, these methods allow for aggregating large amounts of information and displaying this information in a way that reveals overall patterns in a way that can be easily grasped. Third, the methods (once set up) can easily be used to conduct comparable research over time and across countries (it can be expected that in all countries with e-Research programmes, the funded projects will maintain web presences via project websites). Fourth, while the information that can be extracted from content and hyperlink analysis is somewhat limited compared with a detailed survey, it still reveals features about how projects and research organizations represent themselves online, which is itself an increasingly important part of research generally.

However, online research using digital trace data such as that presented in this chapter does have some limitations, compared with more traditional social science methods. First, websites are not always accurate or complete. Second, if one were to rely on large-scale information only, one may not come to grips with more detailed and qualitative characteristics of projects or research programmes. Third, the patterns that the online information reveals may not represent underlying realities, and it is necessary to infer the meaning of, for example, a hyperlink between two project websites.

Nevertheless, it is always difficult to analyse ongoing changes in research, regardless of the methods used and we advocate that where possible, online research methods should be combined with more traditional social research methods (for example, in a mixed research design).

5 Best Practices and Recommendations for Academic Research Teams

Apart from a choice of research method, researchers also have to make a choice with regards to the *tools* they select to implement their research strategy. The affordances on offer differ a lot from one tool to the other. For instance the two tools that we have employed for this paper are radically different in terms of ease of access versus capacity for fine-grained control. In what follows, we assume that a researcher is planning to conduct analysis of digital trace data (e.g., website text content analysis or hyperlink analysis) similar to that we have conducted here. Rather than giving advice regarding specific tools, we offer the following more general recommendations. While there is undoubtedly a trend towards the use of sophisticated e-Research tools, any researcher embarking on empirical research needs to choose the best tool for the job at hand. We hope the following will guide researchers in making this decision.

Does it need to be an e-Research tool? We are defining an e-Research tool as software that is available over the web that can be used collaboratively. Unless these qualities are essential for the research, then the researcher may be better served by sticking with software that is installed on the client machine and can only be used by a single person. Despite the advances in web technologies such as AJAX that have vastly improved the performance and usability of web applications, web applications typically still have poorer performance (and hence usability) than applications that are installed on the client machine. However web applications do have advantages: no need to install software other than a web browser (thus overcoming IT administration restrictions regarding what software can be installed on university computers), and automatic access to software updates. With regards to the collaboration aspect of e-Research tools, research team members tend to take particular roles and there might only be one person who actually needs to access the data and analysis tools. In such a situation, is it really necessary to use a tool that allows all team members to collaboratively access the data and analysis?

Build it or buy it? This is a question that often is faced by empirical researchers working on cutting-edge research. Sometimes the available tools cannot do what is needed or have been designed for use in another discipline, and the research will be constrained or simply unachievable unless a new research tool is built. In the case where it is necessary to build the research tool, there are some basic pointers. First, do not reinvent the wheel – if you can base your research tool on something already out there (e.g., modifying an existing open source project) then do it. Second, use open source rather than proprietary software – as noted above, this will present more opportunities for using existing code, and will be cheaper, assuming the required programming skills are available. Third, make the tool as basic as possible (especially with regards to user interface) for achieving the immediate research goals: if the research is successful and others want to use the tool, then that should hopefully lead to additional resources for further tool development.

Assuming you have decided to "buy it" i.e., use an existing research tool, then the following considerations are relevant.

Open source or proprietary? As long as it does what you want, it does not really matter. Open source software will typically be cheaper in terms of licensing, but there might be a cost in terms of usability/support. However, the choice of whether to use open source or proprietary software may impact on some of the following considerations.

Ease of use? The ease of use will depend on the sophistication of the research. It is important to choose the tool with the minimum set of features that allow you to do the research you want to do. For many researchers, the (nowadays) very basic combination of email/word/excel are adequately "generative" (Zittrain 2006) and there is no need to go beyond this. While empirical social scientists have traditionally used software such as SAS, SPSS and STATA which are reasonably complicated to use and often require training, the Google era has led to expectations that research tools need to be very easy to use. We already have the atomization of music (individual songs being available for download via iTunes) and the traditional media are resisting the seemingly inevitable atomization of news (via Google). The question is whether e-Research is leading to the atomization of research: research services being served up in easy-to-chew bite sizes, so that almost anyone can generate a visualisation regardless of whether they understand the underlying data or the technique used to generate the analysis. However, perhaps this is a good thing in that it is helping to bring sophisticated analytical tools to a wider audience?

Level of interoperability? This refers to the extent to which the tool allows you to export data in a format that can be used in third-party tools, or even directly interoperates with other tools. As with most of the above, it is a case of "horses for courses". However, as noted by Ackland (2009), with regards to the analysis of web data (text and hyperlinks) it is highly unlikely that a single tool is going to provide all the required techniques e.g., text mining, statistical network analysis and visualisation, and so it will be necessary to use a range of tools. The research will be more feasible if there is interoperability between these tools and e-Research is meant to provide the means, via web services, to connect up various disparate research resources (tools, data, compute). However there is a worrying trend towards data repositories and archives, under the guise of e-Research initiatives, attempting to set up "one-stop-shops" – analytical tools and services that sit on top of the data source. It is understandable that data archives want to provide services that add value to their data. But Ackland (2009) argues that if data providers are to also become tool providers, rather than providing APIs into their data that can be used by third-party tool developers, then this can have negative implications for competition and innovation in research. This essentially amounts to a case of vertical integration, something that in the case of other industries is recognised by economists as being potentially anti-competitive and leading to efficiency/welfare loss.

6 Conclusion

e-Research is being fostered by a world-wide effort to develop and deploy a new generation of advanced infrastructure to enable new advances in scientific research. The UK e-Science programme is part of this effort. In this paper, we have explored the use of some of the networked, interoperable, scalable computational tools that are being developed to locate, access, aggregate, and manipulate digitised data documenting the UK contribution. The online research methods that we discuss in this chapter have allowed us to draw some informative conclusions regarding the changing scope and foci of the UK e-Science programme. Further analysis, including comparisons with the findings from analyses which use more traditional social science methods, would be needed to fully investigate some potentially worrying conclusions from the analyses presented in our chapter: Has the programme mainly been supporting the simple side of e-Research and shied away from more risky undertakings? Has the programme managed to create momentum for e-Research, or is interest already fading away? And is the distinction between e-Social Science and e-Science within e-Research in the UK a necessary one, or does it merely reflect the way in which the programmes were organized? Online research such as that presented here can thus help to identify potential obstacles and problems that need to be addressed in order for e-Research to have a lasting impact on scholarly behaviour and to contribute to new discoveries in the sciences, social sciences and humanities.

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e-Research in International Cooperation Networks in Science and Technology Research

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Abstract This chapter discusses the methodology that has been developed and the lessons learned in a case study aimed at enhancing the role of e-Research in assisting and nurturing existing and emerging Communities of Practice (CoPs) in International Cooperation in Science and Technology and Innovation Research. International Scientific and Technical Cooperation among geographically dispersed partners, possibly belonging to different economic and cultural environments, constitutes a challenging endeavour. The proposed methodology involves the application of innovative Knowledge Management (KM) strategies and processes based on the intensive use of the new e-Collaboration tools to favour the establishment of Virtual CoPs (VCoPs), a type of social networks where knowledge sharing and exchange processes occur across organizational, cultural and international boundaries. The methodology has been applied to several projects within the scope of the different European Union Programmes on Scientific and Technological Cooperation with Mediterranean Partner Countries. The chapter includes (1) An analysis of the contextual framework; (2) The design, implementation and maintenance of an Organizational KM Strategy; (3) The development of appropriate e-Collaboration tools; (4) The proposal of an assessment analysis model of the impact of these initiatives; and (5) The conclusions and lessons learned in these projects. The latter include the practical importance of some key KM issues such as mutual trust and acceptance of the e-collaboration technology-platform, the need to enhance participation efficiency and to foster members' commitment, the complexity of the relationships within international cooperation initiatives and the key role of an effective governance mechanism for the sustainable functioning of these VCoPs.

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1 Contextual Framework

Rationale International Scientific and Technical Cooperation among geographically dispersed partners, possibly belonging to different economic and cultural environments, constitute a challenging endeavour. Cost savings and performance improvement in scientific and technological (S&T) cooperation are forcing the intensive use of e-Research Collaboration tools, which could complement and partially substitute traditional face-to-face processes (research projects meetings, events organization, etc.). However, the implementation of these new platforms in S&T international cooperation among regions with strong socio-economical and cultural differences, such as the existing between the European Union Member States and the so-called Mediterranean Partner Countries (MPC), presents peculiar characteristics that lead, for example, to the need to use effective, low-cost e-Research Collaboration tools.

1.1 The Euro-Mediterranean S&T Research Cooperation Context

The role of Knowledge in Research-oriented organizations has changed due to the paradigms associated with the Information Society Technologies (IST) and the new knowledge-based economy. In particular, this affects the Euro-Mediterranean International Cooperation in Science and Technology Development (INCO-RTD). This is an activity of long tradition, chiefly based on the quality of the scientific community on both sides of the Mediterranean, the longstanding relationships that have yielded excellent results in terms of scientific publications and research personnel training programmes and, above all, the need to cooperate in solving problems of common interest, such as how to "mind the gaps" associated to existing knowledge divides.

Recent events related to the launching of the so-called Union for the Mediterranean (13 July 2008) as a natural development of the Euro-Mediterranean Partnership (launched as a consequence of the Barcelona Declaration, 28 November 1995), the development of the European Neighbourhood Policy (ENP), the future creation of the Euro-Mediterranean Free Trade Area (EU-MEFTA) (scheduled for 2010), etc. have reinforced these processes. The importance of these developments stands in spite of suffering a shortage of appropriate infrastructures (both material and administrative) to channel many of these activities.

This cooperation has revolved around, on the one hand, the bilateral cooperation initiatives between the 27 EU Member States (EU-MS) and the MPC (Algeria, Egypt, Israel, Jordan, Lebanon, Libya, Morocco, Palestine, Syria, Tunisia and Turkey, where Israel and Turkey are also Associated Countries to the Framework Programme) and, on the other hand, the actions funded by the EU by means of the use of several instruments, mainly the latter MEDA Programme (e.g. the EUMEDIS Project on IST) and the different EU Research Framework Programmes (FP).

The EU Commission Directorate General for RTD (DG-RTD) has just launched within the FP7 (2007–2013) the so-called INCO-NET projects which aim, among other objectives, to foster the political dialogue and to seek synergy mechanisms for the assessment and implementation of effective cooperation policies in S&T research, development and innovation between the EU-MS and other World regions (Minch 2008).

In this chapter, the design and implementation of an Organizational KM strategy to support the e-Research collaboration mechanisms within (and among) the so-called INCO-NET projects is presented. As a practical example, this chapter will discuss one of them, namely MIRA (Mediterranean Innovation and Research Coordination Action), developed to support the Euro-Mediterranean scientists' CoPs. This case study extends previous research work by the authors on VCoPs and Networks of Practice (NoPs) and their implementation by means of e-Collaboration tools, e.g. ASBIMED; EUROMEDANET 1&2; MED 7 and MELIA Projects (González-Aranda et al. 2008).

2 Design of an Organizational KM Strategy to Support VCops

This section proposes an iterative Organizational KM Strategy (O-KMS) approach which combines the Nonaka and Takeuchi (1995) model and existing VCoPs and NoPs theoretical models (González-Aranda et al. 2008).

2.1 Theoretical Framework: Fundamentals of VCoPs

Communities of Practice (CoPs) are combination of three structural elements:

- The DOMAIN of knowledge, which defines the areas of shared inquiries and the set of issues discussed in the community.
- The COMMUNITY, its members, the social fabric, their motivation, and interactions.
- And the PRACTICE, the set of interacting processes, frameworks, ideas, tools, information, styles, language, stories and documents that the community members share.

The DOMAIN is the space of questions that could interest a number of parties, individuals, organisations, etc. In this sense, it defines the universe where different COMMUNITIES are created, considering a COMMUNITY as the network formed by the interested parties that have entered into contact by any means (physical contact, letters, news in journals, electronic communication, etc.).

The PRACTICE of the COMMUNITY is the interaction among its members, in such a way that it could be more or less guaranteed that a member of a CoP can reach another member in a direct or an indirect interaction. In a given DOMAIN there can be several CoPs that could expand or merge by interacting with each other. Motivation is the driving force behind the contribution of CoP members and it links their thematic goals with the declared interest of the organization in a concrete outcome and, on the other side, the open space for self commitment given to its members (working time and financial resources).

The COMMUNITY is subject to an evolution process and changes itself as time goes by. It is initiated and develops over time to the current shape and it is also embedded in a political, environmental, social and economical context that is always evolving. Newcomers become members of a COMMUNITY initially by manifesting their interest and/or participating in minute and superficial yet productive and necessary tasks that contribute to the overall knowledge goals of the COMMUNITY. This evolutionary newcomers' participation defines the so-called Legitimate Peripheral Participation (LPP).

There is a mutual interaction between the COMMUNITY and its surrounding Context. Every CoP has some kind of output, outcome and impact. Outcomes are the results of a programme or project relative to its objectives that are generated by its respective partners' outputs. Outputs are the tangible products (goods, services) of a programme or project. And impacts are the effects, positive and negative, primary or secondary long-term changes produced in a community by a programme or project, directly or indirectly, intended or unintended. In this sense, it is clear that depending on this positive and/or negative impact the sustainability will or will not be guaranteed.

From an organizational point of view, CoPs can be internal (i.e. confined entirely within a single organization) or they can occur in Network Organizations, i.e. through relationships among independent organizations (Powell 1990). Our analysis focuses on the latter CoPs in Network Organizations where member organizations work in close and continuous cooperation on projects or processes involving partnerships, common products and/or services, and possibly sharing a common strategy. In solving problems in today's environment, it is becoming increasingly important to cross boundaries, either within the organization or to external organizations for fresh insights. Learning and knowledge exchange through networks focuses on the inter-organizational network as a resource generator to enhance learning.

Traditionally, CoP members could interact on a face-to-face basis, but online VCoPs enable geographically dispersed members' ongoing participation. The development of VCoP whether purely virtual or hybrids that have both traditional (e.g. face-to-face) and virtual components relies on ICT as an essential enabler (Bieber et al. 2002; Griffith et al. 2003; Lee and Choi 2003).

Therefore, VCoPs are CoPs where organization members and individuals interact supported by collaborative ICT in order to bridge time and/or geographical distances. They are a type of social networks where knowledge sharing and exchange processes occur across organizational, cultural and international boundaries. Practical cases may be joint R&D inter-organizational initiatives carried out through specific international cooperation programmes, projects or other forms of collaboration which involve knowledge suppliers, customers and even competitors giving cause for raise new Frameworks and Tools of e-Research Collaboration.

2.2 Towards the Establishment of an Organizational KM Strategy

It is necessary to develop an O-KMS so that the explicit (written down) and tacit ("implicit", unwritten) knowledge held by the organization members who use those e-Research collaboration mechanisms can be collected, assessed, stored, made accessible, shared and re-used.

Nonaka and Takeuchi (1995) proposed a model where four stages of conversion operate in a never-ending spiral sequence to create and transfer knowledge throughout the organization (see Fig. 1). The four stages are:

1. *Tacit to tacit – Socialization.* Through social interactions (not necessarily face-to-face events only), individuals within the organizations exchange experiences and mental models, transferring their "know–how", skills and expertise. The primary form of transfer is narrative "storytelling". Training Seminars,

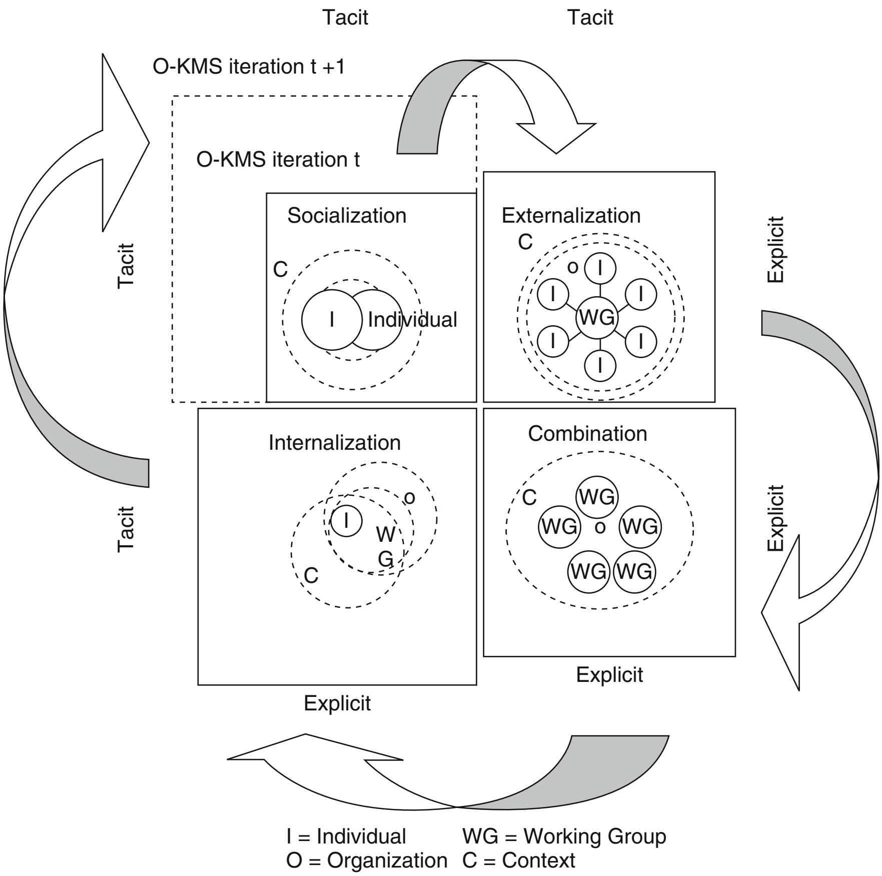

Fig. 1 Adapted from Nonaka and Takeuchi's knowledge creation spiral model

Thematic Workshops, Observation, Mentoring, etc. and on-the-job training (practice) build experience; additionally, these activities also build work group teams that develop shared visions and values.

2. *Tacit to explicit – Externalization.* The articulation and explicit codification of tacit knowledge moves it from the internal to external realm. This can be done by capturing narration in writing, and then moving to the construction of models. Externalization is the creative stage where experience and concept are expressed into explicit ways. This stage can be found in the creative phase of writing, invention/scientific discovery, and, hypothesis creation.
3. *Explicit to explicit – Combination.* Once knowledge is explicitly represented, different objects can be characterized, indexed, correlated, and combined. This process can be performed: (a) by humans or (b) by computers and can take on many forms.
4. *Explicit to tacit – Internalization.* Individuals within organizations "internalize" knowledge by hands-on experience in applying the results of the previous stage of combination.

Internalization leads to further socialization, and the process leads to further tacit knowledge sharing, and overall knowledge expansion. Nonaka and Takeuchi (1995) asserted that evolution from individual to organizational knowledge can be considered one of the main outcomes of organizational learning. At the organizational level, information, in the sense of an established, institutionalized organizational information resource (Levitan 1982) is considered a precursor of knowledge. Organizations base their actions on opinions which denote the beliefs and views of their members who usually gather together in form of working groups sharing a "groupthink".

In what follows, and based on this spiral model, the concept of an ever-learning organization, expanding its knowledge by means of the application of certain O-KMS processes, will be discussed. The proposed O-KMS is specifically aimed at International Scientific and Technical Cooperation among asymmetrical partners (see Fig. 2).

2.3 From Socialization to Externalization Knowledge Processes

Assume that, initially, one of the above-mentioned small-sized "groupthink" working groups is made up of relevant knowledge experts who formally (or "informally") meet, define a common targeted objective and institute a Coordinator. The Coordinator usually is a well-reputed, experienced senior scientist but may also have nothing to do with the knowledge areas the experts are dealing with. In fact, the Coordinator's figure should be chosen according to selection criteria based on previous coordination and managerial expertise in this type of initiatives. This starting SEED GROUP defines a set of general KNOWLEDGE GENERAL GOALS and expected outcomes for the VCoP, taking into consideration not only

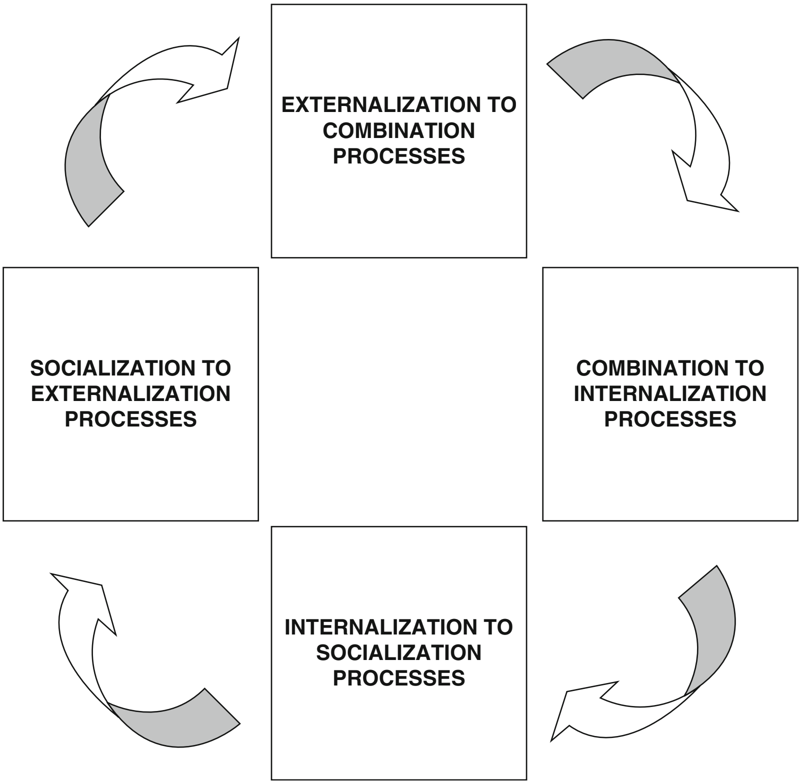

Fig. 2 Proposed spiral-type O-KMS approach

their own opinions, but also the criteria of invited experts coming from similar previous and on-going initiatives. In this way, they can take advantage of previous LESSONS LEARNED, such as good (and best) practices and barriers of any type (if any) they encountered for the "successfully" establishment of their VCoPs, etc (see Fig. 3).

In order to achieve these general goals, SEED GROUP members define a series of basic rules and work procedures which are accepted (after discussion and consensus) as a working hypothesis. These include two important requirements:

1. The appointment of the Chief Knowledge Officer (CKO). This knowledge "strategist" will focus on the organization values, techniques and objectives. The CKO will devise mechanisms to adapt this knowledge through KM processes to the external business/activity context and will permanently support the VCoP Coordinator by assuming the role of knowledge manager. In many cases, the CKO also acquires other "extra" roles such as person in charge of the design and maintenance of the KM System. Thus, he assumes the technical leadership of the O-KMS.

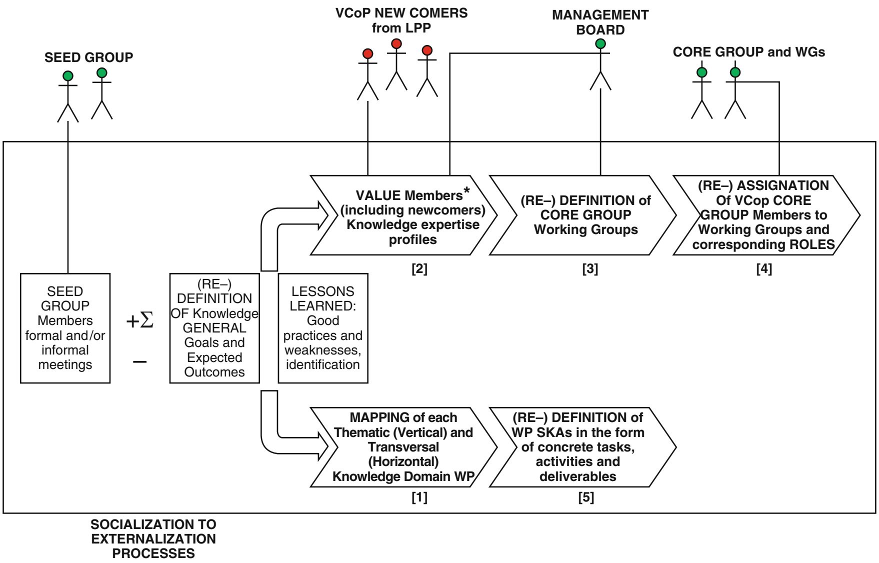

Fig. 3 Socialization to externalization knowledge processes

2. The distinction between two operational levels:
   - *Operational Knowledge Level:* This is the basic level and consists in the creation of different types of Shared Knowledge Artefacts (SKAs) by implementing an operational model adapted from Nonaka and Takeuchi (1995) spiral model.
   - *Operational Coordination and Managerial Level:* After initial Operational Knowledge Level creation and sharing processes are defined, in subsequent cycles, these processes will be constantly evaluated and re-defined (if necessary) by taking into account the VCoP general knowledge goals and expected outcomes. These monitoring, evaluation and re-definition processes are not only applied to SKAs, but also to:
     – The establishment of effective coordination mechanisms for the VCoP Members relationships (VCoP Governance)
     – The definition of the managerial aspects related to the different identified knowledge domains structures and topics covered
     – The design, implementation and management of O-KMS System ICT resources and related services
     – The provision of VCoP infrastructures and funding resources and the setting up of coordination and management procedures to support collaboration.

More specifically, these Operational Coordination and Managerial Level goals are achieved through the parallel execution of the following couple of processes (see Fig. 3):

Process [1] – MAPPING process: It consists of the identification of each knowledge DOMAIN and gives form to the so-called Work Packages (WPs). WPs may be categorized in Vertical (or thematic), which are those covering most thematic-oriented knowledge aspects, and Horizontal (or transversal), comprising common transversal knowledge issues and processes distributed throughout all the vertical WPs.

Process [2] – The identification and valuation of the knowledge expertise profiles corresponding to the existing SEED GROUP Members' and to candidate newcomers' to join the VCoP. This knowledge expertise profiles can be considered at the individual or institutional level.

Process [3] – Then, several Working Groups (WGs) are defined and will give form to the initial CORE GROUP. Although, in most cases, during the initial iteration cycles of the O-KMS there exists just one WG for each WP, it should be possible to define as many WG per WP as necessary, depending on the complexity of the targeted objectives. In addition, other types of WGs are established, such as the so-called GOVERNANCE WGs (e.g. Management Board WG, Steering Committee WG, Advisory Board WG), in order to assist the continuous evaluation of the project and the carrying out of the coordination and managerial tasks.

Process [4] – Later on, there is an assignation/re-assignation process of previously identified and evaluated VCoP Members to each WG.

Process [5] – Simultaneously to processes [3] and [4], the VCoP SEED GROUP members produce and articulate, for each WP, specific goals and expected outcomes defining the so-called Shared Knowledge Artefacts (SKA). They are concrete tasks, activities and deliverables (i.e. VCoP PRACTICE) which will be carried out taking into account their corresponding timetables and execution schedules. In order to achieve these objectives, it is necessary to define certain coordination and governance mechanisms not only throughout the VCoP, but also within each WG. That is the reason why a role-oriented scheme is followed.

The set of all these VCoP PRACTICE rules conform an O-KMS methodology which is collected in the so-called "Technical Annex" of the project. This document is written by the SEED GROUP Members and it can be considered as a "waybill" which gathers and makes explicit all these premises in the form of knowledge maps, conceptual diagrams, Gantt charts, PERT networks, Petri nets, etc. The Technical Annex will assist the day-to-day coordination and managerial activities during the lifetime of the VCoP.

During the first periods of life of the VCoP, there exists a reinforcement process of the VCoP based on the evolutionary growth from the starting SEED GROUP towards a CORE GROUP composed by initial SEED GROUP members plus some capable newcomers selected in process [2]. These CORE GROUP Members get to know each other and through interaction they will discover their "reciprocal interest" in sharing knowledge by means of a "*trusting*" process. In this Socialization phenomenon individual priorities (which in turn develop within an institutional context) take precedence over VCoP CORE GROUP "partnership". This is so because the cooperating organizations often simultaneously compete ("*coopetition*" concept; (Loebbecke and van Fenema 2000)). Therefore, during the initial

VCoP periods of life, most of the work may be accomplished at the individual level and not jointly with other VCoP Members. This is perfectly understandable during this VCoP "kick-off" stage but not later on when most of the work must be carried out in a collaborative manner by the WGs.

2.4 From Externalization to Combination Knowledge Processes

After the written (re-) definition of the SKAs corresponding to different knowledge WPs (Fig. 3, process [5]), they must be brought into operation (practical articulation). This process [6] (see Fig. 4) is performed taking into account:

1. The Organizational aspects related to the face-to-face events: Workshops, Capacity Building and Training Seminars, etc. This includes pushing the VCoP Members' elicitation process, i.e. how to articulate latent knowledge, knowledge that the owner might not even be fully aware of (Huff 1990) as well as an efficient O-KMS method for chairing and reporting face-to-face discussions.

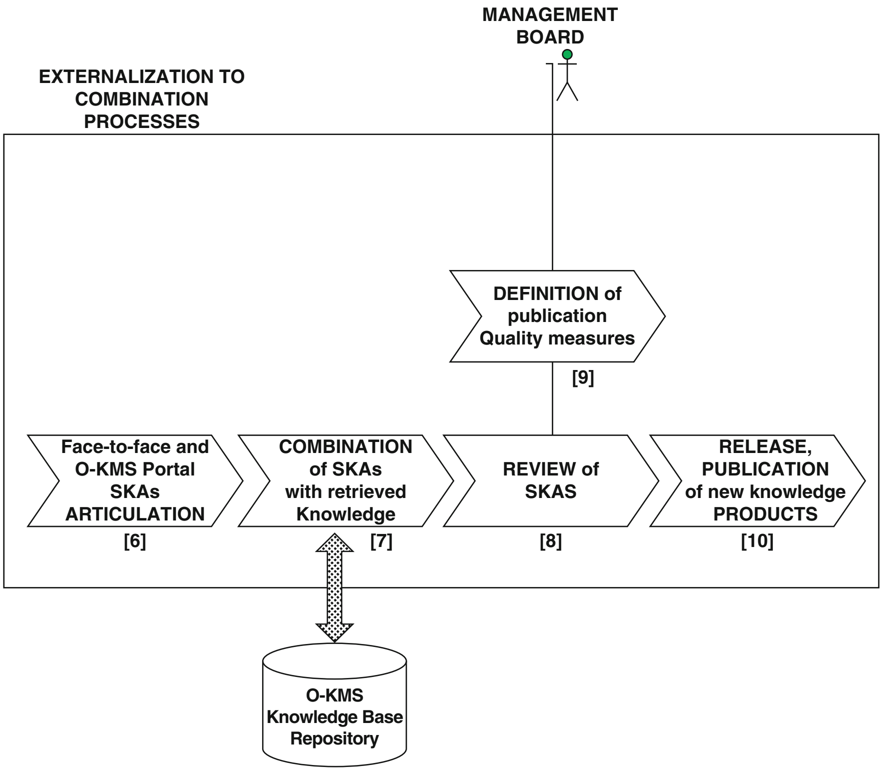

Fig. 4 Externalization to combination knowledge processes

2. The O-KMS design, implementation and maintenance, according to the "Tailorability vs. Uniformization" principle: Provide appropriate Collaborative Virtual Spaces (CVS) and Groupware tools through ICT support, coupled with a permanent monitoring of its usage and possible improvements.

2.4.1 O-KMS ICT Platform Design Requirements

A Knowledge Management System is one whereby the explicit (written down) and implicit (unwritten) knowledge held by the organization and its employees (members) is collected, assessed, stored, made accessible, shared and re-used (Nonaka and Takeuchi 1995). More specifically and from the operational point of view of our O-KMS, it can be defined as a system which combines and integrates functions for the contextualized handling of both, explicit and tacit knowledge, throughout organizations that are targeted by the O-KMS.

International Scientific and Technical Cooperation is a complex process that requires an ICT platform able to be easily handled, to fulfil social networking needs, collaborative work and quality control. There is not a unique model for such requirements. In this chapter we describe a customised model that has been tested in several EU-MPC projects.

In any VCoP context, the people and their interactions, i.e. their common language (mutual understanding) and their communication needs are critical. In the case study presented here:

(a) There are a large amount of actors involved in the VCoP CORE GROUP
(b) These actors are geographically (internationally) dispersed, which provokes budgetary limitations associated with their displacements (travels, etc.) justifying the creation of Internet-based ICT supporting platforms

The ICT Platform should allow efficient coordination and should facilitate knowledge mapping and sharing. In that sense, the use of traditional asynchronous ICT instruments such as those based on the simple exchange of emails are not enough. They would be inefficient and could cause serious instabilities in the normal functioning of these VCoPs, not only because of the functioning problems derived from well-known phenomena such as "email spam", but also the practically unmanageable amount of replies to any single topic or issue under discussion.

On the other hand, in order to achieve acceptable coordination mechanisms, another essential requirement is the provision of Collaborative Virtual Spaces (CVS). In general, for simplicity, each WG uses just one CVS (see Fig. 5). These CVS need to offer WG members intuitive and ubiquitous access to secure and transparent information and resources using their physical workplaces and their own tools. Thus, a context-oriented ICT Platform must be created to support spatially distributed WG members (taking into account also their mobility needs) to access their own working resources from different locations, providing a ubiquitous and secure access to their services and contents. Moreover, they must

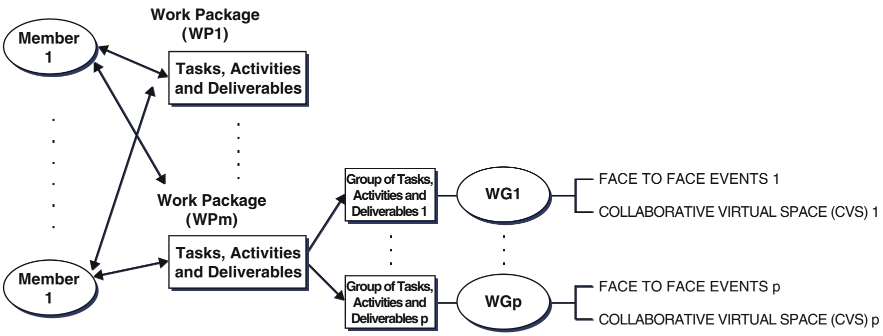

Fig. 5 Relationships between WPs, WGs and CVS

facilitate the e-collaboration of people belonging to different WG and working on different WP.

Most of these requirements are met by the so-called Groupware tools, which may be plugged in or removed as required, in order to provide specific CVS needs. Groupware user interfaces are generally based on Web technology, which is a commonly well-understood and accepted user interface paradigm. In addition, interacting through Web-based portals allows the use of efficient Content Management Systems (CMS).

Therefore, the basic component is a web portal, which will be the Internet visible face of the overall O-KMS (from now on O-KMS Portal). Two separate but interrelated areas must be distinguished within the O-KMS Portal:

1. *Public site:* In this area it is where VCoP knowledge products are made public and available to all the Internet community visitors. They are the final result of all the processes of transformation (articulation, combination, review, etc.) of the SKAs. They are shown within specific and categorized contents sections in the form of document and multimedia files, HTML pages, URL links, etc.
2. *Intranet site:* The contents in this area are visible to VCoP members only. Their "degree" of visibility, accessibility and discussion (feedback) will depend on the WPs they are involved and their role as members of the WGs associated to those WPs. It may be advisable the implementation of a special sub-intranet area for dealing with Administrative issues (budget, funding resources allocation, costs statements, etc).

There is a common procedure to access this platform by means of the use of a secure accession mechanism based on providing a personal login and password to each Intranet user. This procedure will later assist to perform the traceability and monitoring of the knowledge and work activities within the VCoP.

The O-KMS Portal must comply with (at least) the following general requirements to guarantee the integration between e-collaborative and knowledge management mechanisms:

- To provide a single entry point, i.e. a common gateway, for accessing all relevant information related to the VCoP WPs and their WGs. In addition, the Portal must serve as a central area for VCoPs Coordination Actions, allowing the flow of information from/to inside/outside the VCoPs.
- To aggregate access to many different profile users (providing personal User Preference areas), who in turn will have access to filtered, selected information depending on their user role within the O-KMS Portal. Also, the O-KMS portal must provide control access and privileges depending on these established roles.
- To provide flexible visual design customization tools (e.g. giving the possibility of adding "Smart" Portlets, widgets, etc). This will allow an easy and intuitive future handling of the O-KMS Platform.
- To display an overview of overall and individual activity, including the traceability of knowledge products within the Platform.
- To coordinate appointments using personal and project team calendars, providing a common project calendar with scheduled events and milestones.
- To conduct and automatically capture discussion by means of uploading, downloading and updating contents corresponding to the different WPs tasks, activities and deliverables. Articulation, organization, categorization and archiving of these SKAs even prior to their final transformation into VCoP knowledge products.
- To provide mechanisms to work collaboratively on the same versions of the SKAs, by means of the use of friendly client office computer systems (Microsoft® Office™, OpenOffice™, etc…). Some of the applications which are compliant with this requirement are, for instance, on-line whiteboards, WebDav-based external editors, etc. These collaborative writing systems such as text processors provide asynchronous support by showing authorship and by allowing users to track changes and make annotations to working documents, including mechanisms for locking parts of the document or linking separately authored documents. In this way, VCoP Members work collaboratively on the same version of a specific SKA of which they are co-authors.
- To provide efficient workflow tools to help plan and coordinate the SKAs evolution towards final knowledge products. This workflow tools should have some features such as the capability of sending notifications to the SKAs co-authors (e.g. via email) after the review process indicating, for instance, the decision of make them public or not, etc.
- To capture and index their associated metadata of published knowledge products in order to classify them by following a taxonomies-based criterion. As a result of this process, an initial set of WPs Virtual Libraries composing the VCoP Knowledge Base should be established. Later on, these taxonomies-based Knowledge Base may evolve, giving raise to specific knowledge domain Ontologies.
- In order to complete last requirement, it may be interesting to include (at least) one search engine to allow fast searches for both SKA and knowledge products by using full-text and metadata searches. Likewise, this search engine might

evolve towards a more powerful, smart semantically-oriented tool. Therefore, the advanced search criteria may be based on specific keywords previously introduced into the contents descriptions, abstracts and authors annotations.
- To provide synchronous support tools (chat, videoconference systems, etc.) in order to allow VCoP Members to communicate each other in real-time. Access to these tools may be granted through controlled access or by the inclusion of discussion moderators.
- To provide technical and maintenance support guaranteeing advanced Web server policies: disaster recovery, backup and replication copies, manage web cache and databases to improve performance, etc. In addition, it will be necessary to guarantee O-KMS Portal compatibility with most of the Internet Browser Navigators (MS Internet Explorer, Mozilla Firefox, etc…).

Based on the above requirements, the selection of a proper O-KMS Portal should consider the existing Groupware and Content Management Systems (CMS) ICT Platforms. The following selection procedure is suggested:

Step 1 Define a list of available:

- *Commercial platforms*. Such as the well-known IBM® Lotus™, Microsoft® SharePoint™, etc.
- *Non-commercial platforms*. In recent years, open source platforms have gained lot of attention because of their functionalities and cost perspectives. Indeed, the most evident and direct advantage of their use is the low (or null) purchase costs. Among other benefits, there is no need to manage and track licensing use, e.g. adjust budgets if there are a variable number of Platform users. Moreover, there exist many European institutions that have adopted this type of platforms to improve its team-working and content management. A representative sample of this type of ICT Platforms are: Joomla!, eGroupWare, Postnuke, Typo3, EzPublisher, Xoops, Drupal, phpGroupWare, OpenCms and Zope/Plone based architectures.

Step 2 Determine a shorter list of CMS software for detailed evaluation. A benchmarking study of the available ICT Platforms is performed in order to measure their maturity based on the analysis of two interrelated variables: their degree of deployment (considering for example an acceptable threshold of their use of at least one hundred existing deployments) and their degree of technical development (based on an estimation of the evolution of their supporting community of software developers). In this case study, this shortlist was reduced to two choices: Zope versus OpenCms from Alkacon Software®. These systems were under testing activities on several pilot probes.

Step 3 Final solution adopted:

After the testing probes, the Zope/Plone Platform was selected due to its ability to face and cover all the mentioned functionality and requirements proposed during the software selection process and, in particular, the overall costs (licenses, customization, hosting, etc.) and the experienced community of users developing software modules, add-ons or products based on CMS framework (indeed, one of them co-author of this chapter).

Zope is an open source web application server primarily written in the Python programming language. One of these plug-in Zope components is the so-called CMF (Content Management Framework) which adds numerous tools and services to Zope to allow community or organization-based *content management*, complete with a workflow system and a powerful customization framework. These systems use Zope's built-in security architecture. Zope includes its own HTTP, FTP, WebDAV, and XML-RPC serving capabilities, but can also be used with Apache or other web servers. Specifically, a CMS based on the Zope Content Management Framework was selected, namely PLONE.

2.4.2 Establishment of a Common Knowledge Workflow Methodology

In this case study, the knowledge workflow methodology essentially consists of the generation of new VCoPs knowledge products as a consequence of their evolution from original SKAs which comprises the different Working Groups knowledge activities developed during the VCoP face-to-face events as well as within their corresponding Collaborative Virtual Spaces (CVS). This knowledge workflow is shown in Fig. 6 and is explained in detail in the following section.

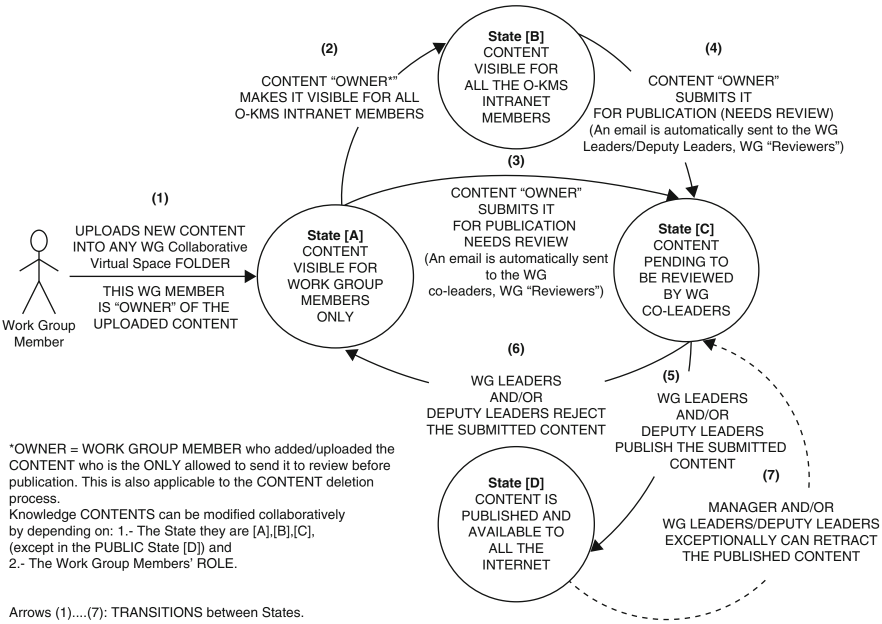

Fig. 6 INCO-NET MIRA knowledge management system CONTENTS workflow

2.4.3 Articulation of Shared Knowledge Artefacts

SKAs are given in the form of concrete digital contents that gather the different contributions and feedbacks coming from all the VCoPs members, according to their specific ROLE within the WG they belong to. These WG members may decide the degree of visibility and accession of these digital contents by changing their STATE attribute.

Indeed, CVS are supposed to be the main instruments of assistance to apply knowledge workflow methodology through an on-line practice. SKAs are made explicit as concrete contents uploaded by WG Members into the CVS areas, specifically into the discussion (e.g. working documents) folders. They may be:

- *Events:* Gathering information related to VCoPs calendar of internal activities (e.g. face-to-face events details) or interesting milestones from similar external initiatives and resources.
- *Files:* Any type of files. In fact, O-KMS file system recognizes uploaded file formats: MS® Office™ (Word, Excel, Access, Powerpoint, . . .), OpenOffice™, Adobe® Acrobat PDF™, etc.
- *Folders:* Allowing sub-folders structures.
- *Graphic Images:* BMP,GIF, TIF, JPEG, etc.
- *Links:* To interesting websites resources, either internal to the O-KMS Portal or external.
- *News:* Regarding this and other similar VCoPs practice activities.
- *Pages:* Static web-pages (HTML or plain text contributions).
- *Chat:* In the beginning, any of the WG members could add as many synchronous discussion threads (chat rooms) as required, but due to operational aspects related to the coordination of the discussions threads, it was decided to provide this content uploading facility to the CKO only, following the instructions of the CA.
- *Calls for Cooperation:* It is also worth to mention this special content-type which represents an example of the use of O-KMS Portal meta-data facilities so that "on demand" SKAs can be implemented according to VCoPs specific customization requirements. In this case, any WG member can upload a special announcement corresponding to an open call for science, technology and innovation research as well as its details, such as Category, start/end dates, description, funding data, contacts, web and RSS feeds (if any), etc.

When uploading these new digital contents, WG members are free to navigate through their corresponding CVS sub-folders structure. Once any content is uploaded into the O-KM System, it automatically acquires the State of "*Visible for WG Members ONLY*" (State [A] in Fig. 6).

2.4.4 SKA Combination Process

Once SKAs are explicitly represented in the form of digital contents, they may be combined, i.e. completed, characterized, indexed and correlated with other existing

SKAs of the same knowledge domain. These processes will be performed by WG users by taking into consideration the existing O-KMS Knowledge Base repository (process [7], see Fig. 4). At the VCoP "kick-off", this repository is not empty since it is initially fed by WG Members with a small but representative amount of background documents on the considered knowledge domain, including thematic documents (such as technical and white papers, etc) as well as links to O-KMS Platform external knowledge resources.

In order to gather and summarize the feedback coming from all WG members, mainly based on the review of this background literature and the result of the face-to-face discussions, it is necessary to implement working tools which comply with certain operational requirements (1) The possibility of working collaboratively on the same SKA digital content version; (2) To be compatible with most of the well-known software clients installed on WG members local (personal or organization) computers to make more "smoothly" the production process of the final knowledge products.

In that sense, *External Editor Clients* are powerful applications that once installed in a WG member computer (front-end) allows integrating the O-KMS Portal server more seamlessly with client-side software tools. They may automatically retrieve the last changes introduced into the uploaded content in the server without ending the editing session. They also lock contents while they are being edited and then they automatically unlock them when the editing session ends. Moreover, they associate any client-side software application (MS® Office™, OpenOffice™, Adobe® Acrobat™, Dreamweaver™, Photoshop™, etc.) with any server uploaded content-type by using a smart syntax highlighting or file type detection mechanisms (e.g. *.doc, *xls, *.mdb, *.ppt, etc.).

As practical functioning sample, let us assume that there exists a working document entitled "*Conceptual Framework of Water Conflict in the Mediterranean*" which was uploaded in order to provide a basic document skeleton to start discussion. The reader can check that there is a small "pencil" icon on the Fig. 7,

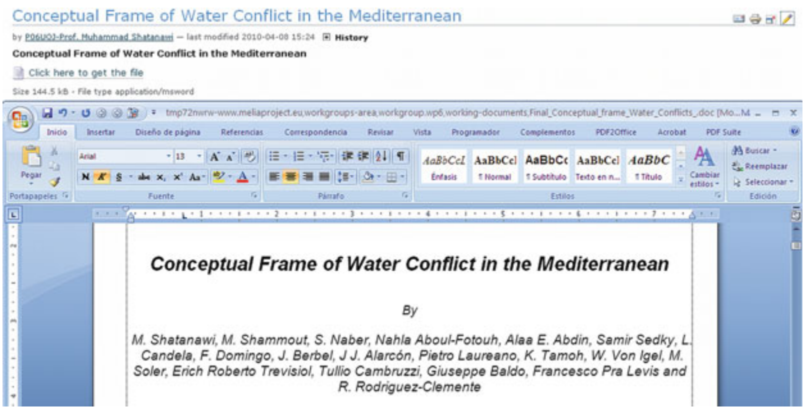

Fig. 7 External editor use example for e-collaboration

above right side. After clicking on it, this document will be automatically open from MS Word application allocated on the WG Member's local computer. File document is opened as a *tmpxxx.doc* document. Actually, the Internet browser starts the local editor when a particular type of data is downloaded with the browser. It just creates a temp (tmp) file and decides which registered application to use, passing it the file path. Indeed, once the editor is running, it is only aware of the local file, and has no concept of where it originated or came from. To solve this problem, an external editor determines the correct editor to launch for a given server content type and then gets the data back into the server when the changes are saved. This saving process can be performed as usually by clicking on MS Word (Save) disk icon  or simply closing the document window (user will be kindly asked to save recent changes). It is important to mention that while the document is open in the local editor, it is locked in the web server to prevent concurrent editing. Then, after ending the editing session (i.e. by closing the external editor) the object is unlocked.

This combination process may be performed by taking into account (1) Only the feedbacks of the WG Members where the SKA was uploaded; by default, when any content is uploaded into the O-KMS it automatically acquires the State [A] of "*Visible for WG Members ONLY*". (2) Taking into account the opinion of the members coming from the rest of WGs. This is a decision that can be only adopted by the SKA "*Owner*" by using the Workflow tool. In last case, SKA acquires the State [B] "*Visible for all the O-KMS Intranet Members*" (see Fig. 6).

2.4.5 SKA Review

After completing the combination process, SKAs must be reviewed (process [8], see Fig. 4) before being transformed into new knowledge products (process [10], see Fig. 4), i.e. they are "*released, published*", workflow State [D] (see Fig. 6). This review process must take into account certain QUALITY measures previously defined by Management Board members who are a special WG composed by VCoP Coordinator, the CKO and WG knowledge reviewers, a.k.a. WG Leaders (process [9], see Fig. 4). In fact, these leaders are the persons in charge of the review within the corresponding CVS where the SKA was uploaded. Also, this is a decision that can be only adopted by the SKA "*Owner*" by using the Workflow tool. In that case, "*Owner*" executes Transition # (3) (from State [A]) or Transition # (4) (from State [B]). Both transitions have the same destination: State [C], "*Content pending to be reviewed*". The reviewers will automatically receive an email notifying them they have new SKAs to review.

2.5 From Combination to Internalization Knowledge Processes

The creation process of new knowledge products from the O-KMS through collaborative working triggers the need for an efficient categorization and classification

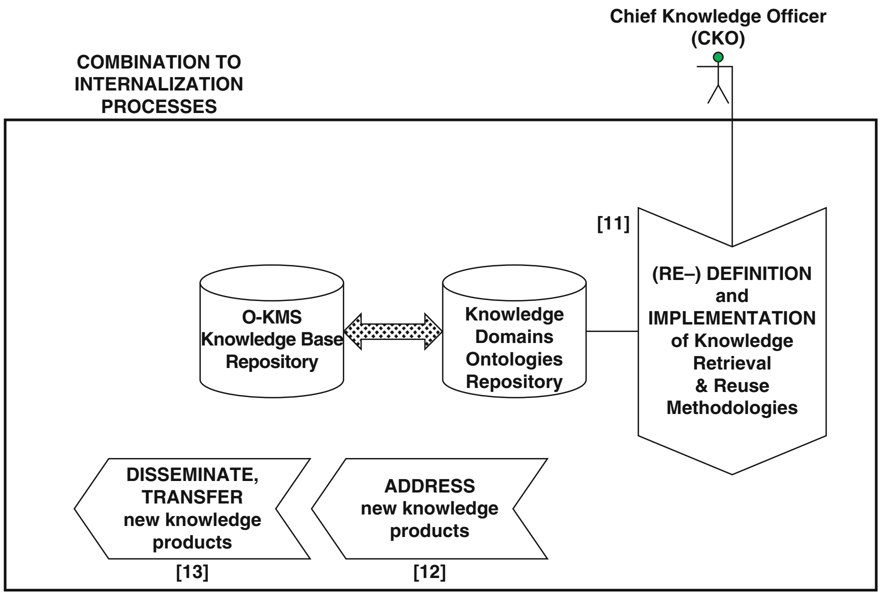

Fig. 8 Combination to internalization knowledge processes

strategy, i.e. *the design and implementation of knowledge retrieval tools* (process [11], see Fig. 8). In that sense, the appearance of the Semantic Web means contents that are readable by computers using knowledge representation that relies on languages that express information in a machine "process-able" form (Berners-Lee et al. 2001). The "conventional" Web mechanisms rely on encoding schemes based on technologies such as HTML and XML (eXtensible Markup Language). However, the information which is adhered to this encoding lacks explicit semantics.

The Semantic Web basically uses two enabling technologies: RDF (Resource Description Framework) and ontologies (Brickley 1999). If we consider that HTML is a mark-up language for displaying data, and XML a mark-up language for describing them, then RDF provides the semantic mark-up, and ontology languages supply a shared common understanding of a concrete knowledge domain. RDF represents knowledge as triples, represented as directed graphs. These triples represent *subjects* which are associated with *objects* by means of *predicates* such as each of these terms can be represented by a URI (Universal Resource Identifier). On the other hand, ontologies provide the formal specification of a knowledge domain. A particular knowledge domain consists of classes, their instances, and the relationships among them. This knowledge domain specification can then be transferred, e.g. among heterogeneous O-KM Systems, improving knowledge retrieval and sharing mechanisms. Therefore, knowledge domain ontologies are useful for sharing a common understanding of a specific knowledge domain among the WG members of the VCoP by analyzing and/or reusing domain knowledge products as well as by making explicit any knowledge domain assertion.

There are many ways to develop ontologies: From using text classifiers (Woods, Poteet, Kao, & Quach 2006), allowing individual WG members to add to an existing list of terms, or alternately forming expert sub-groups of employees to develop *keywords* to be incorporated into the ontology (Markus 2001). In any case, using these methods individually to develop ontologies may create serious functional problems. In the case of text classifiers, this method is suitable only for ontologies that use existing knowledge products. It is observed that the main problem of allowing WGs members to simply add to an existing list is that the O-KMS Knowledge Base may originate a situation where there can be so many "key" terms that nothing can be grouped together in order to make up a canonical structure. For example, if one WG member uses the term "integrated water management" and another one assigns the term "multiple viewpoints on water management" and each added its own term to the final list of terms, then the knowledge terms categorized in both examples may not be grouped together.

The setting of specialized experts' sub-groups within the WGs to develop the specific knowledge domain ontology may solve the above mentioned problem. However, there exists the risk of newcomers not knowing how to search and assign the correct keyword (Markus 2001). Indeed, if WG members are unable to use this semantically-oriented system, then only their designers will really use it. Therefore, it is necessary to establish appropriate assistance mechanisms to train VCoP newcomers for using these new O-KM Systems features.

Once knowledge products have been "released", i.e. made public as well as semantically indexed and categorized, further steps are required, namely:

1. A proper ADDRESSING strategy (process [12], see Fig. 8), i.e. to which sectors and stakeholders (a.k.a. knowledge customers) are these knowledge products relevant.
2. A DISSEMINATION/TRANSFER (process [13], see Fig. 8) of these knowledge products itself. In order to enhance this strategic process, pushing and lobby measures based on knowledge customers' specific peculiarities are helpful.

The use of Semantic Web technologies will assist to achieve these two purposes by fitting most of the knowledge customers' search preferences *through the use of Internet search tools and engines.*

2.6 From Internalization to Socialization Knowledge Processes

Finally, knowledge customers will make use of the knowledge products by *applying* them to their specific needs (process [14], see Fig. 9). In that sense, it is worth making reference to the concept of organization's absorptive capacity. Cohen and Levinthal (1990) state that an organization's *absorptive capacity*, i.e. its ability "to absorb" new knowledge (products), is a function of the organization's previous knowledge that allows it to recognize and synthesize new knowledge. They also assert that Information Systems may not be able to handle the transfer of knowledge

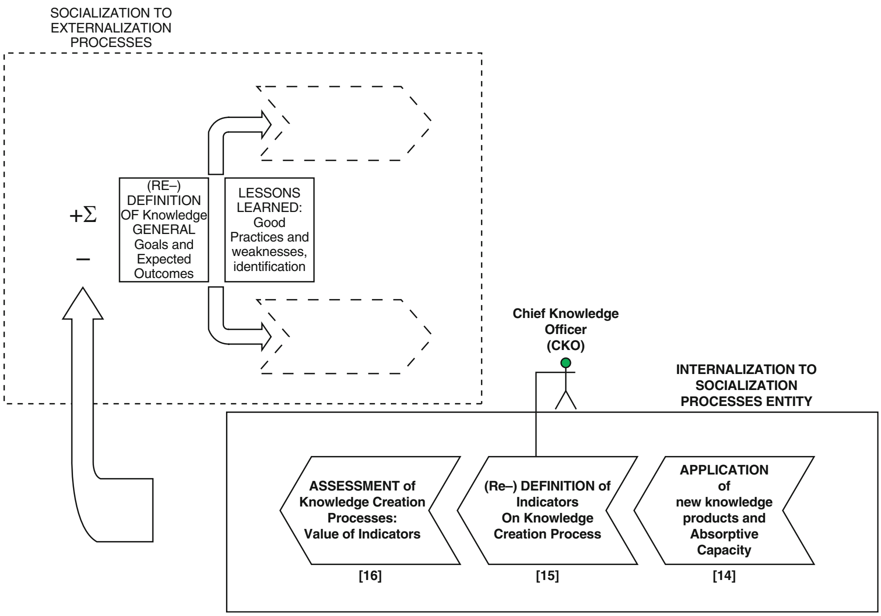

Fig. 9 Internalization to socialization knowledge processes

from external sources, as most knowledge sharing support systems are only designed for internal use. Organizations can be reluctant to open up their O-KMS, as technical challenges and innovations occur without a universal integration and security mechanism that interfaces with different parties' own O-KMS. In many occasions the control of the new knowledge products, given in the form of concrete digital contents, may be lost. Also, external knowledge transfer can push the locus of control beyond the organization's (the VCoP, specifically the CORE GROUP, in our case) boundaries which for some may cause "apprehension" mechanisms.

2.6.1 Towards the Next O-KMS Strategy Cycle Iteration

In theory, the proposed iterative O-KMS, jointly with its feedback cycles, should continuously improve, enhance and enlarge the whole VCoP, as well as guarantee its sustainability over time. In that sense, on the one hand, VCoP best practice processes, and on the other one, weaknesses must be identified throughout the different O-KMS processes. These identification activities jointly constitute the so-called *LESSONS LEARNED* which at the VCoP "kick-off" only included the experiences of previous VCoPs initiatives. This process supports the *continuous audit process* consisting of measuring the difference between the desired and present knowledge, that is, the (Re-) Definition of the VCoP knowledge GENERAL goals and expected outcomes (see Fig. 9). To that purpose, the establishment of an assessment analysis model of the impact of these organizational knowledge activities takes precedence over these processes (processes [15] and [16], see Fig. 9).

2.7 Discussion and Analysis Model of the Impact of the O-KM Strategy Processes

The last section showed how knowledge creation process is continuous and expanding along the successive O-KMS iterations. Simultaneously, as the VCoP matures, it accumulates and applies new knowledge products, resulting in an internal learning process where KM processes take place in an organizational context. In order to guarantee the *effectiveness* of these processes, clear links must be established between (and among) them. Moreover, process performance measurement mechanisms should be established. It is necessary to check which knowledge aspects can, or cannot, be appropriately measured. At this point some critical questions emerge:

1. From the point of view of the *effectiveness*: Are the VCoP's general goals and objectives consistent with its composition and knowledge management structure? If yes, is the knowledge being produced relevant to the needs of possible knowledge customers (institutions, NGOs, decision-makers, etc.)? Are the VCoP members fully realizing the advantages of working together? Maybe VCoP members also begin to question themselves why they are bothering to do their work within a VCoP context, that is: Where is the value added? What is the sense of ownership of the VCoP members? The last group of questions are signals of a maturing of the relationships among VCoP members, recognizing implicitly (if not explicitly) that they may be limiting their effectiveness by not adding value to each others' work. In addition, regarding the O-KMS Governance Structure: Is the VCoP well-coordinated, from the perspective of the desired goals? In other words: Are structural and governance issues impeding (in some way) its effectiveness?
2. From the point of view of the *efficiency*: Is capacity being built or improved across the VCoP? Has the VCoP created an adaptive culture, based on internal monitoring of its work, in order to minds the gaps and ensure efficiency as far as possible? Do the Governance Structures consistently refine their objectives and their actions in keeping with their observations on what may or may not be working, either in the VCoP's strategic plan, in its structure and governance, or in the efficiency of its operations?

VCoP members will probably meet face-to-face several times to assess the effectiveness of the VCoP with respect to its knowledge goals and contributions. Therefore, for a good monitoring of the processes, key knowledge indicators must be created in order to detect and avoid possible stagnation phenomena, i.e. whether VCoP Members miss deadlines, do not execute their assigned tasks or activities or do not produce the planned deliverables and so forth. All these questions may find an answer according to the applied O-KMS. Indeed, the results of these assessment processes must be periodically analyzed and discussed by the VCoP Governance Structures, each at its own level of competence and responsibility. It is during these reflection activities when good practice members, or better work design may emerge and guarantee efficient commitment to the goals of the VCoP and thus, guarantee its Sustainability, independently of future personalized Governance Structures. These good-performing VCoP members guarantee improvements in the relationships building and interaction among members, such as peer review, joint work, permanent communications and real recognition and influence beyond the frontiers of the VCoP.

On the other hand, financial management and reporting is an essential part of the Project, which takes enormous resources in terms of time and psychological stress. The simplification of this important issue can only come from a learning exercise of all the members of the VCoP about the correct mechanisms of management. If the VCoP is planning to work together for a long time into the future, it needs to address a number of O-KMS goals, including management, mainly based on the Lessons Learned after the assessment analysis performed in the course of the different described O-KMS iterations.

In principle, the VCoP can evolve over time in one of the following possible directions:

(a) VCoP crash, if the above defined stagnation phenomena persist
(b) May be activities reduce to simple knowledge sharing of the VCoP member in face-to-face events
(c) May be activities reduce to simple knowledge sharing of the VCoP members exclusively by means of the use of the ICT Collaborative tools (O-KMS Portal)
(d) Evolution towards a Good functioning, if a significant subset of members of the VCoP can work together and exert a pulling effect on the rest
(e) Optimal functioning, if all partners deliver according to expectations. The carrying out of knowledge activities (not only sharing, but also creation, combination, etc.) is balanced and needs few (e.g. yearly) thematic VCoP face-to-face events complemented with an intensive use of the ICT Collaborative tools (O-KMS Extranet systems) in the VCoP day-to-day

Whatever the evolution of the VCoP is, it is clear in general terms that until a reasonable period of time has passed (1–3 years depending of the complexity of the goals), VCoP knowledge productivity may oscillate between two extreme cases:

1. Quite high, indicating VCoP Members commitment to VCoP objectives and proficiency in the handling of the O-KMS platform
2. Quite low, indicating either a lack of commitment towards the objectives of the VCoP, or a lack of capability or efficiency in the handling of the O-KMS platform. This second situation indicates, perhaps, a mismatch between the nature of the partners and the technical structure created

The productivity indicator, i.e. the results obtained versus the work plan, can show the efficiency of the proposed O-KMS, but a deeper analysis is needed of the Sociability, defined as an extent to which the social interaction policies, incorporated into the O-KMS, support the purpose of the VCoP by making it acceptable to the WG members (Preece 2000).

2.7.1 Measuring the Knowledge Creation Process

In order to ensure that knowledge handling in a particular VCoP is indeed effective and efficient, the performance of its O-KMS processes has to be measured. To properly measure what is needed, key performance indicators can help to assess, guide and manage the evolution of O-KMS practices. Once a proper set of indicators has been selected, good practices and benchmarks can be collected and systematically used to improve the VCoP operations and the O-KMS. The key idea is to make a diagnosis consisting of comparing actual with initially desired (i.e. benchmark) values and giving a proposed course of action to address underlying problems.

Indicators are quantifiable measurements which reflect the critical success factors in VCoPs. They reveal a reliable snapshot of the VCoP, a way to find out if the general O-KMS goals and outcomes are being achieved. However, successful O-KM outcomes might exist that do not show in the selected quantifiable indicators. Therefore, it may be convenient to find out also how some variables without quantifiable indicators are evolving within the VCoP. The *Intellectual Capital Method* (mainly based on Bontis et al. 1999 and Edvinsson and Malone 1997 works) is perhaps the best suited, as it provides both a theoretically complete and practical approach for measuring intangible resources like knowledge creation. This model was further developed giving rise to another sub-model, the so-called the Intellectus Model. On the one hand, there exists a correspondence between Tacit Knowledge and Human together with Relational Capital (intangible assets); and on the other hand, between Explicit Knowledge and Structural Knowledge (tangible assets). The Sympathized knowledge is the tacit knowledge shared through common experiences. Examples are the organizational skills and the know–how and trust between members of the VCoP.

For each of the proposed O-KM Strategy stages, a set of indicators needs to be developed. An idiosyncratic simple adaptation based on the Intellectual Capital model is proposed next in order to check the *effectiveness* of O-KM processes within the VCoP.

2.7.2 Definition of the Indicators

Indicators for Socialization: Socialization leading to sympathized knowledge, which is the tacit knowledge, cannot be measured directly. Indirectly, however, it can be assessed by measuring the socialization process itself. The following indicator is proposed to measure the physical and regulating facilities for socialization: The number of *Direct communication links* of each WG member (two indicators, measured at individual and institutional level, as a percentage of the total) related to the organized VCoP face-to-face events (thematic workshops, training seminars, working meetings, etc.) and including both attendance and participation.

Indicators for Externalization: The main outputs of externalization are conceptual knowledge products. Two indicators are proposed: (1) The *number of SKAs created by VCoP members*. This amount will provide a rough indication of the degree to which conceptual knowledge has been worked out. (2) The *real person months (p.m.) engaged in the VCoP objectives*: the average percentage of real dedication is compared with that initially planned or expected. In this case study the definition used the Framework Programmes of the European Union is adopted so that the p.m. effort concept reflects the equivalent of a monthly average of full-time researcher devoted exclusively to the completion of a certain project. That time may be spent by a single researcher or comprises the partial sum of the dedications of several researchers during certain time. An important value to consider is the number of hours equivalent to that obtained as a monthly average of the productive hours of the researcher, i.e. the division of productive hours per year by the number months.

Indicators for Combination: The result of the combination process is systemic knowledge. Two indicators are proposed: (1) The *Number of categories in the O-KMS knowledge base repository taxonomy*: the total number of thematic categories in which knowledge stored in the knowledge base is subdivided. The knowledge base repository is the most important implementation of systemic knowledge, usually given in the form of several digital libraries. More specifically, this indicator includes the number of "*canonical keywords*" that are used for the knowledge retrieval processes and the categorization and indexation of new knowledge products. (2) The *Total number of new knowledge products stored in the knowledge base repository*. This includes not only the number of released publications, but also, as a clear indicator of the effectiveness of the combination process, the number of co-publications and the geographically distribution of their contributors.

Indicators for Internalization and second cycle of Socialization: The output of internalization is operational knowledge. Most knowledge networks (including VCoPs as a particular case) assess knowledge outputs using as main indicator the number of scientific papers published in a certain domain. These outputs are generally stored as knowledge products within the O-KMS Knowledge Base Repository, which may be accessible through Internet. However, the question is if knowledge products created by the VCoP are relevant to those coming to the O-KMS Knowledge Base Repository from inside of the VCoP, i.e. if its new knowledge products are being used internally. To this end: (1) The *internal frequency of use of the knowledge base* is quite a precise indicator for Internalization: The average number of times the knowledge base has been accessed (during the past month or year). On the other hand, (2) the indicator for second cycle of Socialization measures the relevance of the activity of the VCoP, in terms of its

Table 1 Indicators to measure the knowledge creation process in e-research collaboration networks

Category	Knowledge process	Indicator	Units of measurement
Sympathized knowledge	Socialization	*Direct communications links*	%
Conceptual knowledge	Externalization	*Number of SKAs created by VCoP members*	Kilo- or Mega- bytes
		Real person months (p.m.)	%
Systemic knowledge	Combination	*Number of categories in the O-KM System knowledge base repository taxonomy*	Integer numeric value
		Total number of new knowledge products stored in the knowledge base repository	Kilo- or Mega- bytes
		Internal frequency of use of the knowledge base	
Operational knowledge	Internalization and Second cycle of Socialization	External impact of knowledge: *Average number of times that that the knowledge base has been accessed from outside the VCoP*	Number of accesses and Kilo- or Mega- bytes of knowledge products downloaded

impact on the external environment, which can lead to the attraction of new potential VCoP members. People use the new knowledge products downloaded from the O-KMS Knowledge Base Repository to learn about new concepts and apply it directly to their purposes. The value of this indicator can be measured by the use of specialized analytical tools such as Google Analytics™, internal O-KMS database analysis, etc. (Table 1).

3 The INCONET MIRA e-Research Collaboration Tool

Since its official kick-off on January 2008, the *INCONET MIRA "Mediterranean Innovation and Research Coordination Action"* (http://www.miraproject.eu) acts as a seed initiative whose main purpose is to vertebrate, and support a Euro-Mediterranean scientists VCoP by providing a Coordinating Structure (a.k.a. CORE GROUP) of (initially) 28 relevant Euro-Mediterranean Science and Technology Research organizations. Many topics are covered (see Fig. 10) and structured around several Thematic and Horizontal Work Packages (WPs) where in turn, give rise to several online Work Groups (WGs) developed following a role-oriented scheme (see also Fig. 10). In addition, several other WGs have been established following specific demands from the EU-MPC dialogue platform, e.g. the Euro-Mediterranean Monitoring Committee for S&T Cooperation (MoCo) and the Euro-Mediterranean Innovation Space (EMIS). Indeed, INCONET MIRA represents a practical case study about the implementation and adaptation of the discussed

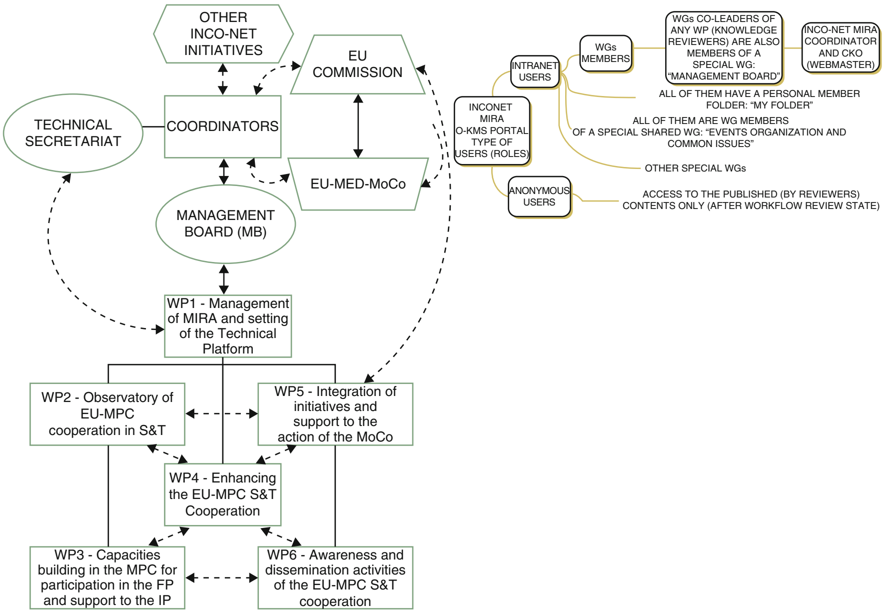

Fig. 10 INCO-NET MIRA knowledge domains and GOVERNANCE WGs (*left*); structure and ROLE-ORIENTED scheme mind map (*right*)

O-KMS framework and the establishment of its corresponding e-Research collaboration tools.

3.1 Preliminary Assessment Analysis and On-going Impact

After one year and a half of existence (2008–2009) the INCONET MIRA still does not define consolidated trends of functioning for the e-Research Collaboration. But, certain common patterns to other research projects using similar O-KMS platforms have been detected after its analysis and the subsequent comparison, for the same period of time, of the indicators values corresponding to the appropriation of the same e-Research Collaboration tool mechanisms by the VCoP members in a similar but, less evolved O-KM Strategy. That's the case of the *MELIA Project "Mediterranean Dialogue on Integrated Water Management"*.

The major goal of this kind of VCoP is the inclusion of all its members in the general O-KM Strategy and a good matching and complementation of their contributions. The inclusiveness of the VCoP relates to its capability to induce the appropriation of the goals and technical tools by its members. It must be noted an evolutionary tendency as the project matures from a very low level of appropriation at the beginning of the project to a sort of "steady state" in the final stage. Certainly, the success of a VCoP will be marked by the full appropriation of all its members in the steady state, but the reality is that the final categorization of users at the mature stage shows us different practice groups defined by the different VCoP members' attitude and the level of appropriation and use of this O-KMS Platforms. To measure this level it has been taken into account a linear combination of:

1. On the one hand, the Socialization indicators, i.e. the *Direct communication links*: expressed as an average percentage of the member's level of attendance and participation respect to the total number of face-to-face events organized by the VCoP.
2. On the other one, the Externalization indicators, i.e. The average percentage of SKAs and final knowledge products created by a specific VCoP member respect to the whole amount created by all its members.

Roughly speaking, five categories can be defined:

1. "*Good* (including *Best*) practice": This group includes those VCoP members that contribute (at individual or institutional level) in *most* (even *all*) of the knowledge tasks, activities and deliverables assigned to them within their WGs, either through the participation in the face-to-face events and the *active use* of the O-KMS Portal.
2. "*Frequent* practice": This group includes those VCoP members that contribute (at individual or institutional level) in *many* of the knowledge tasks, activities and deliverables assigned to them within their WGs, either through the participation in the face-to-face events and the *frequent use* of the O-KMS Portal.
3. "*Increasing* practice": It includes those VCoP members whose activity engagement was intensive in the beginning, then it was stopped for a certain interval of time (a few months) and then it was taken up again intensively.
4. "*Eventual* practice": This group gathers those VCoP members which periodically (for instance, from one month to another) participate in the face-to-face events and make use (at least once) of the O-KMS Portal.
5. "*Trial* practice": VCoP members that tried (at least once) to contribute anything but they did not use the e-Collaboration tools properly or although they showed interest in participating in face-to-face activities, they did it but only in a few occasions.

It worth noting that the different levels of appropriation and the time of "catching-up" are correlated with the heterogeneous background of partners (ranging from farmers associations to university departments) and with the cultural and administrative divide between Northern and Southern Mediterranean Countries. The time until appropriation of the technical tools of the VCoP is a strong factor to be considered in International Cooperation projects.

In the case of MIRA the time-lag for appropriation has been considerably reduced due to three different reasons: (1) the average background in the use of ICT tools was higher, (2) the acquaintance between partners was higher as most of them are official institutions such as Ministries and other public administrations, high level research institutions or companies with international experience, (3) the training in the use of the O-KMS was improved.

4 First Conclusions

This chapter presents a new Organizational KM Strategy and the description of its corresponding e-Research collaboration tools both designed in order to support the different Euro-Mediterranean S&T VCoPs. The experience gained and the lessons learned during the execution of this research have led to a number of interesting conclusions that are summarised below:

(a) The importance of "*Mutual trusting*", based on the notion of "*reciprocity*" instead of "*take but not give*". Note that most WG members within the VCoP move in a "*coopetition*" environment, that is, the cooperating organizations often simultaneously compete. "Mutual trusting" is therefore the essential premise to allow collaboration. It aims to consolidate WGs which may be the "seed" for new VCoPs or other types of social networks initiatives.

(b) "*Users acceptance and appropriation*" of these e-Research Collaboration platforms has not been easy to achieve and it has taken more than 1 year since the initiatives kick-off. Specifically, it is necessary to establish appropriate assistance mechanisms to train VCoP newcomers for learning and using the O-KMS Portal. In that sense, the degree of "*inclusiveness*" of the VCoP members is related to the initial design of the O-KMS, which in turn is based on the O-KMS initial WGs, Governance Structure, etc.

(c) Initial difficulty in "*fostering commitment*" due to the persistence in some organizations of a certain autarchy sentiment, incompatible with an increasingly globalized environment.

(d) The "*complexity of the relationships*" within the international cooperation initiatives, where the different administrative, time management and cultural barriers are the main obstacles to build up sustained e-Research collaboration networks. All these arguments are reinforced after the analysis of the "digital gaps" existing between both sides of the Mediterranean area (Rodríguez-Clemente and González-Aranda 2007).

(e) "*Efficiency of participation*" is in this type of e-Research Collaboration Networks is improved, as it takes less time of the day-to-day activity of their members.

(f) A "*solid but flexible e-Governance Structure*" in the e-Collaborative network is key: solid enough to clearly allocate responsibilities regarding the different targeted objectives; flexible enough to assume an "*adaptive*" practice through the internal monitoring of its work and of the new possible outputs that can redirect the overall goals of the VCoP.

(g) The "*inclusive*" character or will of a VCoP can be measured by the rate of attainment of a high level of use of the e-Collaboration tool by its members, and the increase of "*effectiveness*" of their participation.

(h) Good monitoring and quality control of the knowledge products of the VCoP is essential to guarantee the "*internal and external impact*" of its activities and its sustainability and projection beyond its limits.

In addition, some very interesting new research lines have been opened, comprising not only sociological but also technical aspects. With respect to the latter, it may be noted that the continuous appearance and refinement of new semantic web-based instruments (mainly Ontology driven, e.g. OWL techniques) for the existing e-Research collaboration tools allows the improvement and upgrading of these e-Research collaboration platforms and therefore a continued, effective support of this type of online social networks.

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Appendix. Glossary of Key Terms Used, Their Acronyms and Definitions

Acronym	Key term	Definition
CKO	*Chief Knowledge Officer*	Person responsible for the design, implementation and management of an Organizational Knowledge Management Strategy (O-KMS) aligned to the business strategy of an organization
CMS	*Content Management System*	In general terms, a Content Management System is a computer application used to manage workflow needed to collaboratively create, edit, review, index, search, publish, archive and retrieve various types of digital contents
CoP	*Community of Practice*	Communities of practice are groups of people who share a concern, a set of problems, or a passion about a topic, and who deepen their knowledge and expertise in this area by interacting in an ongoing basis (Wenger et al. 2002)
CVS	*Collaborative Virtual Space*	On-line working area shared by VCoP members in order to develop their PRACTICE activities
INCONET	*International Cooperation NET*	Projects which aim, among other objectives, to foster the political dialogue and to seek synergy mechanisms for the assessment and implementation of effective cooperation policies in S&T research, development and innovation between the European Union Member States (EU-MS) and other World regions (Minch 2008)
LPP	*Legitimate Peripheral Participation*	Knowledge process consisting of how VCoP newcomers are welcome to participate in its Working Groups even if their positions in the social network are peripheral and their contributions marginal (Lave and Wenger 1991)
KM	*Knowledge Management*	A systematic process for acquiring, creating, integrating, sharing, and using information, insights, and experiences to achieve organizational

(*continued*)

Acronym	Key term	Definition
		goals and how to provide a disciplined and organized methodology for constant improvement and development of knowledge domains
O-KMS	*Organizational Knowledge Management Strategy*	Organization's plan for modelling and applying knowledge-oriented resources (knowledge assets and knowledge processing capabilities) in the interest of supporting the organization's purpose. This plan includes, among other activities: (1) To get a compilation of best practices, experiences, and skills (2) To oversee the concept, design, implementation and management of ICT supporting knowledge management (KM), e.g. Intranet, knowledge repositories, data warehouses, Groupware etc. (3) To globalize knowledge management, share and dissemination (transfer) and thus coordinate several existing KM initiatives as well as to measure the value of intangible assets
MPC	*Mediterranean Partner Countries*	The so-called Mediterranean Partner Countries are: Algeria, Egypt, Israel, Jordan, Lebanon, Libya, Morocco, Palestine, Syria, Tunisia and Turkey, where Israel and Turkey are also Associated Countries to the Framework Programme of the European Union
NoP	*Network of Practice*	A type of knowledge-based social network focused on work PRACTICE which may exist primarily through electronic communication (Brown and Duguid 2000; Teigland 2003)
SKA	*Shared Knowledge Artefact*	It provides common resources for VCoP members to focus their collaborative PRACTICE activities and to obtain facilitative feedback from each other about the current state of these activities
VCoP	*Virtual Community of Practice*	A type of knowledge-based social network whose members relies primarily on networked ICT to communicate in order to: (1) discuss problems and issues associated with their day-to-day activities; (2) collaborate on projects; (3) share documents, solutions, or good (and best) practices; plan for face-to-face meetings, or continue relationships and work beyond face-to-face events
WG	*Working Group*	Organizational work structure whose members have to carry out specific tasks, activities and deliverables according to certain time schedules. WGs use to follow a role-oriented scheme

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Wikis in Design Engineering Research

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Abstract Wiki technology has been successfully used for collaboration in various settings. Wikis are, however, rarely used in design engineering research. The authors' research involved studying how design research occurs and how wikis can be used to support it. The authors observed, and report on, several instances of design research where wikis were used. We find that successful application of wikis depends on the software exhibiting certain characteristics. Some of these characteristics include: both WYSIWYG and "raw" editing modes, the ability to edit page elements without editing the entire page, and the ability to comment on or annotate content. To validate these findings, we are developing a new wiki, the intended user community of which are design researchers. While that development is still ongoing, we report early findings here.

1 Introduction

Many researchers have reported the value of wiki software. A wiki is a web application that allows multiple users to create content collaboratively. The look and feel of the wiki is determined by the platform; users structure content in accordance with the look and feel. A key feature of wikis is that it is trivially easy to create links between pages, thus promoting a rich interconnectivity between information. Many popular wikis provide some sort of What You See Is What You Get (WYSIWYG) editing, but all wikis have some kind of shorthand to format content, such as emphasis (for instance, `_text surrounded by underscores is emphasized_`) and section headings (for instance, `==A section heading==`). Some wikis support more advanced structuring such as tabular data,

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macro facilities, embedded spreadsheets, and web forms. Most wikis also support some kind of revision management, allowing errors to be corrected easily, and revision histories to be compared and analyzed.

The rest of this paper is laid out in two major sections. The first will describe the work done in studying the use of wiki technology as a collaboration tool for researchers in design engineering. The second will introduce Xiki and describe how it addresses some of the issues identified from our other work. In 2002, a review of several wiki implementations such as OddMuse (http://www.oddmuse.org), TWiki (http://twiki.org), Kwiki (http://www.kwiki.org), Mediawiki (http://www.mediawiki.org), Tiki Wiki (http://tikiwiki.org), Wikispaces (http://www.wikispaces.com), and MoinMoin (http://moinmo.in/) was conducted. Each offered a different set of functionality. The review considered a target user community of engineering students and faculty members conducting typical research activities in design engineering, which is the authors' speciality. A secondary community of interest were instructors using wikis to deliver courseware, and students using wikis for projects and assignments.

After this exploratory study, it was found that no single wiki platform was suitable. For example, TWiki provided the right level of access control and compartmentalization of content, but the shorthand used was clumsy for non-programmers, and its WYSIWYG was insufficiently robust. MediaWiki, ostensibly the gold standard of wiki engines, required a database back end that our research team was unwilling to administer because of the time and effort that is generally required to maintain the software infrastructure, database, and web services associated with MediaWiki. TWiki does not require such administration support. This would have placed an unacceptably high load on our relatively modest web server.

To verify this finding (a task that is on-going still today), a number of activities were undertaken to elicit input from the user community. The results of those activities to date support the hypothesis that, for the targeted user community, no existent wiki platform was satisfactory. A by-product of those activities was a refined sense of what functionality our users desired most. Key criteria were found to be the following:

- Based on free/opensource software
- Low installation and administrative load on existent platform (Mac OS X/Linux)
- No requirement for external databases
- Preferably based on Perl (programming with which the authors are very comfortable)
- Simple access control
- Ability to treat bibliographic information in a sensible way
- A look and feel that appeals to the targeted user community
- Easy compartmentalization of large chunks of content and
- Simple, intuitive, and consistent syntax (or robust WYSIWYG) suitable for non-programmers, in preference to existent conventions in the wiki community at large

As a result, the it was decided to begin implementing a new wiki engine, called Xiki, that would address the needs of the targeted user community and the problems found to exist in other wiki platforms. Xiki is currently only usable by students of the lead author because it is still under heavy development. Once it is more mature, Xiki will be made available to a much broader audience. The second major section of this paper describes the rationale and details of Xiki in some detail.

2 Studies of Wiki Software for Design Engineering Research

In 2005, we received a Canadian Federal grant to study wikis in combination with concept maps as engineering design tools, and joined a team of researchers in a national research program studying collaborative design tools in automotive engineering. The results of that work are summarized in this section.

Design engineering research is becoming increasingly global and multidisciplinary. The "lone genius" researcher is being replaced by national and international networks of researchers and students collaborating intensively. Time zone differences, disciplinary differences, cultural differences, and the increasing role of teams of graduate students are making easy and accurate communication more important than ever. Wikis could provide lightweight yet powerful tools to facilitate this progression. Incremental content development (Leuf and Cunnigham 2001) and collaboration (Wagner 2004) are key features of wikis and a procedural cornerstone of design engineering research. Wikis also provide a central repository for a project, increasing information integrity, and reducing the computational resources need by participants.

As a research project progresses through the stages of its life cycle, the costs of making changes to the project can rise exponentially, so the decisions made in the preliminary design phases of the project are the most critical (Hyman 2003). By using a wiki to centralize all the requirements, researchers are more likely to make the best possible decisions. Engineering researchers are always looking for the rationale behind decisions, what other options the designers thought about, what they tried and what mistakes they made in the past (Hatamara 2006).

2.1 Graduate Teaching

Wikispaces (http://www.wikispaces.com) has been used for 4 years, in a graduate design course in Mechanical Engineering. Wikispaces is a commercial system that offers free wikis to educators. It has a robust revision management system, WYSIWYG editing, and "plugins" for advanced functionality.

The instructor introduced students briefly to the system, but did not direct them in any specific way regarding its use for their semester-long design projects. To ensure that students were driven to use the wiki, it was stipulated that only the wiki itself would be graded at the end of the semester. The students quickly learnt through practise that wikispaces could be used to capture their personal research notes, share those notes with team mates, collaboratively prepare reports synthesizing their research findings, and carry on asynchronous discussions regarding their work. While no hard data was gathered, it was the perception of the authors that the teams that were able to acclimatize to the wiki and take advantage of its benefits tended to develop the best project results. By organizing the information in a logical way the students were able to better interact with it (Wodehouse et al. 2004).

The greatest difficulty encountered by the students in this course was that authorship was cumulative. While this is generally not a significant problem in small- and medium-sized research teams, students are often concerned of ensuring their work will be properly reflected in their grades. This understandable instinct of self-interest tended to slow adoption of the collaborative nature of wikis. Again, it appeared that teams that performed the best at the end of the project were those who most easily abandoned this self-interested stance.

One other phenomenon noted over the years, was that the most successful cohorts were those in which self-identified student "wiki champions" took it upon themselves to urge others to use the wiki, assumed the role of general editor, and learnt how to use the system well enough to act as a tutor for other students. In those cohorts, we also noticed that the role of the champion became less important as the semester went on and more students became used to the wiki system. It would appear that champions, though necessary at the outset, are not required throughout entire projects if teams include properly motivated individuals.

2.2 Automotive Research

The authors also used another wiki, TWiki in a multi-university research project on automotive research. Originally, the authors had proposed the OddMuse wiki, but within weeks, the users (engineering professors and graduate students) expressed significant disappointment with it. Reasons given for this included: the "unnatural" syntax of the text editor (OddMuse had no WYSIWYG editor); the "clumsy" layout of pages; the "unprofessional" look and feel of the site; and the severely limited ability to represent tabular data. TWiki directly addressed all these problems: it provides a WYSIWYG editor as well as a markup-based text editor, a far better default layout that users thought was more "professional," a facility to alter the look and feel in response to user requests.

All of the problems encountered with wikispaces in ME8101 were also encountered, and similarly overcome, with TWiki in this project.

We noticed two interesting trends in TWiki usage. First, all *new* users to the system uniformly used the WYSIWYG editor, but *every* user eventually migrated to the "raw" editor which required the use of a shorthand notation to structure content, even though the keystroke combinations were sometimes rather obtuse. Users informed us that this was because they found it easier and quicker to type those special characters than to use the mouse to select items from the WYSIWYG toolbar. A few users indicated that they did not "trust" the WYSIWYG and felt that they had more control over their content using the raw editor. In any case, we found that the WYSIWYG editor acted as "bait" for users, attracting them to the wiki and letting them discover its usefulness. That they then tended to switch to the raw editor signifies they had learnt enough to move on to more advanced (and creative) usage.

Second, activity on TWiki increased immediately after a face-to-face meeting of the research team. When we surveyed our users informally, the unanimous response was that the intense collaboration that occurred during face-to-face meetings motivated them to update information and participate in online discussions. This suggests a mismatch between the needs of the users and TWiki's functionality with respect to rapid collaborative exchanges. One significant feature we could not add to our TWiki installation was a capacity to "doodle" sketches and diagrams easily, such that the images could be directly embedded in wiki pages. There was a great deal of doodling during the face-to-face meetings. Another factor that may have influenced wiki usage is that graduate research in engineering is still largely an individual act and not an exercise in teamwork. This is exacerbated by the students being located at different universities, each with slightly different schedules and academic rules.

Some features of TWiki were particularly attractive to the users in this project, none of which were available in OddMuse (at the time the project occurred). The authors have come to believe these are fundamentally important wiki functions for collaborative research.

2.2.1 Change Notification

TWiki has both RSS-based and Email-based notification systems. Most users in this project subscribed to the Email notification; very few used RSS. Each day, users would be notified of pages that were changed, and be given a synopsis of the changes. The Email messages were distributed in HTML, and so included links to the pages themselves. Users could then very quickly navigate directly to those pages to see the changes in more detail, and take actions as necessary. This helped keep users focused on the tool and responsive to changes in the content. Individual pages could also be "watched" by given individuals. Our premise here was that participants working exclusively on, say, automotive brake systems would not need to know about changes to pages in other systems. While this assumption was validated with respect to undergraduate students working on the project, we found that most of the graduate students subscribed to all changes on all wiki pages. We did not discover why this was, but we suspect the graduate students simply had a broader research interest in the project.

2.2.2 Comments

TWiki supports a simple, non-threaded commenting system that allows a user to add comments to a page via a small web form, without having to start an edit

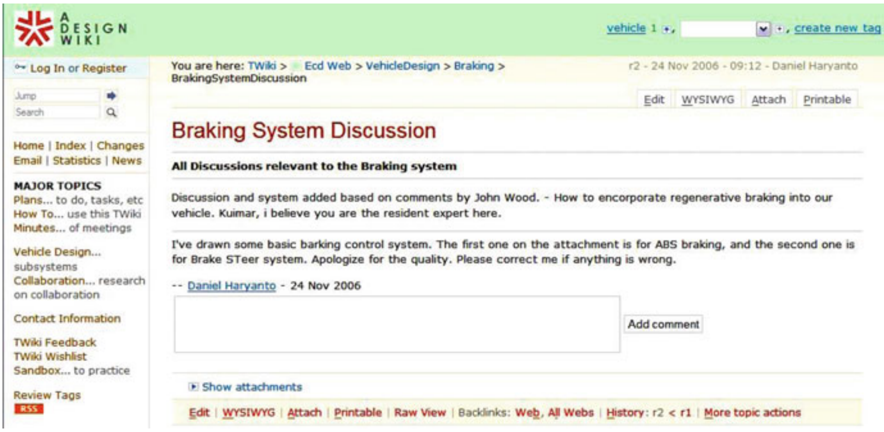


Fig. 1 Sample TWiki page with comment box

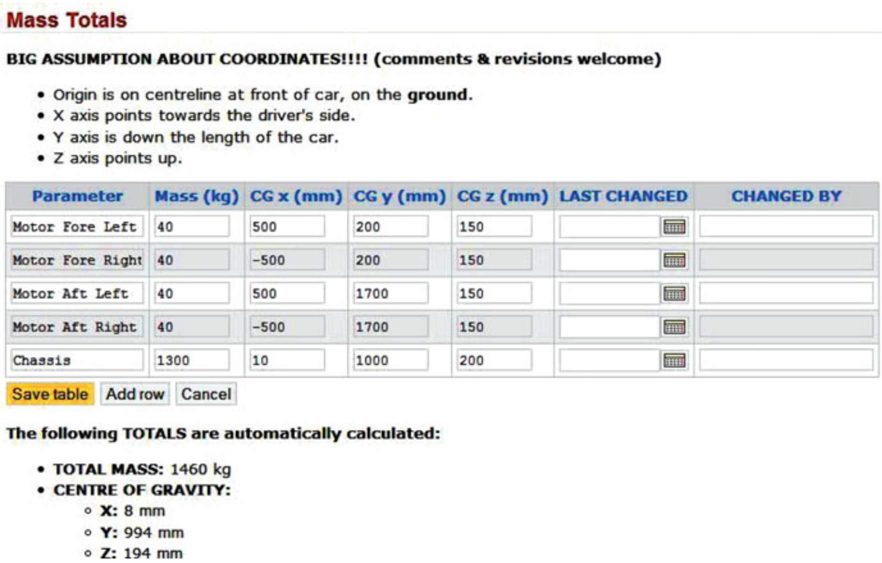
session on the whole page. This allowed users to inject their thoughts – indeed, to carry on discussions – quickly and easily. To simulate threaded discussions, with which most participants were familiar, each thread was assigned a separate page within the wiki. In combination with change notification, comments provided a means to rapidly and efficiently provide feedback to other users and answer questions. An example is shown in the Fig. 1.

2.2.3 Editable Tables

TWiki supports editing tabulated data without having to start an edit session on the entire page containing the table; rows can be added and changed and the table can be sorted using any column as the sorting criterion. One can also pre-fill certain fields; this facilitates automatically adding dates and user names to specific cells. Tables can be a very efficient way of summarizing data. Since this project involved a great deal of data, much of which was updated frequently, editable tables were found to be particularly useful.

2.2.4 Spreadsheet Function

TWiki also supports spreadsheet functions that can be used in any table structure. In combination with editable tables, one can generate interactive spreadsheets that do not require full editing of pages, that are embedded within pages containing all kinds of other information. While the functionality is not nearly as extensive as, say, Excel, our user community found it more than sufficient to build very interesting pages. For example, different student groups were in charge of designing the subsystems of an automobile (steering, drivetrain, chassis, etc.) Each subsystem



Mass Totals

BIG ASSUMPTION ABOUT COORDINATES!!!! (comments & revisions welcome)

- Origin is on centreline at front of car, on the **ground**.
- X axis points towards the driver's side.
- Y axis is down the length of the car.
- Z axis points up.

Parameter	Mass (kg)	CG x (mm)	CG y (mm)	CG z (mm)	LAST CHANGED	CHANGED BY
Motor Fore Left	40	500	200	150		
Motor Fore Right	40	-500	200	150		
Motor Aft Left	40	500	1700	150		
Motor Aft Right	40	-500	1700	150		
Chassis	1300	10	1000	200		

Save table Add row Cancel

The following TOTALS are automatically calculated:

- **TOTAL MASS:** 1460 kg
- **CENTRE OF GRAVITY:**
  - **X:** 8 mm
  - **Y:** 994 mm
  - **Z:** 194 mm

Fig. 2 Example TWiki editable table in edit mode

had a mass "budget" that contributed to the location of the automobile's centre of gravity, both of which were key parameters. We developed an editable spreadsheet table that allowed teams to update the masses and centres of gravity of their respective subsystems, and which calculated the overall mass and centre of gravity of the vehicle automatically. We note that the rather intensive use of editable spreadsheet tables resulted in a rather significant re-factoring (re-organization) of wiki pages. An example of this is shown in Fig. 2.

2.2.5 Page Tags

Each TWiki page can be "tagged" (as in social bookmarking) with distinctive labels. These tags form a network (a set of overlapping hierarchies) of pages. One can browse the tags, generating lists of topics that are similarly tagged (e.g., meeting logistics, minutes, wiki help, etc). TWiki also offers a hierarchical system of connecting pages to their "parent" pages, but we found that tagging was more often used by the participants in this project. This is likely because TWiki's implementation of tags made them easier to use and modify as the wiki changed structure, than did the more rigid parent/child hierarchy.

As the project progressed beyond the preliminary design phases and into a detailed design phase (Louridas 2006), there was a shift from needing to share ideas and documents, to having to share CAD files and simulation data. At this stage, the conceptualizing of the vehicle was finalized and all the emphasis was put on systems design and integration of parts. Some students would be using CAD models of their subsystems to test structural integrity as well as verifying system assembly, while other students would be running simulation software to show drive characteristics.

Many students stopped using the wiki when it came to these complex packages because the amount of data they needed to share was too large. It was as if they were worried that CAD data would "break" TWiki. They would still use the wiki to post progress reports on results gained from simulations of image files on the current state of the CAD design, but the updates would be quite rare. During detailed engineering design, each worker could work in relative isolation on their own assigned parts, but when interaction with others was needed, it was usually urgent because progress on the part design was blocked until the outstanding matter is resolved. Due to the urgency of the situation, users were unwilling to post a question to the wiki and wait for a reply. Thus, communicating CAD and simulation data reverted to familiar tools like email and instant message services. Students would email data files and then discuss them via messaging to optimize the design.

While email and messaging were still powerful methods of communicating and collaborating, no permanent records were captured as a result. This prevented the research team from being able to study the processes that the participants followed, and failed to capture important meta-data such as design rationale.

So, while the wiki was useful in the early stages of a product design, it seems like its applicability for active collaboration diminishes as the project moves to latter stages as it requires synchronous or near synchronous communication for some aspects (Raygan and Green 2002).

3 The Xiki Wiki Engine

To further the use of wikis in research settings, we are also developing a new wiki engine, called *Xiki*, intended to address the issues identified above, as well as other ideas we have developed separately.

Xiki is a Perl-only CGI-based wiki engine that the lead author is developing. Select graduate student researchers and some undergraduates currently use it, but it is not yet available for general download. Xiki can be browsed by anyone at http://deseng.ryerson.ca/xiki/. The version described here is version 0.71.

In addition to the requirements noted in the Introduction, Xiki is being implemented with the following other requirements in mind. These requirements have all arisen from feedback obtained in the study reported above, plus analysis of usage of previous versions of Xiki by the authors.

- A limited macro (variables and functions) capability
- A simple capacity to manage bibliographic information
- A capacity to organize conference and journal calls for papers easily
- Fast rendering of pages

- A particular emphasis on the design of the shorthand – called *wikan* for Xiki – that does not require WYSIWYG but still makes visualizing "raw" content as simple as possible and
- A limited, user-definable way to extend the shorthand

Generally, Xiki operates by applying a series of Perl regular expression substitutions to a single text string containing the unprocessed content of a page. This dramatically improves performance compared to parsing the input string and producing output in "chunks." Of all the wikis we have examined so far, Xiki is the fastest when rendering typical pages. However, this approach does suffer if page content must be created dynamically upon request (e.g., when searching for pages that contain user-supplied keywords) because one must wait for the entire search to be complete before any output is created. However, we have found searching to be of limited use generally, because links between pages guide users to relevant other pages without the need to search.

The authors have not implemented WYSIWYG editing for Xiki for several reasons, the most important of which is that there simply are no schemes available at this time for providing true WYSIWYG capabilities in wikis. While some approximations are possible (as in TWiki and other wikis), any difference between the WYSIWYG version and fully rendered version undermined the whole purpose of WYSIWYG. It would also be a very onerous programming task, since there are no existent web-based WYSIWYG editing packages that can accommodate *wikan*. Instead, we focused our attention on making the *wikan* shorthand as lightweight and usable as possible.

For example, in many wikis that provide a shorthand notation, multiple single-quotes are used to mark bold or emphasized text. This means that in some cases it is necessary to place five single quotes in a row to start bold, emphasized text, and other five to end it. In Xiki, asterisks surround bold text, and single forward slashes surround emphasized (italicized) text; the two forms can be combined to produce bold, emphasized text `*/like this/*`.

Xiki has some relatively atypical features intended to achieve simplicity and usability for our target audience. These features are briefly described below, for the goal of showing how careful, user-centred syntax design can lead to very different constructs than are commonly supported in other wiki platforms.

Xiki supports collections of pages, called *webs* (similar to TWiki), that can be accessed and modified individually. Webs let users partition content into disjoint units by project or purpose. One web contains courseware, another contains private notes and information. For years, each of the lead author's graduate students was given a private space for keeping research notes. However, as these students graduated and left the research team, their personal webs were forgotten by new students, even though the new students could benefit from the information in those webs. New students simply did not think to look in the webs of graduated students for useful information. Therefore, the lead author has begun a process of creating a single web for all his researchers; they will be expected to work together to maintain a "tidy" web, and hopefully, in so doing, will tend to leverage existent information and build on the work of others.

Xiki currently uses basic http authentication. Only registered users can edit pages (modulo other permissions). The anonymous user, called *Guest User*, has very limited access. This is not done to artificially limit access but rather to promote user's customizing their personal spaces and to help ensure proper attribution of content, which is very important in collaborative research contexts. Users can be put into groups, and privileges can be assigned to groups rather than to individuals. There are administrative groups for a given site and for each web in the site. This allows different projects to be managed through a single instance of Xiki, streamlining administration while letting different research groups decide the degree of "visibility" of their projects.

Xiki currently supports only two privileges: browse and change. These privileges can be assigned to an entire site, to individual webs, or to individual topics. We have found this very simple structure to be sufficient for all our research needs to date.

RCS (http://www.gnu.org/software/rcs), an open-sourced and very robust revision control management system, is used to maintain revision histories for every file, including uploaded attachments. While RCS supports both major (i.e., significant) and minor (i.e., less significant) revisions, experience has showed that for our user community, only one type of revision is sufficient. We found that users had a difficult time deciding whether or not a particular revision constituted a significant change in a particular context. For example, courseware pages might submit to a major revision each year and minor revisions otherwise; on the other hand, in the Lenk project (described below), a page revision is major if any new content is added, and minor otherwise. While we originally thought that supporting such flexibility was useful, users have made it clear that it introduces a level of complexity they do not need or want.

Previous versions of Xiki supported *namespaces* similar to those of Mediawiki. Each page could have an arbitrary number of qualifiers that appear as different subpages. Some standard namespaces were built into the system to facilitate the consistent partitioning of information relating to some topic into meaningful chunks. However, after about 2 years of experimentation, we found that namespaces were rarely used, especially since the character set used to name Xiki pages is rich enough to simulate namespaces as part of conventional page names. To streamline the software, namespaces were removed.

Early versions of Xiki supported automatic linking of "CamelCase" words, as is common in many wikis; that is, the occurrence of the string `FlyingButtress` would be rendered automatically as a link to a page titled FlyingButtress. However, we found the syntactic requirements of this approach to be too limiting: single words cannot reasonably be CamelCased, and many kinds of phrases typical in the research of our user community (e.g., "St. Venant's Principle") included non-standard characters that could only be accommodated with great difficulty (given other syntactic constructs in *wikan*). We therefore abandoned the use of CamelCase. Instead, Xiki now uses a syntax similar to that of Mediawiki: strings in single square brackets are recognized as names of other pages. The set of acceptable characters for page links is not arbitrary, and we have found the likelihood that this syntax would conflict with plain content by our user community to be very low (not one case reported to date).

Similarly, bulleted lists in Xiki are lines of text starting with an asterisk and a space. In many wiki engines, one indicates nested lists with multiple asterisks. However, in some common applications, such as email, multiple asterisks usually mean extreme emphasis `**like this**`. In TWiki, bulleted lists must start with non-zero multiples of three spaces followed by an asterisk. In Xiki, any multiple of two spaces signifies a (nested) list item; furthermore, blank lines can appear between bullet list items to improve readability. These minor differences are enough to catch the eye of users, who have commented favourably on the syntax, as easier to read during editing sessions.

In addition to the usual page links described above, a specific syntax is implemented for links to bibliographic entries for the Abib project (described below). Examples of these links are `[Sal00a]` or `[ABC98+]` (i.e., similar to the LaTeX "alpha" bibliographic style). We found this syntax helps users remember specific references mnemonically. To support Abib, Xiki constructs like `[Sal00a]` render as a link to a page in the Abib web named Sal00a (containing information about that work), and constructs like `[[Sal00a]]` are replaced by a complete citation of that work, extracted from the Sal00a page. Thus, constructing a list of references is as simple as creating a list of their Abib identifiers, each in double-square brackets.

Older versions of Xiki supported a tagging system similar to TWiki. However, and contrary to our experiences with TWiki, the current Xiki community has not found keywords useful. Currently, tags are disabled. In the next version of Xiki, following any page link will not only render the page, but also list pages the references that page. Links to pages that do not yet exist will produce lists of referencing pages when rendered (which is essentially what tags do anyway).

In research, it is common to need to inject side-notes, lemmas, or other marginalia. Many wiki engines support some footnoting system, but footnotes (notes at the bottom of a page) require the user to scroll or jump to different parts of a page, which can interfere with the continuity of presentation, and distract the user's attention. On virtual pages, this distraction is unnecessary. Xiki therefore supports *sidenotes* which are rendered as small text boxes that float to the right or left of the main text. Sidenotes can be automatically numbered, flagged with an icon, or have no identifier at all. Sidenotes are specified as text between double parentheses. In combination with Abib functionality, one can write `(([[Sal00a]]))` to create a uniquely numbered sidenote containing the full reference of another work.

One can define macros and abbreviations in Xiki, so that one can abbreviate typing long technical terms with easier abbreviations. Various functions are also available to fetch related pages, search for regular expressions, set off text in various ways, and incorporate various information icons into text. Variables can also be set and used in macros and as parts of other macros. Signature abbreviations of various types are available. For example, ~~ will insert the current user's name, and ~~~~ will insert the user's name, the date, and the time. This is important to facilitate capturing date and authorship information in research notes, especially in collaborative settings.

Wikan, the macro language used in Xiki to structure and format content, is much more complex than has been indicated here. What has been discussed above is only a brief introduction to particular functionality that pertains especially, in our view, to research environments.

4 Xiki Projects

In this section, we describe briefly three Xiki projects aimed to study the use of wikis in design engineering research settings.

4.1 Abib: An Annotated Bibliography System

In Xiki, one may identify a web as an *annotated bibliography* (Abib) web. Each reference work in an Abib web has its own page. Each page contains a citation of the source, the abstract (if available), and any notes by the contributor. Adding a new reference to Abib is done via an HTML form embedded in the Xiki page called `New Reference`. A special module written to support this project provides functionality to construct a new page for the reference, including creating a unique identifier for it in a style similar to BibTex's "alpha" style, from the form's values, as described above.

As of this writing, there are over 1,500 items in the authors' Abib web. It is used as a repository of background literature research used by the lead author and his graduate students. We have found, however, that putting notes about a paper in the page describing the source effectively hides the notes from users. That is, users who do not know there are notes on a specific source, will not think to search for them in the Abib web. In addition, it is hard to *synthesize* an overview of a collection of sources because the notes are in separate pages. Instead, we have found it much more sensible to have only the citation and abstract in the Abib file, and then embed the comments in a living collection of integrated notes in some other web.

4.2 Ded: The Design Engineering Dictionary

The Ded project is intended to investigate the possibility of a single-source "dictionary" of design related concepts in engineering. We intend to develop Ded in a manner similar to that of the Oxford English Dictionary (Winchester 2003). Each new term is given its own page. Authenticated users create pages for new terms when an instance of a term is found in the literature. The definition of the term is not necessarily given; rather, the usage of the term is noted in the form of a quotation from the originating source, plus an Abib reference to the source. As examples of the term usage are added to the page, a working definition is proposed, including possibly many *senses*. The working definition will be developed collaboratively by many users. New usage instances can be added at any time. When sufficient instances are accumulated, the working definition must be revisited and changed as required to remain accurate with respect to all usage instances.

This project is still in its infancy because support for it was highly experimental prior to Xiki. We expect activity to improve in this project over the next 12–24 months.

4.3 Lenk: A Linked Encyclopedic Resource

Lenk is meant to capture general reference information in highly abbreviated form, as well as refer to "best in class" external resources on the web. Lenk can appear somewhat similar to Wikipedia, but we do not claim to compete with it in any substantive way. Lenk grew from the recognition by the lead author and his graduate students that too much structure would make organizing information too onerous. A system was needed to organize information loosely yet meaningfully; Lenk is supposed to address this. Some pages are just bulleted lists of briefly annotated links, while other pages include narrative descriptions of topics with embedded links to other sites, and still other pages are chronological descriptions of events (e.g., "news" about a particular topic). One interesting organizing principle we are developing is the notion of "faces, places, and cases" which divides information into significant contributors (faces), exemplary web sites or other resources (places), and important instances of work done (cases). So far, we are finding that no new functionality needs to be added to Xiki to support Lenk; rather, the organizational structure is a matter only of defining conventions that appear to represent best practises.

We reviewed various social bookmarking and online notebook systems, but found none that were as simple and flexible to use as we would have liked. A tag-like cross-referencing system exists in Xiki (described above), so the basic functionality is available. The research question here is to develop a flexible framework to represent the information that is both easy to browse/search and easy to maintain. We hope to use Lenk to study different ways by which information structures can evolve, rather than defining those structures a-priori. Because we are finding Lenk's structure is practise-based rather than requiring specific software functionality, it may be that Lenk's principles can be used with other wiki implementations just as easily.

5 Recommendations for Researchers

We summarize our research so far in the form of recommendations for groups interested in using wikis in research settings.

5.1 Mandate Wiki Usage

The only way to truly know if a wiki is the right tool for a particular project is to have all participants fully committed to it. If participants already know how to work with wikis, a mandate will be unnecessary. However, many researchers are not yet aware of the collaboration model implicit in wikis and may try to use other tools for actual collaboration, turning the wiki into not much more than a repository of final products. This generally makes group communications more different in the long run and certainly more difficult to *manage*. Mandating strict use of the wiki as the sole tool for information capture and sharing can circumvent this problem.

5.2 Wikis Are Most Helpful for Richly Collaborative Settings

If a research project is based on a strict hierarchy of responsibility, wikis may not help very much. If, however, there is shared leadership and blurred roles, then wikis are perhaps the most suitable tool.

5.3 Allow for A Change of Mindset

Even if intense collaboration is encouraged, relatively few researchers have had experience with it. Give people time to acclimatize to how wikis work.

5.4 Champions Are Essential

Based on the authors' experience, one out of every 10–20 researchers on a team should be a wiki "champion" – a person willing and able to facilitate learning about wikis by the others, and advocating for wiki adoption by all research team members. It is still possible to benefit from wikis without a champion, but progress will be slower. The champion's role is temporary; eventually most team members will know enough to not require the champion's advocacy and assistance.

5.5 WYSIWYG Matters for Beginners

A WYSIWYG editing capacity in a wiki is important for beginners by presenting them with a more familiar interface. However, one should expect users to migrate to more low level – and usually more powerful – editing modes as they gain experience with the system.

5.6 Change Notification Is Important

Change notification is very useful. Virtually every wiki implementation supports change notification by RSS. However, one should survey one's user community to see if such "pull" technologies are comfortable to them. If not, one should choose a wiki that supports email (i.e., "push") notifications.

5.7 Expect Usage to Vary Depending on the Kind of Content to be Stored

If specialized data is to be stored – such as CAD models – one should expect wiki to usage to drop unless measures are taken to ensure that such data can be safely stored and easily accessed. For sufficiently large research projects, there is the possibility of developing one's own plug-ins to augment the functionality of many of the open source wiki's to enhance functionality. However, such software development must be managed to maintain focus on the actual research goals.

5.8 Discourage Private Collections of Information

To help develop synergy in the team, discourage wiki users from keeping notes and other data in "private" areas. This information will tend to get "lost" and is less likely to be fully integrated into the research. Encourage or mandate that all information be collected, synthesized, and integrated as it is developed into a single collection.

5.9 Recommendations for Wiki Implementations

Because wiki technologies are evolving rapidly, it is important to assess which wiki implementation is best suited for a research project as close as possible to the start of work. The information presented here may quickly become dated, but based on our experiences we recommend two wiki implementations.

- *Wikispaces.com*. If facilities and system administration are not available to the research group, we suggest wikispaces be considered seriously. It provides the most simple interface, and the most robust and broad level of functionality.
- *Foswiki.org*. Foswiki is a recent re-implementation of the TWiki wiki, which has demonstrated itself, in the lead author's opinion, far more useful than its

predecessor. If one has the facilities and manpower to host one's own wiki, Foswiki is the best of the available implementations.

6 Conclusions

This article has discussed the use of wikis in engineering design research, and briefly described a new wiki, Xiki, being developed particularly for engineering design research support.

From the projects discussed early in the paper, it is evident that wikis have a limited but potentially powerful role in an engineering design research setting. The greatest hindrance to their usage seems strongly related to the attitude of the user community: wikis appear to be very helpful only if adopted voluntarily by the majority of a user group. This phenomenon did not seem to have anything to do with the nature of the wiki as all the participants found it adequate for meeting their basic needs. There may have been residual hesitation based on unfamiliarity.

Sometimes, users' comments must be taken with some reservations. For example, users initially disliked the text editor in Oddmuse strongly. However, after using TWiki's WYSIWYG editor, users tended to return to its text editor, which was essentially the same as that in OddMuse. This was not due to particular problems with the WYSIWYG editor, but rather a matter of familiarity and efficiency: once users became accustomed to the wiki, users saw the WYSIWYG editor as more complicated than the text editor. So, were the users right to so roundly dislike the original text editor?

We have noted a few possible trends in wiki usage among engineering designers (and probably similarly educated groups). We will continue to examine usage patterns of wikis in our user communities, to determine the veracity and details of these trends.

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Shifting the Research Grant Collaboration Paradigm with Research 2.0

Andrea Duffy

Abstract The research environment is changing rapidly. Scarcity of resources and the need for broader collaboration among researchers has brought about increasing innovation in online research tools. MyNetResearch and other tools provide the online collaboration capabilities to universities seeking more efficient ways to find and win new funding. Universities which are ready and willing to ramp up quickly with new technology options and apply for grants leveraging Research 2.0 – research collaboration enabled by Web 2.0 – will have an advantage over competitors and even better funded institutions for the same grant funds. The objective of this chapter is to examine this new research paradigm. The main contribution is to make researchers fully cognizant of the importance of Web 2.0 and how to exploit the opportunities created by this new environment to gain competitive advantage with particular emphasis on finding a more efficient and effective process for (a) finding new grants, and (b) winning new grants.

1 Introduction

For universities, funding is especially important in today's competitive environment. From the growing number of workshops, mentoring programs and other initiatives designed to promote and enhance academic grantsmanship, to the announcements, publications, and events showcasing departmental, faculty, and/or university research success stories, researchers hardly pass a day without some message to apply for grants. Indeed, it's been suggested that the old imperative to "*publish or perish*" is being displaced by another – "*provide or perish*". The energized grant giving environment has inspired a more energized funding proposal environment as

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well – opening up new levels of competition and opportunity between research institutions for grant funding.

The prototypical model of research grant collaborations has been relatively closed with collaborators being functional silo-based, and lacking connections and interactions among departments, colleges, and universities. The emergence of Web 2.0 technologies has sounded the death knell for this closed model of research collaboration and the emergence of an open, collaborative model. Web 2.0 breaks down barriers and allows researchers to collaborate with other researchers well beyond the borders of department, discipline, university, and country. This new paradigm will change the model of research grant collaboration from a typically closed model to one that is more open and broad and is based on collaborations of expertise, rather than collaborations of convenience.

This shift in paradigm is clear when one examines how the advent of Web 2.0 technologies has led to the creation of new social networks, such as Facebook and LinkedIn. These social networks have dramatically reduced the barriers and obstacles of people interacting with each other across the world. However this shift of paradigm is just beginning to emerge in research collaboration. In a recent study, Anandarajan et al. (2009) reported that little over half of researchers surveyed had never used or were not familiar with Web 2.0 technologies from a research context. Furthermore, the study reports that researchers reported issues such as managing collaborators, transmitting information, and finding collaborators as the major hindrances to their research grant collaborative efforts. In this chapter, we propose that universities will need to adapt themselves in order to prepare for the paradigm shift of Research 2.0. This shift in paradigm will bring about low-cost cyber infrastructures and overall competitive advantage to research institutions.

2 Driving Forces of Web 2.0

The emergence of the Internet (Web 1.0) increased the speed of communication between research collaborators. Web 1.0 was the earliest form of the web, which typically featured static content or database content from catalogs that were presented to the user, but with little user-provided content possible. The emphasis of Web 1.0 was "publishing" content onto the web for the users, not user-provided content.

While Web 1.0 revolved mostly around e-commerce, Web 2.0 technology builds on the increased speed of communications and focuses on encouraging user participation. Collaboration was the inevitable conclusion of this rapid paradigm shift, as users sought out like-minded individuals with whom to collaborate.

The key aspects of Web 2.0 are interconnectivity and interactivity of web-delivered content. As shown in Fig. 1, there are five forces which drive Web 2.0 technologies and these are discussed below.

(a) User Generated Content refers to any material created and uploaded to the Internet by non-media professionals. This includes user comments to a research

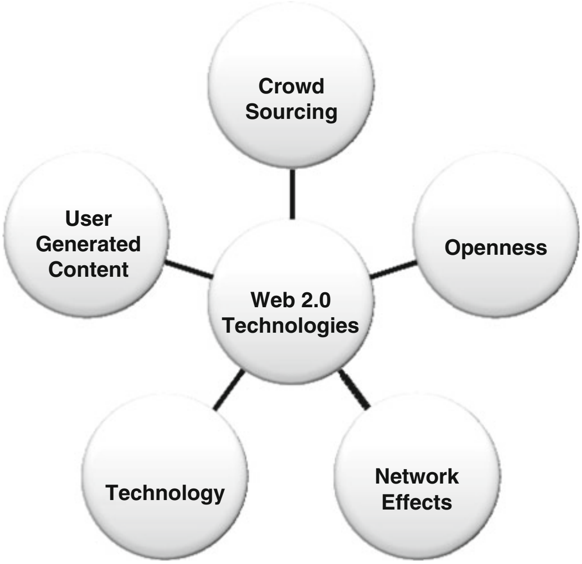

Fig. 1 Driving forces of the Web 2.0

forum or a research video uploaded to YouTube, or a professor's profile on MyNetResearch. User-generated content is now one of the fastest growing forms of content on the Internet. It fundamentally changes how individuals interact with the Internet, and how advertisers reach the market.

(b) Crowdsourcing occurs when an institution takes a function once performed by employees and outsources it to an undefined and generally large network of people in the form of an open call for proposals. In crowdsourcing, the *crowd* is the collection of users who participate in the problem–solving process. Since it takes place through the Web, the participants comprise Web users i.e., of individuals or organizations that posit solutions to the problem. It is in this composite or aggregate of ideas, rather than in the collaboration of individuals, where the strength of this Web 2.0 lies. According to Surowiecki (2004), under the right circumstances, groups are remarkably intelligent and are often smarter than the smartest people in them i.e., collective intelligence.

(c) Openness has its foundations in the open source software development communities. According to O'Reilly (2003), these communities organize themselves so that barriers to participation are lowered and a market emerges for new ideas and suggestions that are adopted by popular acclamation. The most successful Web-based services are those that encourage mass participation and provide an architecture featuring ease of use, toolboxes etc. that lower barriers to participation. As a Web 2.0 concept, this idea of opening up collaborations and encouraging participation goes beyond the open source software idea of opening up code to developers, to opening up content production to all users and exposing data for re-use and combination in mashups. A mashup is the result of combining data from different sources. It is comprised of three parts: (1) the *content provider* – who has the data and makes it available through Web services, (2) the *mashup* site that uses data from different content providers to create a new service, and (3) *client web browser* that helps to mashup content using client side scripts.

(d) Network Effects is a general economic term used to describe the increase in value to the existing users of a service in which there is some form of interaction with others, as more and more people start to use it (Klemperer 2006). The concept is commonly used when describing the extent of the increase in usefulness of a social system as more and more users join it. For example, as a new person joins a social networking site, other users of the site also benefit. Once the network effect begins to build and people become aware of the increase in a service's popularity, a product often takes off very rapidly in a marketplace. Given the social nature of Web 2.0 technologies, they rely heavily on the network effect for their adoption. Indeed, the major reason for joining a research collaborative website is the network effect, i.e., having access to other researchers.

(e) Technologies contribute to Web 2.0. On the hardware side include such developments as pervasive broadband, especially within developed countries where the majority of users now possess broadband connections. These enable the use of graphics-rich user interfaces that characterize Web 2.0 websites. Others include weblogs or blogs, wikis, podcasts, RSS feeds, social software, and web application programming interfaces (APIs). These Open APIs – with "Open" signifying their availability to anyone – allow other developers and even users, to develop their own applications or "applets" that can work in concert with Web 2.0 websites.

3 Web 2.0 + Research = Research 2.0 Portals

There are a number of Web-based services and applications that demonstrate the foundations of the Web 2.0 concept, and they are already being used to a certain extent in research. These are not really technologies as such, but services (or user processes) built using the building blocks of the technologies and open standards that underpin the Internet and the Web. These include blogs, wikis, multimedia sharing services, content syndication, podcasting and content tagging services. Many of these applications of Web technology are relatively mature, having been in use for a number of years, although new features and capabilities are being added on a regular basis. It is worth noting that many of these newer technologies are *concatenations*, i.e., they make use of existing services. However, while Web 2.0 technologies have dramatically changed the way Internet users manage social relationships, for example one need only look at FaceBook with its 350+ million users to understand the transformation, the same cannot be said from a research perspective. It is a natural extension that research relationships are evolving through the use of Web 2.0 features in research networks (Gambadauro and Magos, 2008). This collective intelligent computing network is called Research 2.0.

Anandarajan et al. (2009) states that Research 2.0 is the unifying term of:

- Researchers, who interact socially as they strive to satisfy their own research needs and have a shared purpose, such as an interest, need, information exchange or service that provides a reason for the community.
- Policies, in the form of tacit assumptions, rituals, protocols, rules and laws that guide collaborative interactions.
- Web 2.0 technologies which support the research activities of the collaborators.

Research 1.0 has transformed into an integrated online collaboration management network in a short time. The evolution to Research 2.0 is clear as shown in Table 1 below:

Research 2.0 portals provide a holistic project management platform for researchers. Many universities have wikis, blogs, online forums, chat, and document management. The goal of Research 2.0 is to provide all of these research management tools in one integrated platform that is accessible from anywhere at any time simply by logging on. This implies the elimination of problems previously experienced such as misplaced documents or versions of documents, carrying of heavy briefcases for conferences, and more clarity with respect to task management among the research collaborators. Research 2.0 portals also utilize elements from social networking. These social networks introduced user forums, searchable professional profiles, and communication. Blogging also makes a natural addition to the research environment, where researchers share their professional experiences and ideas. Networking tools also contribute meaningfully to portals for research collaboration, through contact management, referrals, and communication. Thus, Research 2.0 shifts the paradigm of research collaboration from *one of convenience to one of opportunity*; by bringing about a complete transformation of the current conduct of research and major productivity gains.

There are some prime examples of the emerging class of Research 2.0 research portals for the academic and industry community The major web portals in this new genre include Intouch, MethodSpace, ResearchGate, and MyNetResearch. MyNetResearch is the leading Research 2.0 portal in terms of functionality

Table 1 Impact of Web 2.0 on the research process

	Research 1.0	Research 2.0
Knowledge sharing	Search engines	Customizable news alerts, RSS feeds, Blogs, Wikis and other news aggregates deliver grant opportunities directly to the user
Communication	Emails	Integrated communications for research teams
Research management	–	Centralized dashboards, project audit trials, and task lists
Research tools	–	Expert system based decision aids
Document management	Track changes (MS word)	Version controls and other audit tools integrated into projects
Collaboration	Calendar requests	Real-time collaboration and integrated communications tools

and features. An integrated project management and global networking tool, MyNetResearch was created by researchers for researchers and has served an unmet need in the market by breaking down the barriers of collaborations of convenience and networking researchers in a searchable database where collaborations can be made based on discipline, geography, or other interests.

4 Grant Collaboration with MyNetResearch

Universities around the world compete daily for grant funding. Collaborating with the best researchers for the project are critical elements of obtaining research grants. Research 2.0 online collaboration management tools, available to all universities, help many researchers continue their work including starting new and potentially ground breaking research, and funding the future of their disciplines. Research 2.0 tools such as MyNetResearch are designed to help researchers both write the grant and provide the needed cyber infrastructure requirements to be eligible for the many grants being awarded.

Collaboration management is a mature solution to help researchers seeking new grants to level the playing field when competing with better-funded research institutions or stay ahead of the competition. Online collaboration tools provide an integrated, start-to-finish solution to help universities through the entire grant writing process, even if members of the team are located across campus or around the world by supporting researchers in three critical stages: research management, research networking, and research awareness, as shown in Fig. 2 below.

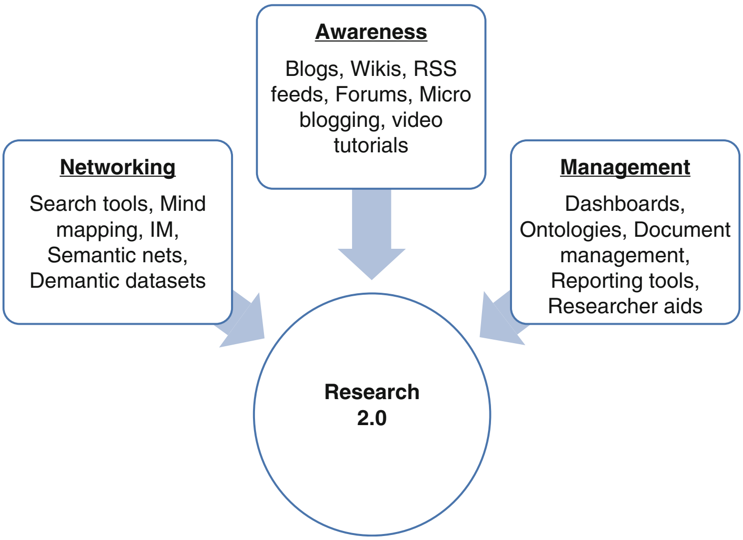

Fig. 2 Integrated components of research 2.0

Research 2.0 can help researchers in three aspects of the research grant collaboration process:

1. Research Awareness: This is where researchers learn about new ideas, work done by other researchers etc. The tools used for such awareness include, blogs, forums, RSS feeds.
2. Research Networking: Once a researcher thinks of the idea, they need to find a team. Research 2.0 helps by providing the social networking tools. Here we can discuss the Find a Researcher functionality.
3. Research Management: Online collaboration management is a new paradigm in project management. From emails and multiple versions of documents to an integrated collaboration management system – research management allows collaborators to manage complex grant projects from anywhere at anytime.

4.1 Research Awareness

How do researchers learn about new ideas and work being done by other researchers? Research 2.0 tools including blogs, forums, RSS feeds, connect countless researchers with their like-minded colleagues around the world. Awareness of new ideas and the empowerment to communicate is bringing the practice of research in to new territory – and has the potential to increase productivity and generate new ground-breaking results.

MyNetResearch and similar tools provide a global platform to raise awareness of researcher's work and ideas. To date, more than 12,400 researchers in 70 countries have connected through MyNetResearch tools including interactive blogs (Fig. 3) and forums (Fig. 4).

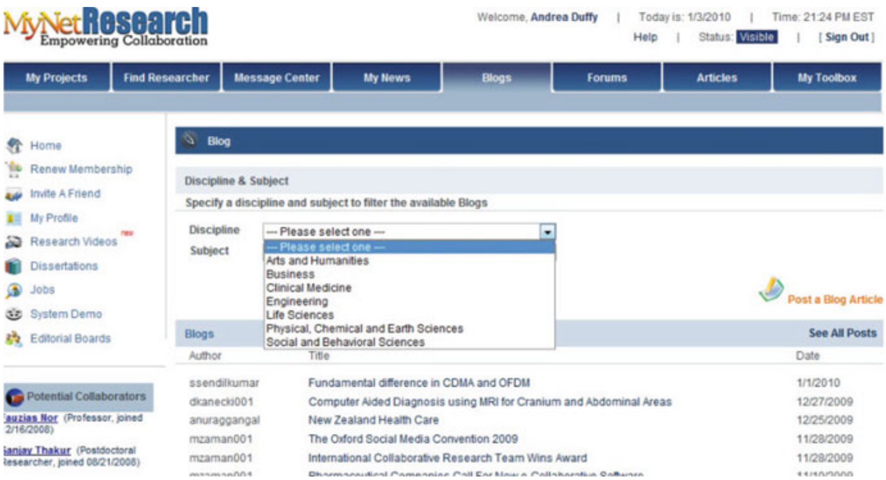

Fig. 3 MyNetResearch blogs provides user-generated content that is searchable by discipline and subject matter

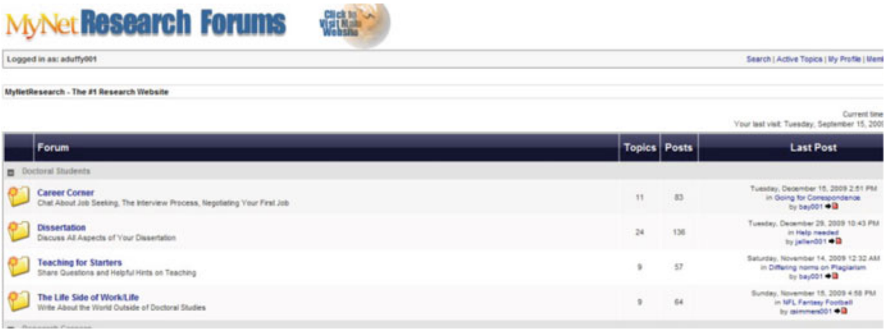

Fig. 4 MyNetResearch forums provide articles and papers on timely subjects that are important to researchers in the global network

Finding a researcher or research project is a two-way street. Direct outreach to a fellow researcher, found in a search of the MyNetResearch network, is one way to begin the process of developing a new research team. Participation in the network is another way that researchers can learn about what is going on in the research network, reach out to fellow researchers to inquire about new projects, and even find new opportunities to publish and win grant funding.

Wikis, blogs, and forums – all standard features of Research 2.0 networks such as MyNetResearch – allow researchers to "see and be seen" globally. In a growing network of 12,000 researchers, MyNetResearch is a good example of how the network and Research 2.0 tools bring together researchers in the most efficient way.

For example, consider a Washington, D.C.-based researcher wishing to find a new, funded project that will enhance the profile of the University and the discipline. This researcher, a member of the MyNetResearch community, can simply log on to the network and check his aggregated news items, delivered directly to his/her inbox based on previously determined criteria for news delivery.

Through the network, information is delivered to this researcher that provides details of a new project being pursued in Mumbai. The D.C.-based researcher reads about the grant opportunity his Mumbai colleague is pursuing and the new project he is proposing. Further news items found in the MyNetResearch users forum show that the topic is being widely pursued and the competition may be quite intense. The two researchers, although they have never met or worked together before, are directly linked through their mutual membership in the MyNetResearch network and similar research interests. A simple email from Washington, D.C. to Mumbai, India through the email functionality in the MyNetResearch program allows the two researchers to discuss their goals, competencies, and availability, and successfully develop a new collaboration. The Mumbai researcher also knows of a colleague in London who is also keen to contribute. The two members reach out once more to the researcher abroad in the UK, and form a research group.

Once the group is formed, information and prior research will help this new global team, and other teams in the network, to complete their projects. MyNetResearch integrates collaborative project management tools with communications tools to create a fully integrated Research 2.0 platform including blogs, wikis, and forums, which are open to any member at anytime. These tools enhance the process of grant writing and research while also strengthening the community overall by building on the cache of resources available to all 12,000 members of the MyNetResearch community. Researchers who participate in forums, comment on blogs, contribute to wikis, and so on are far more visible to the community at large as well, which often leads to more invitations to new projects and gives the researcher first run at the best projects going on around the world.

Researchers working on grants can also cite specific research relevant to the proposal. Once the project is completed, a database of publications from every imaginable discipline streamlines the publication process. Finally, once published, researchers can track how often, when, and where, their findings have been cited in the works of other researchers.

The maturity of Research 2.0 has risen rapidly. Not long ago, researchers had access to diverse grant information and availability with just a few clicks. Today, researchers can access that grant information, build a research team, write a grant application to conclusion, all the while tracking the project's progress, assign tasks to teammates, and manage deadlines. The fundamentals of Research 1.0 matured to create Research 2.0 in short order, but expanded the opportunities for researchers to identify and compete for grant funding incrementally with each new participant. Considering the rate of relevance to the profession and the potential it provides, implementing Research 2.0 today could help research institutions prepare for future innovations in online collaboration management, which may arrive sooner than we think.

Research 1.0 has transformed into an integrated online collaboration management network we now know as Research 2.0 in a short time. Today, research projects and researchers are visible to a global community of likeminded individuals who may be potential collaborators. As time goes on, Research 2.0 may become a key criterion for researcher communication and collaboration and universities which are not ready to be left behind.

4.2 Research Networking

Global collaboration is often compared to social networking, and although they are related, they are not the same. Collaborative management tools, including Research 2.0 tools such as MyNetResearch, are designed to enhance the existing workflow of researchers by incorporating communication, file sharing, file access, and research tools in one integrated platform.

For example, a researcher in China is working on a project that could potentially diagnose cataracts sooner. The research will require several experts in multiple fields. How can this researcher put together a team of professionals who are willing and able to participate in the research collaboration process? With MyNetResearch, a researcher in any discipline need simply log on to the network to get started. Simple search tools allow users to search for collaborators by location, discipline, expertise, availability, and other criteria. Integrated chat and other messaging tools allow the user to announce a new project idea and wait for responses or simply email researchers directly anywhere in the world and request their participation in the new project. Once a team is established, as we learned earlier in this chapter, version tracking and other document management tools allow all team members to stay up to date on the latest findings from the team.

Finding a researcher is always a challenge. However, Research 2.0 technology allows researchers to not only find the most appropriate collaborators, but to also feel confident that collaborators around the world can work together efficiently and effectively to achieve the goals of the project.

So, although Research 2.0 is not social networking, the fundamental social networking paradigm is the essence of the new research collaboration. Research networking is special in that it generates the kinds of ideas through collaboration that can change the face of science, humanity, and/or technology. Therefore it is essential for universities to seek out Research 2.0 platforms built with research collaboration in mind.

Researchers collaborating through the Research 2.0 environment can communicate and collaborate from thousands of miles away as if they were sitting side-by-side. Integrated, mature networking tools such as message centers and instant chat allow ideas and collaborations to occur at anytime from anywhere. Deadline changes, new team members, progress reports, document reviews, and much more can be communicated to the team instantly. Chat should also be part of any collaboration. Chat has become an essential business tool, and research is not far behind.

4.3 Research Management

The current time is opportune because the United States government has set aside billions of dollars to fund scientific and other forms of research with the goal of bringing the nation to the forefront of research and discovery. Leadership in research is a priority of many countries right now and will not only help bring needed funds from around the world to the nation which achieves top marks, but aid in its global competitiveness and economic growth.

The tide will surely change throughout the competitive grant writing marketplace. Where the government goes, so too will philanthropists, foundations, and other grant awarding bodies that appreciate the value of collaboration to achieve research goals.

To drive the goal of collaboration, many grants, especially those deriving from the U.S., are awarded based on a University's ability to network with researchers involved in multiple disciplines, from multiple research institutions, and in some cases from more than one country. This broad thinking in research and development to solve societal issues and bring national economies into the modern age requires an infrastructure which will break down the traditional barriers of collaborations of convenience – those collaborations formed simply because fellow researchers are in the same laboratory or facility – and open up a new world of optimal collaborations without boundaries.

Research 2.0 can help researchers achieve remarkable results. But how does a university get started?

The matter of managing the grant process can be easily addressed with the right tools. Research 2.0 tools are available for a low cost to easily connect teams using resources to manage this process, create a paper trail, and collaborate across disciplines, universities, and geographical borders. MyNetResearch, one of the largest online research communities, combines the benefits of social networking with the necessity of project management – delivering Research 2.0 to the grant process.

To get started, first a team must be established. Continuing the example of MyNetResearch, users can easily search for potential team members to help work on this grant proposal by plugging the required criteria into the platform and searching for a list of possible collaborators. Automated tools such as "Invite" or "Email" allow users to easily invite researchers to be part of the process.

Working with remote or unseen collaborators is a big part of the new paradigm for researchers. However, effective collaboration does not require researchers to be in close proximity. The key is to find an online research community that understands the needs and processes of research professionals. MyNetResearch has several functions integrated within its system that allows researchers to:

- Manage team assignments by tracking versions
- Track progress of the project against deadlines
- Manage all files, both public and private.

The critical benefit of these tools is that they are fully integrated and create a one-stop-shop which provides start-to-finish support for any grant writing project.

Research 2.0 eliminates any reason why a University should not pursue new funding. Online collaboration management tools such as MyNetResearch provide access to up to the minute research ideas, direct contact to the best and brightest researchers in every discipline in more than 70 countries, and integrated tools to help manage projects from idea development to grant award. The only challenge universities face today is how to change the paradigm of research collaboration.

5 Guidelines for Selecting Research 2.0 Portals

Universities must broaden their research collaborative networks to ensure communication and collaboration between departments, disciplines, colleges, universities, and even companies. Evaluating and selecting a Research 2.0 portal requires both a complete assessment of the research needs of the university and a direct comparison of portals to determine which technologies best suit the needs of the researchers.

As Subramanyam (1983) points out, there are many types collaborative relationships. Thus, a research institution needs to assess its stakeholder's needs in order to begin evaluating research 2.0 portals. The different types of collaborative relationships include:

- Size of the team; number of researchers
- Various disciplines and levels of expertise within the team
- Various locations involved including: inter-University, intra-University domestically, or intra-University locally or on a global basis
- Group dymanic – is the team global, part of a university or group of universities?

Once the research institution understands its research collaborative requirements, the next step is to understand how a research portal can enhance its competitiveness in terms of research grants. Collaboration has become a priority for many funding agencies, with the goal of breaking down the barriers of traditional silos to address complex research issues. Successful collaboration will be contingent on the following:

- Is the Research 2.0 platform appropriate to the research community? What it built with researchers in mind?
- Are researchers able to collaborate with labs that have different resources?
- How easily can researchers find qualified and competent collaborators?
- Can researchers access up-to-date documents from anywhere at any time?
- What data points can the university provide when applying for research grants to prove cyber infrastructure?

Research 2.0 portals provide individual licenses where researchers can sign up independent of a university in order to initiate new projects with the benefit of having access to a global network. The open network environment is useful, but does not ensure that universities students and faculty have across-the-board access to the same network and the same functionality. It also does not ensure consistent membership in the network by each individual in a way that helps universities consistently tap global collaborators and stay competitive. MyNetResearch provides research institutions with their own private Research 2.0 cyber infrastructures. These cyber infrastructures can help universities guarantee collaboration resources to their stakeholders and compete effectively with better-funded universities without spending millions on new research buildings. The added benefit of providing demonstrative cyber infrastructure capabilities also helps maintain a research institutions grant-competitive edge.

With the aid of Research 2.0 based cyber research infrastructures, universities can unleash the synergies of research collaboration and enhance their chances of obtaining research grants. Where once larger and better funded universities would likely win grants that require certain technology standards, today's affordable, secure, and easily implemented Research 2.0 infrastructure helps all universities to compete. For example, in 2008, 214 grants were awarded to Universities for the purpose of research, totaling nearly $US45 million.[1] Research project funding received 54% of that total.[2] Universities of varying sizes and available resources have received the funding, but one thing they all must have in common was the existence of a cyber infrastructure. It is, in a way, the most important competitive resource a university can secure in the current grant award winning marketplace.

A major US University recently proposed MyNetResearch based Research 2.0 portal enhancements to existing research structures. The university and research institution's goal was to bring together its researchers and others to maximize funding opportunities, promote and support new research projects, all while encouraging the formation of collaborative and multidisciplinary research groups. This proposed cyber infrastructure will lie beyond any that currently exists and stretch the frontiers of what future research infrastructures will look like.

6 Conclusions

Today, research grants and technology go hand-in-hand. Research 2.0 is not only becoming the norm among many researchers, it is becoming a priority among research universities and the bodies that award research grants. Using Research 2.0 as a research grant collaborative tool can help researchers:

Identify Opportunities: Research 2.0-based systems will enable researchers to identify opportunities for collaboration in research and research funding within and external to the University. This would include such activities as identifying funding bids and academic-industry partnerships, and participation in major international research consortia. For example, Lincoln University's School of Social Sciences and Behavioral Studies, in collaboration with University of Pennsylvania and ten community-based organizations, proposes a Virtual Research Infrastructure to conduct research on community health related issues. The MyNetResearch based infrastructure will bring together professional researchers in Health Policy with those in Clinical Medicine, and Community based organizations in an innovative form of research organization that will be an example for other consortia to follow.

Breakdown Silos: Research 2.0 will provide interconnections between the different centers of research across the University, as well as connections with other researchers who may be able to contribute in an interdisciplinary way to research initiatives outside their departments.

Provide a low cost Cyber Infrastructure: Given that many universities lack the advanced laboratories available at better-funded institutions, Research 2.0 provides a prime opportunity for research institutions to level the playing field versus more

[1]Source: NIH Report online. http://report.nih.gov/reportsearchresults.aspx?refUrl=index&sS=&sI=&sP=2&sM=9,10,11,12,13,14&sA=&sD=&sV=&sY=

[2]Source: NIH Report online, R21s, Research award size and Research Project Grants (ppt). http://report.nih.gov/reportsearchresults.aspx?refUrl=index&sS=&sI=&sP=2&sM=9,10,11,12,13,14&sA=&sD=&sV=&sY=

financially endowed universities. The lack of advanced brick and mortar research facilities has eliminated one of the fulcrums needed to become a research leader. Research 2.0 will dramatically change that.

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Doctoral Programs in the Age of Research 2.0

Maliha Zaman

Abstract This objective of this chapter is to examine the impact of Web 2.0 on the doctoral program. PhD students face different challenges relative to doctoral students of even a decade ago. This chapter deals with the challenges the students face with particular emphasis on the challenges posed by the necessity to deal intensely with electronic research and to collaborate in an electronic based environment. The characteristics of present day doctoral students (referred to as generation of Gen Y, i.e., those born between 1982 and 2000) are discussed. This chapter then deals with the five key forces that drive Web 2.0. The chapter proceeds to provide an overview of how these forces impact and impinge on the process of going through a doctoral program. The author develops a matrix of which aspects of Web 2.0 PhD students need to be conversant with at each stage of the doctoral program. Illustrative examples are provided for clarification on the issues discussed.

1 Introduction

According to the generational school of thought it is important that organizations recognize the influence and work preferences of different generations to be effective in the future. Generation Y (Gen Y) is the most technically literate, educated and ethnically diverse generation in history (Eisner 2005). Universities have considerable interest not only in attracting, and retaining this talent but in developing it as well. Evidence suggest that Gen Y graduates places a great deal of importance on personal development and continuous learning (Terjesen et al. 2007). Whilst there

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has been research into the pedagogical challenges of teaching Generation Y and the strategies needed to enhance their learning (Shih and Allen 2007), these have not focused on the doctoral program. Gen Y doctoral students will enter the program in the age of Web 2.0 technology. Most of their will be familiar with this technology and will likely expect to meet some of the challenges using such technology. The author of this chapter offer the paradigm shift needed to support the demands of Gen Y. Core advice given by Mills (1959) in the twentieth century is applied here to the demands of intellectual craftsman of the twenty-first century.

The chapter begins by examining the characteristics of Gen Y'ers, and their likely expectation upon entering Academia. This is followed by an overview of the developmental phases of a doctoral student. The remainder of the chapter examines the impact of Web 2.0 on the doctoral program and the lives of its students. The last section provides readers with example of Web 2.0 at work using an established online research collaboration site – MyNetResearch.com.

2 Who Is Generation Y?

Generation Y is the term used to describe the demographic group whose birth year falls between 1982 and 2000. As more and more of this generation enter the workplace, it is increasingly obvious that they possess different characteristics and expectations from the preceding generations in the workplace (Glass 2007). A review of the academic literature attributes a number of very specific characteristics to Generation Y. These include, being tech savvy, (i.e., at ease with the digital world), and continually wired to digitally streaming information, entertainment, and contacts (Eisner 2005). Gen Y'ers are described as confident, independent and individualistic, self reliant and entrepreneurial (Martin 2005) and at the same time socially active, collaborative, team oriented and used to having structure in their lives (Glass 2007; Shih and Allen 2007). This structure manifests itself in a desire for clear directions from their managers about assigned tasks. There is however, "a demand for freedom and flexibility to get the task done in their own way, at their own pace" (Martin 2005). Furthermore, despite being independent they are viewed as being emotionally needy and consequently, constantly seeking approval and praise (Crumpacker and Crumpacker 2007). Gen Y are capable of multi-tasking (Freifield 2007), are result-oriented and have an appetite for work (Shih and Allen 2007) and above all expect to be empowered (Morton 2002). They seek work life balance and if forced will select family and friends over work (Crumpacker and Crumpacker 2007).

In summary, Gen Y'ers constantly seek opportunities to learn and grow professionally (Eisner 2005) and look for challenges and meaningful assignments to be far more important for their self development than lifelong employment (Baruch 2004) Given these characteristics the next section explores the implication on doctoral programs.

3 Generation Y in Academia

The indisputable characteristic differences between Gen Y and their predecessors suggest that Gen Y'ers requirements and expectations from the PhD program will not meet the status quo. This is mainly because technology has shaped how Gen Y learns and processes information (Martin 2005). They enter university having experiences and skills sets which require structure both within the classroom and to learning administration and infrastructure (Shih and Allen 2007). Their attitude is more towards staying connected, and advocates collaborating on issues that commonly affect them. Unfortunately, the current doctoral program structure is ill-suited to support these requirements.

A doctoral program is one in which an individual enters as a student and develops into a researcher. Emulating life, a doctoral student goes through various phases that are well defined and structured (lectures and exams) in the beginning to a rather ill defined structure (idea generation, dissertation etc) by the time they are considered to be academicians. We start by examining these developmental phases that exists in the life of a doctoral student. This will in turn help us understand how these phases will impact the incoming Gen Y researchers.

4 Life of a Doctoral Student

In her monograph, Gardner (2009) identifies three phases (I, II, III) in a doctoral student's development. She emphasizes the term *phase* portrays fluidity rather than the term *stage* which suggests distinct periods with no overlap. Fluidity is important in the PhD program because it allows students to visit and revisit issues and opportunities throughout the length of their program (Gardner 2009). It also means that student development is a continuous process and can occur at different phases based on the background and experience of the student. Doctoral program is quite unique in that students in the program range from those who just graduate from a Bachelor or Masters program with limited industry experience to others having long standing career in industry (Strange 1994). These development phases are shown in Fig. 1 along with their respective challenges and support structure and explained thereafter.

The need for challenges and support at every phase stems from cited (Komives and Woodard 2003; Evans et al. 2009) work by Sanford (1966), who suggests student's development requires an optimal balance of challenge and support. Meaning, overwhelming a budding scholar with challenges without providing equivalent support will hamper their growth in becoming good researchers. As discussed below, some of these challenges are specifically set by the program (e.g., exams) while others are a result of the stagnated process that is in need of a revision to meet twenty-first century demands.

Phase I: Generally, students enter the doctoral program having rather an optimistic view of their future life in the program. This view at times is distorted due to

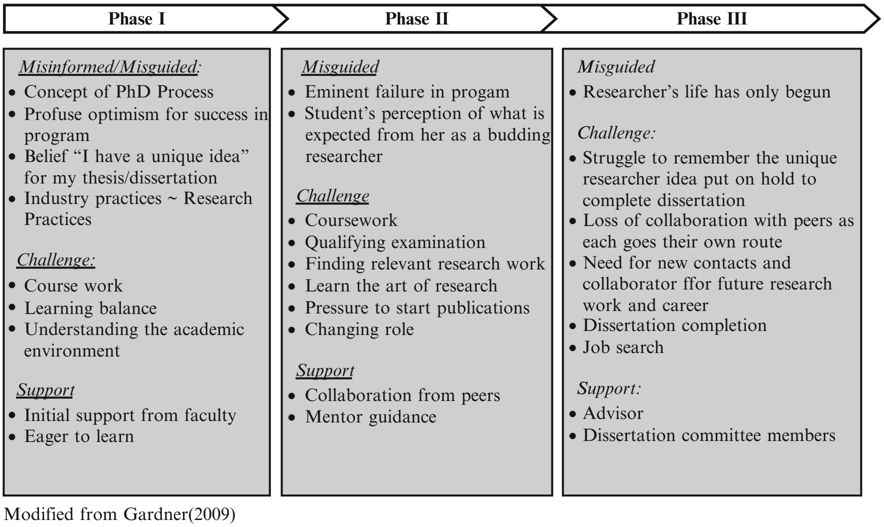

Fig. 1 Doctoral student development phases. Modified from Gardner (2009)

the limited source of information available to the to-be students. Most information is obtained through PhD brochures which concentrate on the positive aspects of the program but do not provide a holistic view of a student's life. Few students therefore have a clear understanding of the time and behavioral change needed to earn a PhD.

In addition, the students need to quickly assimilate the information propelled at them during the first couple of years of intensive course work. They are usually inept to cope with such pressure and at times the stress permeates into their personal life. People outside the program have very little understanding of the turmoil being faced by the student. It tends to be a very lonely period in a doctoral student's life.

Phase II: Time of reckoning with all major course work qualifying examinations being scheduled during this phase. Peers begin to perceive doctoral students as researchers. Students are expected to ideate viable research ideas for their doctoral dissertation. Many students upon losing the structure during their course work days lose direction on how to proceed in this new role of a researcher. Guidance from faculty and senior doctoral students can be critical at this stage.

Students need to learn the art of collaboration in Phase II. This becomes a daunting task when they realize that they need to considered factors such as personality, research interest, and willingness by faculty to work with junior researchers. Many students struggle to find the right fit but at the end have to settle with the peers in the department even if it is not an ideal match.

Phase III: Do or die situation with the main focus on the completion of the dissertation study and the stress of finding employment thereafter. It is the most unstructured phase of the doctoral program. Major decisions have to be made by the student on the dissertation topic. The work they do during this phase will invariably shape their future career in Academia. It will have an influence in the interrelated areas of publication prospects, job opportunities, promotions and tenure.

Students in this phase at times regret not being more systematic in documenting work done in phases I and II. Being able to access past work could have provided a base to develop robust ideas for the dissertation study. The development of thought through systematic analysis of past research work is missing and students are left scampering for new ideas.

In all the challenges mentioned above, it is clear from Fig. 1 that most of the support a student gets is from the faculty and students present in the respective department. But as stated earlier, Gen Y doctoral student are more comfortable being able to collaborate on a broader scale and require support that is technology based. Both of which can be made possible with the advent of Web 2.0 technology in the research world (a.k.a. Research 2.0) as explained in the next section.

5 Research 2.0 = Web 2.0 + Generation Y + Intellectual Craftsman

Mills (1959) in *The Sociological Imagination*, discusses the importance of one's personal journal in becoming an intellectual craftsman. He argued that the intellectual craftsman should apply their relevant life experiences into their intellectual work and not dissociate the two. If the researchers experiences are documented it is easier for a person to systematically reflect on them to decide how it relates to their current intellectual work. A craftsman's journal can also help in keeping track of past and current work, be a check on repetitious work, and record fledging ideas generated from the environment in which the craftsman is immersed.

This fundamental concept still holds true and can be easily achieved now more than ever with Research 2.0. Anandarajan et al. (2009) states that Research 2.0 is the unifying term of researchers, who interact socially as they strive to satisfy their own research needs. They have a shared purpose, such as an interest, need, information exchange or service that provides a reason for the community supported by Web 2.0 technologies. Whilst Web 1.0 was the earliest form of the Web, led mainly by companies seeking a Web presence, Web 2.0 architectures focus on encouraging user participation. The key aspects of Web 2.0 are interconnectivity and interactivity of Web-delivered content. In short, Web 2.0 technologies provide researchers with a range of features which range in media richness, which increase the range and reach of researchers' access to new potential collaborative partners and provide teams with research management tools. There are five forces that drive Web 2.0 (Anandarajan et al. 2009). These forces can be applied to any industry including research as is done below in the case of the doctoral program:

1. *User Generated Content:* refers to any material created and uploaded to the Internet by non-media professionals. Research 2.0 would allow doctoral students a medium through which they could publish their initial research work without the strict revision process found in journals. Students could then build and refine their work over the duration of the program and on to other projects.

Table 1 Doctoral student process under Research 2.0

Factors		As is process	Research 2.0 process
Research Mgmt.	Data storage	*Disparate storage locations* e.g., flash drives, personal hard drives, networks	*Centralized location* e.g., Research 2.0 dedicated server
	Data loss	*High* e.g., theft, hard drive crashes	*Low* e.g., server backup, Research 2.0 data guarantee
Data security		*Low* e.g., hacking into computer, sharing of computing devices	*High* e.g., User assigned restricted access to data, Research 2.0 encryption assurance
Accessibility to researchers		Limited e.g., students and faculty in department	Global (no geographical boundaries) e.g., anyone with similar interest
Coursework culture		*Silo* – builds up frustration – lack of guidance from peers during initial years – learning is limited to class lectures	*Virtual group* – Blogs, discussion groups allows for discussion of both academic and personal issues faced by students – Learning is extended beyond class room
Discussion		*Restricted* e.g., Fear of ramification for asking questions or stating thoughts not deemed appropriate	*Open* Allows students to ask questions and receive answers when making important decisions e.g., Forums
Dissertation process		*Inefficient* – Redundancy: duplication of e-mail sent to and received from each committee member – Tracking by student: responding to the diverse inquires from members – Tracking by Member: recalling the location and date when thesis was sent and where it was saved – Potential to overlook one or more committee members during communication exchange – Opportunity for "student said, members said" as there is no history of changes made – Loss of data during communication	*Efficient* – Centralized storage of all dissertation related work e.g., thesis, literature review papers • Reduces the need to keep track of dissertation paper by either the student or the members – Centralized communication center • Reduces overlooking any member – History of changes made to the dissertation is documented in Research 2.0 – No chance of losing dissertation work once saved in Research 2.0
Developing collaborative networks		*Limited*	*High*

2. *Crowdsourcing*: refers to taking a function traditionally performed by employees or contractors and instead outsource the function to large network of people or community in the form of an open call for proposals. One of the challenges mentioned in the Phase I and Phase II was that of coursework and having the feeling of going it alone; a feeling that Gen Y'ers do not revere. The ability to request assistance from fellow students who may be in similar situations relives some of this pressure. Solutions can be found to problems through group collaboration.
3. *Participation and Openness:* refers to the lowering of barriers to allow people to share, suggest and at times adapt new ideas on subjects affecting them (O'Reilly 2008). Junior researchers can join online research discussion groups and be able to deliberate or consult with other researcher regardless of geographical limitation.
4. *Network Effects:* a general economic term which states a service becomes more valuable as more people use it and hence encourages others to join (Klemperer 2006). This is probably the most valuable force for a doctoral student. Traditionally upon completion of the program, student's research network of collaborators was restricted to other researchers in their field of study and by geographical location. But through Research 2.0 these limitations no longer exists and doctoral students can begin to build network of collaborators by joining online research communities.
5. *Technology*: is the key enabler of Web 2.0. These include hardware, software applications, broadband support and of course the Internet. Given that the Gen Y is tech savvy they need to have tools which will compliment their research process. Research 2.0 will allow future doctoral students to manage many of the tasks more efficiently.

Table 1 gives an overview of how these five forces can impact the common processes found in a doctoral program. It starts out by looking at the "As Is Process" and compares them under Research 2.0 paradigm. The key difference is quite evident; "As Is Process" is restrictive and limiting in nature whereas "Research 2.0 Process" is global and has added capabilities in areas such as security and research management.

6 Doctoral Student Development Under Research 2.0 (MNR Example)

The following section provides a practical example on Research 2.0 at work. MyNetResearch.com (MNR) uses media rich functionality of Web 2.0 to help researchers develop social capital through virtual teams. A screenshot of some of these functionalities is given in Fig. 2. These functionalities have the following added benefits:

- Virtual access to files at any time and at any location all invited to the project
- Means to track the progression of the paper
- Centralized correspondence through the Message Center

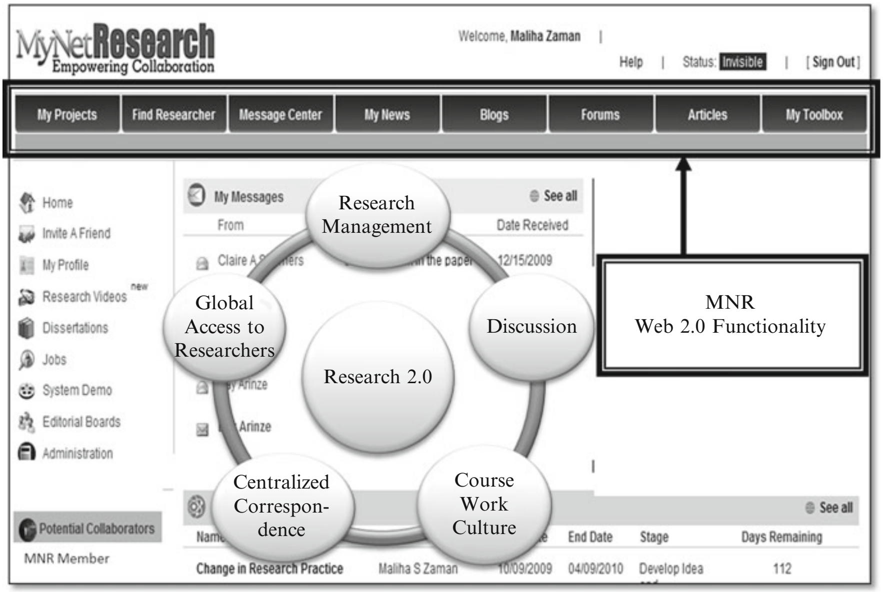

Fig. 2 Screenshot of Web 2.0 in practice (e.g., in MyNetResearch.com)

Table 2 Web 2.0 functionality and doctoral student development matrix

MNR focus	Doctoral activities/ requirements	Web 2.0 functionality	Potential impact on doctoral student
Research awareness	Learn about new ideas, opportunities work done by other researchers etc.	Blogs, wikis, forums, RSS feeds etc	Accurate expectation of the PhD program leading to less stress level in Phase I
Research networking	Formation of a collaboration team	Social networking tools, chat rooms etc	Cornucopia of researchers that students can build relationships with and collaborate on projects while in the program and onwards
Research management	Managing the team research collaboration	Dashboards, Task management, Version management etc	Permanent and secured record of work done to date for systematic retrieval when needed

- Web based survey and direct entry of responses into online database
- The data is secure and can be accessed virtually anywhere and at anytime by survey designer

The MNR core model focuses on three areas: Research Awareness, Research Networking and Research Management. Table 2 is a matrix of these three focus areas against some of the common doctoral activities/requirements examined under

"Life of a Doctoral Student" section above. The table also charts the respective Web 2.0 functionality being used by MNR. The last column proposes the potential impact MNR can have on students in a doctoral program.

Each of the focus areas and where they would benefit the most in the developmental phase of a doctoral student is discussed below. A simple use case is provided to demonstrate each area.

6.1 Research Awareness

Currently lacking in Phase I, research awareness would reduce the distorted idealistic view of the program. It would provide a holistic view which potentials students can benefit from when making this life changing decision. The same awareness would be critical during phase II and III and can be achieved by allowing students to discuss and seek solutions for their coursework, research dilemma or social issues they are facing.

> Example 1: After spending years in industry, Mr. Workforce felt that there was a need to find new challenges in life. He always had the love for teaching and imparting the knowledge gained during years of dedicated service to Business Q to others. Some of his intellectual friends suggested pursuing a PhD program as teaching was a big part of being a scholar. Before undertaking this new path in life Mr. Workforce wanted to become more aware of what was involved in becoming an academician. After doing a quick search on the Internet he came across the Forum section of MNR a Research 2.0 application. He was happy to note others had similar inquires about joining the Research program. Discussions covered areas such as challenges that students face upon joining the program to the best statistical method to use for a study. A common suggestion for people trying to join the program was to know their research interest beforehand. The Articles section was a good place to start. It was a compilation of current work done in different research areas from Social Sciences to Clinical Medicine. All of which were sent in by the researchers who were part of the MNR community. This was a good place to start for Mr. Workforce and he promptly signed up to become a part of this network.

6.2 Research Networking

In the Phase II and Phase III of the doctoral program students start understanding the value of having collaborators with whom they can do research. MNR provides a global list of potential researchers and a means to approach them. This was practically impossible in the traditional research world. A strong network created over the duration of the doctoral program can be of great assistance not only for research but also during job search – a key challenge after the Phase III.

Example 2: Ms. Scholar was contemplating her dissertation topic and wanted to study a research area that was not the focus of her mentors. She needed to find researchers that had similar interest and had published in this area. This was important for two reasons, she could approach them to become a dissertation committee member and she could collaborate with them in the future to publish papers. Since the University was situated in a geographically challenged area she opted to use MNR site. The Research 2.0 application's Find Researcher feature allowed her to search for potential collaborators from around the world. After selecting the required search field she was able to come up with at least six other researchers in her area of interest. She used the application's Message Center to send out an invitation for possible collaboration and waited to hear back from them. Her dreams of working in this particular topic seemed to start becoming a reality.

6.3 Research Management

Doctoral programs starts out very structured but become unstructured in the Phase III. There is a need for systematic documentation of ideas generated during the duration of the PhD program. Figure 3 depicts graphically the support structure and the key activity during each of the development phases mentioned earlier. The figure clearly shows the decentralized nature of the doctoral program as it stands today. Such decentralization is a strain on the already limited time and energy of a doctoral student. The picture is quite different in Fig. 4. Under the MNR model a student is able to centralize all activities and build up on the support structure from the onset of Phase I. The fluidity of term "phase" rather than "stage" is truly represented under this model. There is a seamless flow of student developmental activities that grows throughout the program and can be systematically accessed at any time. The last two illustrative examples follow.

Example 3: Ms. Scholar is in the dissertation phase. After finding two of her committee members though MNR she managed to get the rest of her committee members to join MNR. This has allowed her to centralize the dissertation process. Instead of having to constantly print out or send out e-mail of her dissertation paper she simply uploads the revision in the Public folder of her Dissertation project. The members can then access the paper at their own convenience. This saved her and her committee members from flooding up their email boxes and keeping track of the latest version of the paper. Scheduling of committee meeting was also easier as they could all be reached

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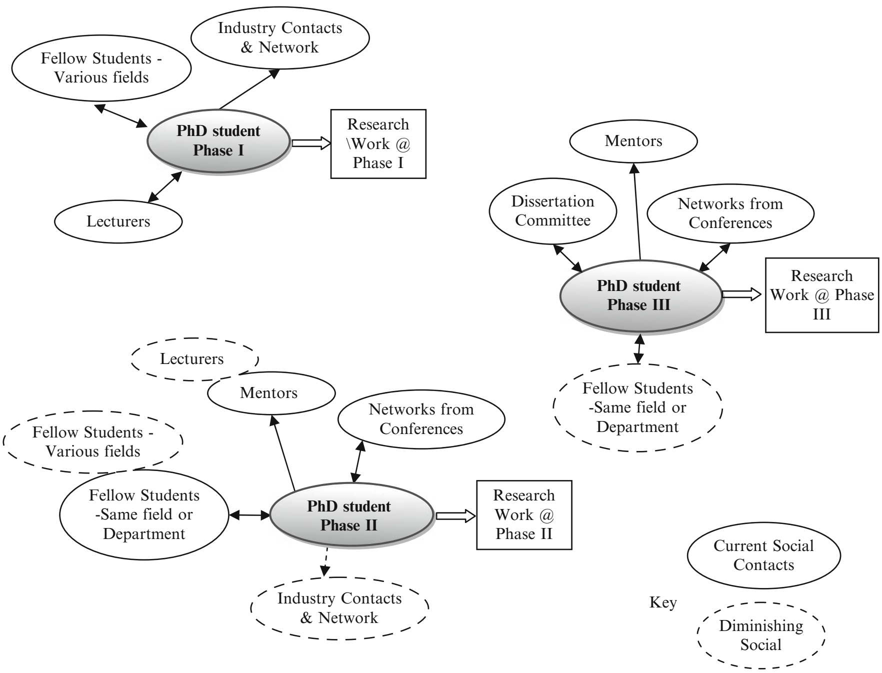

Fig. 3 Current doctoral program paradigm – disparate and decentralized

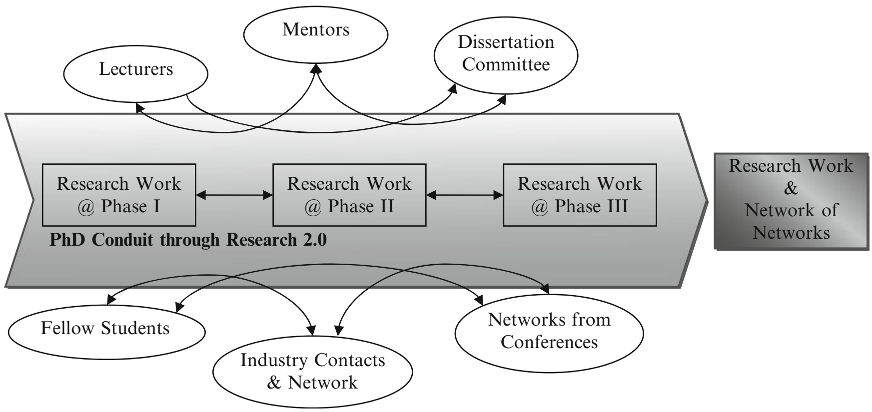

Fig. 4 Research 2.0 paradigm – centralization of tasks and networks

using the Messaging Center in the application. These were not visible to the members themselves and allowed her to place her own comments to follow in the future. After her proposal defense Ms. Scholar got to the task of setting up

(continued)

her survey using the tool provided in MNR. She was confident of the analysis she will have to run on the data to be collected as she had previously used the Research Method Analyzer.

Example 4: Mr. Workforce and Ms. Scholar are in different phases of their PhD program. Mr. Workforce who joined the program recently is knee deep in coursework. Some of the assignments require him to come up with research questions and to generate new research ideas. Mr. Workforce started to realize that he could no longer remember some of the ideas that he initially came up with when he first joined the program. Furthermore, he was frustrated by the fact that he could no longer remember where he saved the list of articles form a literature review he had the previous year. Having that list would have saved him a huge amount of time right about now. So as not to face this problem going forward, Mr. Workforce decided to create a new Project in MNR. Keeping this "journal" of different ideas generated throughout the program would allow Mr. Workforce to systematically find what he needs when dissertation and publication becomes a reality.

7 Conclusion

The great writer Stewart Brand said,

> *Once a new technology rolls over you, if you're not part of the steamroller, you're part of the road*

The research community has a responsibility not to fall behind in adopting technology that is has already started to change our society. Even though this industry is well known for being rigid and of staying true to itself there is a need to incorporate new processes and ideas on how to do research. Gen Y with their collaborating and tech savvy characteristics will demand resources that support their way of life. The doctoral program is responsible for molding the next generation of researchers. It would serve the research community if these new intellectual craftsman are equipped with skills that match the world they are going to investigate and report on. In particular there is a vital need to understand how to exploit the benefits provided by Web 2.0 based technology. This is especially important for doctoral students as, unlike in the last decade, Web 2.0 is now an integral component of the learning process in a doctoral program. Doctoral students need to know how to use it to collect and assimilate data and more importantly, to find other doctoral colleagues in different places who have similar interests and working on similar themes. Doctoral students can benefit from e-collaboration by learning from the trials and tribulations faced by their peers.

Web 2.0 also provides challenges and it is vital for doctoral students to be aware of these challenges. Web 2.0 has various characteristics and tools that can be employed successfully at each stage of a doctoral program. PhD students need to know which aspects of Web 2.0 are most useful as they progress through the doctoral program.

The stages of a doctoral program are trichotomized into, the research awareness stage, research networking stage and research management stage. In the first stage, referred to as research awareness stage, aspects of Web 2.0 such as blogs, wikis, forums and RSS feeds are most useful in finding new research ideas. In the research networking stage (which involves the formation of a collaboration team), social networking tools such as chatrooms are most useful. Finally, in the latter stages, which involves effective management with peers, Web 2.0 tools such as dash boards and version management can be used effectively. The impact of all these different aspects of Web 2.0 technology is examined with illustrations.

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Part III
e-Research Collaboration: Challenges

Issues Related to Research Ethics in e-Research Collaboration

Rohaida Mohd. Saat and Norani Mohd. Salleh

Abstract The advancement of information and communication technologies changes the landscape of scientific research. Today's scientific research demand collaboration among international as well as local members and many have adopted e-research collaboration. It ensures greater sharing of resources and expertise, greater networking and cooperation for scientific advancement while offering greater opportunities for technology, skills, and knowledge transfer. However, collaboration has posed challenges particularly regarding ethical issues. Collaboration projects across disciplines or nations which are governed by different rules cannot be easily resolved. For example, the dilemma arising from research involving countries or institutions that have IRB and those do not. Whose rules should be adhered to? Other issues that threaten e-research collaboration is the distortion of data due to technological glitches, threaten security which include invasion of privacy and tampered confidentiality. These issues need to be addressed to ensure more effective and efficient e-research collaboration that has the support and trust of the larger public.

1 Introduction

Current technology, particularly information and communication technologies (hereafter ICT), has changed the landscape of scientific research. This change is inevitable. Society transforms with the rapid evolution of new technologies. These changes have enabled new ways in which researchers collect, manage, collaborate, and analyze data. Among ICT applications that are commonly employed in scientific

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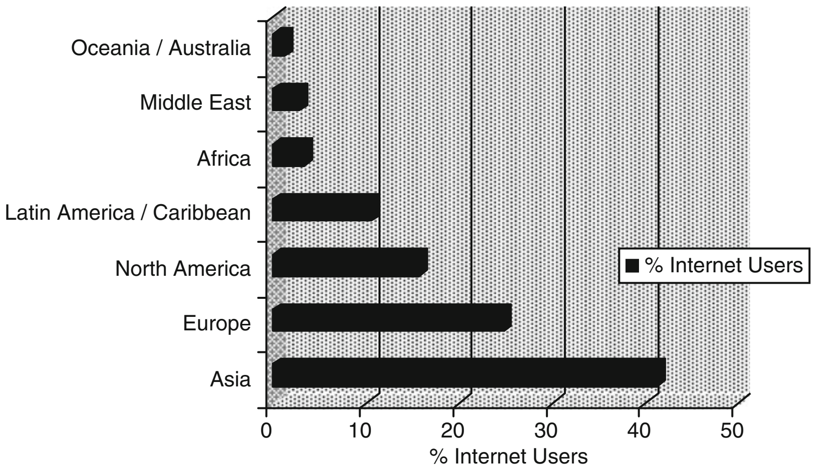

Fig. 1 World internet users by world region (Internet World Stats 2009)

research are quantitative data analysis programs, qualitative data management programs, data-gathering tools, and knowledge-sharing infrastructure, especially from the Internet.

The number of Internet users all over the world has increased significantly; Figure 1 exhibits the percentage of Internet users categorized by regions, with Asia having the most Internet users in the world at 657.2 million (Internet World Stats 2009). The agency also reported that Asia has seen a significant increase in the percentage of Internet users over the past 8 years. The use of Internet-based communication tools by researchers, such as e-mail, electronic discussion boards, and electronic mailing lists, has enabled researchers to communicate with each other and to gain access to their respondents virtually. Data gathering, such as interviews and surveys, can be done virtually. Interviews can be done through Web-based chat tools or Web-based asynchronous conferencing tools, and surveys may be conducted using Web-based survey tools.

Research collaboration among international members is not new. Numerous research grants have been awarded from developed countries sponsoring research done in developing and underdeveloped countries. Developing and underdeveloped countries are unable to spend much in research and development (R&D) as compared to developed countries such as the United States, European Union (EU), and Japan. In 2006, the United States spent US$343 billion, which is equivalent to 2.6% of their GDP, on R&D; the EU spent US$231 billion (1.8% of GDP); and Japan spent US$130 billion (3.2% of GDP) (Wikipedia 2009). Some common research grants awarded by developed countries are the CICHE grant, which is awarded by the British Council, and the Toray Science Foundation Award, which was established by Toray Industries, Inc., in Japan. Awards such as these have enhanced collaboration between researchers from developed countries and developing and underdeveloped countries, because grant recipients are required to collaborate with host countries.

With advancement and innovations in technology, research collaboration has been further enhanced, especially in networking. “MyNetResearch” is a good example of how researchers from around the world collaborate. “MyNetResearch” provides various e-collaboration tools for conducting research collaboratively. These tools have made research collaboration manageable and hassle-free.

2 Technology and Research

It is inevitable for society to transform as technology evolves. The effect of technology on research is no exception. It has changed the landscape of scientific research, ranging from methods of collecting data to analysis of data and reporting data. New forms of data gathering have emerged, such as interview via e-mail, text messages from mobile phones, and Internet surveys. Sampling can be done on a bigger scale, and covering a wider spectrum of population.

One example of technology evolution is the new generation of the Internet: Web 2.0. It has evolved from a group work tool of scientists at CERN into a global interactive space for more than a million users. It can do more than just retrieve information; it also provides network platform computing that allows users to run software programs and applications from a browser (O’Reilly 2006). According to O’Rielly, Web 2.0 is characterized as user participation, openness, and dynamic content. These have been regarded as “social software” technologies consisting of collaborative tools, such as those available in ResearchGATE and MyNetResearch (MNR). MNR, for instance, is very useful in setting up collaboration agenda where one can conduct literature reviews using MNR’s citation tool, create a forum for researchers, search for research collaborators, and manage collaborative research projects. Users from around the world may coauthor, co-create, and co-design, which could give rise to new ideas, innovation, and problem solving. Platforms such as MNR have provided a greater opportunity for research collaboration that one could not previously imagine.

Besides social networking tools, Web 2.0 has tools such as internal wikis. As social software, a wiki is also a piece of server software. It allows users to freely create and edit Web content using any Web browser. This is new, as it allows other users to contribute and edit any page in the Web site, thus encouraging democratic use of the Web and promoting content composition by nontechnical users. Characteristics of Web 2.0 have thus led to the creation of new research networks that enhance collaboration. Forrester Research (2008) predicted that, like any other technological innovation, Web 2.0 will continue to experience growth in the area of social networking, and stated that it has dramatically reduced the barriers to collaboration by researchers around the world.

3 Research Collaboration

Research collaboration can be seen as individuals of multidisciplinary and/or geographically and/or organizationally distributed participants working together and sharing data or resources towards a shared task. It is viewed as a positive sign of quality and progress in having gained importance in the past few decades (Abramo et al. 2009). Research collaboration is common practice in the field of medicine and business. Numerous initiatives aimed at bringing together researchers from different sectors, or alternatively in interdisciplinary fields, by national and international funding agencies suggest that collaboration is widely supported. Serious efforts to foster research collaboration across sectors such as university and industry are often made by governments with clear mentions of priority for funding and other forms of support. A tripartite collaboration between academics, research institutes, and industry may be ideal. In this tripartite collaboration, each collaborator has its own role. For instance, academics might be involved in fundamental research seeking to uncover and discover fundamental knowledge. Researchers from research institutes, on the other hand, might venture into applied research; that is, moving from fundamental knowledge to practice or application of the knowledge in the real world. The role of industry in this collaboration might involve strategizing and commercializing the research outputs. European Union research policies, for instance, acknowledge and support transnational collaboration among research institutions, universities, and industry players as the framework for strengthening research and development programs (Abramo et al. 2009). In developing countries like Malaysia, internationalization has largely translated into working with international faculty in terms of research and publications.

Two scenarios suggest that more collaboration is actually better. Firstly, the ever-increasing number of coauthorship of published journal articles is regarded as a basic counting unit to measure collaborative activity. Second is the massive funding from private sectors in support of institutional research endeavors. There are endless reasons to support collaborations as being a good thing. As mentioned by Smith (1958), collaboration is an intrinsically social process and, as with any form of human interaction, there may be at least as many contributing factors as there are individuals.

3.1 Why Collaborate?

Research collaborations are gaining importance in scientific research for various reasons. The following may be some of the more mentioned causes of collaboration.

3.1.1 Collaboration Ensures Greater Sharing of Resources and Expertise

Modern research is increasingly complex and often requires expensive instrumentation; especially in experimental types of research, the cost is huge and collaboration therefore provides an answer. In scientific research, the need for cost rationalization is easily matched with the need to keep pace with the increasing specialization in the specific discipline. Wide-ranging skills, knowledge, and techniques, especially in such fields as medicine, science, engineering, and technology, could be enhanced through collaboration. In principle, one can learn as much as possible to possess the necessary skills, knowledge, and techniques, but it takes time and is not cost effective (Abramo et al. 2009; Katz and Martin 1997).

3.1.2 Collaboration Ensures Greater Networking and Cooperation for Scientific Advancement

Collaboration may be the fastest way forward to develop and disseminate scientific knowledge, especially for developing countries that are new to global research networks. There is greater opportunity to become visible and recognized as having legitimate authority over a piece of scientific discovery resulting from collaborating with renowned research groups (Abramo et al. 2009; Katz and Martin 1997). Collaboration has encouraged greater cooperation between individual researchers and centers of excellence across the globe. The memorandum of understanding (MoU) and agreement to heighten scientific and cultural cooperation look set to stay. Similarly, patterns of funding agencies have changed in recent years to accommodate collaborative efforts by requiring researchers to seek collaborative partners as a precondition for financial support. Political agendas have promoted bilateral works or groups of members to collaborate at the exclusion of nonmembers.

3.1.3 Collaboration Offers Greater Opportunities for Technology, Skills, and Knowledge Transfer

This closely follows the benefits of networking, which also explains why governments and regional agencies encourage collaboration. Dissemination of scientific knowledge, skills, and technology mostly relies on published articles and hands-on or on-the-job training (Lee and Bozeman 2005). However, there are tacit knowledge, skills, and subject or content practical knowledge that are best learned from interacting informally among a research team. The underlying assumption is that we are essentially concerned about the same thing: good governance, a clean and sustainable environment, and greater access to and opportunity for a better life. It makes sense that scientific endeavors are exploited effectively and disseminates in a way that benefits many rather than few. At the national level, collaboration enhances interdisciplinary and multidisciplinary research apart from promoting apprenticeship to novice researchers (Katz and Martin 1997). Furthermore, collaboration is made easier with many university governances striving for similar international accreditations; there are more similarities than differences among universities across the globe.

3.2 Challenges of Collaborating

Collaboration benefits are undoubtedly plentiful. However, it is important to project a more balanced argument for collaboration, in particular at the international level and especially for researchers and institutions new to global collaboration networking. Collaboration can happen at different levels; inter-individuals, inter-institutional, international, and intergovernmental collaborations. Various aspects need to be addressed.

Firstly, collaboration at any level means working in teams of two or more individuals, and may be across disciplines involving nations in different time zones. Differing purposes and interests that each partner brings must be managed well to accommodate and encourage continuous support, at least until the completion of a research project. Certainly, some applied research projects may become embroiled in moral and jurisdictional controversies due to local scientific policies on research, and may be subsequently rejected by other participating team members that are governed by different rules. For example, in stem cell research, this is highly sensitive and culturally bound research that would benefit from extensive comparative testing. However, the research must not overlook legal jurisdictions and local sensitivities. Setting defensible boundaries and accommodating partners without distorting the results will be tough.

Secondly, collaboration requires effective communication through a common language. English remains the dominant lingua franca within the academic circle, and the ever-growing number of speakers of English as a second language (ESL) reduces the communication problem somewhat. Lastly, technology transfer is not easily measured, and often skills and knowledge gains from collaborative research are not commensurate with the cost. The use of ICT and virtual communication has, to a large extent, reduced costs and allowed for a greater sense of presence.

3.3 e-Research Collaboration

With innovations in information and communication technologies (ICT), research has overcome some of the barriers to collaboration and eased the impact of what is known as the "proximity effect" (Katz and Martin 1997). Collaboration today can be done virtually, and team members who have never met physically or rarely meet face-to-face can work together in a research project. This encourages collaboration when researchers are distant geographically or organizationally. With ICT and virtual communication, local researchers may collaborate with co-researchers from other parts of the world in line with the current trend towards globalization (McDonald 2000). This is timely when team members come from various parts of the world where there are time differences between regions. Indirectly, this allows team members to access e-mail in their own time to read and understand the project or the task before carefully responding to electronic communications that will be shared with other team members (Kock 2008).

A good characteristic of research collaboration is translucence, which has become one of the features in current ICT technologies. According to Bjorn and Ngwenyama (2009), translucence is an important feature of collaborative technologies; it enables distributed research collaborators to monitor and interpret each other's actions during collaboration. The main purpose of this feature is to avoid or recover from communication breakdowns such as interruptions due to unscheduled synchronous interactions that may cause disruption to an activity.

There are some drawbacks of using ICT in research collaboration. One is the lack of face-to-face communication. As discussed earlier, one of the aspects that need to be considered in research collaboration is effective communication. Based on anthropological findings, it was established that humans have evolved over millions of years communicating face to face; that is, the use of both sight and sound, and secondly is the use of sound alone. However, both interaction modes use synchronous communication. The first and predominant mode in human communication is face-to-face communication (Kock 2008). According to Kock and Deluca (2007), communication such as that through ICT applications has low levels of face-to-face communication, and it is hypothesized that it leads to higher levels of cognitive effort during communication. However, it was also found that it has a positive impact on both knowledge sharing among research members and the quality of the research outcome. The contradiction in the research findings gave rise to a new theoretical framework called the compensatory adaptation theory. Kock and Deluca (2007) summarized this interaction through a graphical representation, as shown in Fig. 2.

As Fig. 2 illustrates, the use of electronic communication media among research collaborators resulted in increased cognitive effort as group members are required to communicate their ideas related to the project and to make sense of the ideas put forward by other members. According to the theory, although e-collaboration technologies often pose obstacles to communication, it leads to better team outcomes than the face-to-face medium. The collaborating members interacting through the electronic communication medium modified their behavior in order to compensate for the obstacles posed by the medium. It is suggested that there is a decrease in message fluency by approximately six to five words per minute. Nevertheless, as a result of well-prepared messages, a higher-quality message was produced. Members of the virtual collaboration adopting electronic communication need to be more focused, clear, precise, neutral, concrete, persuasive, and considerate in order to overcome the obstacles posed by the electronic communication medium. As a result of those adaptations, the research members perceived

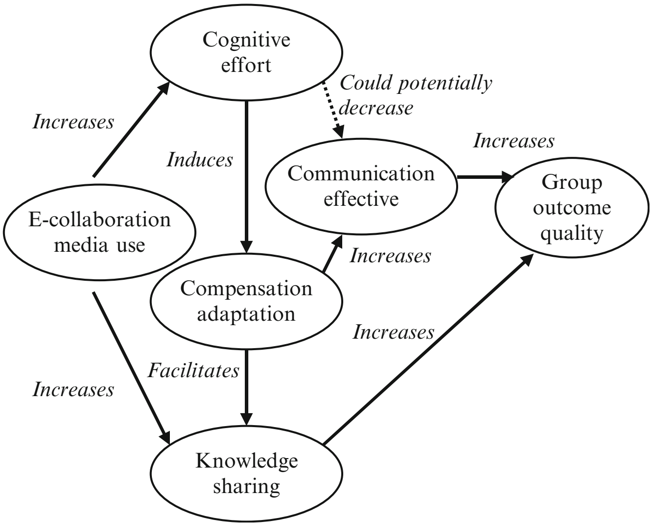

Fig. 2 Interplay of effects leading to compensatory adaptation (adapted from Kock and DeLuca 2007)

better quality and achieved success of the research group outcome (Kock 2008). Based on Kock's argument, it makes good sense to have e-collaboration technologies that can facilitate compensatory adaptation. At present, e-collaborative tools that have features that adopt or compensate for the absence of face-to-face communication elements are very rare.

Another issue related to e-research collaboration is use of a common language among research collaborators. As discussed earlier, transnational research, especially e-collaboration research needs a common language since language is a medium of any form of communication. As perceived by many, English has been the dominant lingua franca in many research collaborations, and it is assumed that all research collaborators are well-versed in the language. However, miscommunication might occur due to the social and cultural context of each collaborator. For example, the term "interview protocol" might mean a set of interview questions that will be used in an interview, while another researcher might envisage it as the procedure of conducting an interview. Instances where research collaborators communicate using Web-based chat tools, on the other hand, are another issue in communication. It is a common practice that people use abbreviations in chat rooms. This poses the issue of misinterpreting the meaning of those abbreviations. Misinterpretation can also occur among respondents during data gathering, particularly in surveys and e-mail interviews. Various respondents from different nations can interpret survey questions differently. Such misinterpretation and miscommunication among research members as well research respondents can indirectly jeopardize research findings.

4 Ethical Issues in e-Research Collaboration

It is widely recognized that ethics is an essential element in conducting research in any context or environment in order to ensure integrity and quality of research. Universities and other organizations are increasingly aware of the importance of ethical research. They are also concerned about the damage, both financial and reputational, of "unethical" research to their institutes and organization (Macfarlane 2009). Many would equate research ethics to a set of principles or guidelines by which researchers should abide, such as obtaining consent from participants, or confidentiality and honesty in reporting findings. Macfarlane (2009), on the other hand, sees research ethics as characteristics that researchers ought to possess rather than as how one ought to act based on a set of bureaucratic procedures. He argues that integrity refers to different things in different activities. In the context of doing research, among the virtues he identifies are courage, respectfulness, sincerity, and humility, and the virtues identified must be lived out at all stages when conducting research. From whatever aspect, the main aim of research ethics is to ensure the quality and integrity of the research.

Today, most professional and disciplined-based bodies, such as the British Medical Associations and the American Psychological Association, and higher institutions in Western countries have issued guidelines and code books. However, higher institutions in many Eastern countries do not have standard guidelines pertaining to conducting research, because the subject of research ethics in many of these countries, such as Malaysia and Japan, is comparatively new (Macfarlane and Saitoh 2008). Although there are no specific research ethics guidelines, many academics in these countries are in fact conversant with ethical procedures in doing research (Salleh and Saat 2008). However, their understanding of ethics lies in their personal academic experiences while studying abroad rather than the research norms of their workplaces.

Ethical issues involving e-research collaboration are identical to those for traditional research, but it cannot be denied that e-research poses other issues. According to Kralik et al. (2005), the use of ICT has led to new contexts in which the application of ethical principles and acting with moral responsibility become ambiguous and uncertain. Basically, general ethical principles, such as respect for persons and justice, do not change; however, considerations of how to uphold these ethical principles, such as in handling data generated from ICT applications like e-mail, need to be addressed. Researchers must be ethically informed and sensitive about the norms, values, and regulations that might emerge in the virtual research context (Kralik et al. 2005). In fact, as argued by Macfarlane (2009), researchers must possess virtues that are closely related to ethical practice to ensure the integrity of any research collaboration.

Researchers and ethics review boards typically rely on dichotomies like "public" versus "private", "published" versus "unpublished", and "anonymous" versus "identified". However, in the context of e-research, these categories are blurred, and the underlying concepts require reinterpretation (Hudson and Bruckman 2005). As illustrated by Hudson and Bruckman (2005), who employed empirical data in answering questions about Internet research ethics. They found that the participants' expectations of one of the ethics principles; namely the privacy conflict with the reality of the cyber chat rooms that they experienced. The finding showed how the experience influences the participants' reasoning about the ethical issues of obtaining informed consent. Another aspect that is related to confidentiality and privacy is the feature of translucence. As discussed earlier, one positive feature of e-collaboration application tools is translucence. Being translucent and transparent can be seen as breaching the basic ethical principles of confidentiality and privacy. Translucence allows research members to monitor each other's work. Some may argue that translucence is an intrusion of one's privacy. This might create a dilemma between a good feature of collaborative tools as opposed to a threat of confidentially and privacy.

Additionally, most principles of research ethics are largely derived from Western philosophical thought, and adoption of such philosophical thought in Eastern cultures has caused considerable controversy (Kass et al. 2003). This issue is prominent in collaborations involving researchers from both Western and Eastern countries. Macfarlane and Saitoh (2008) found that research ethics adopted in Japan accentuate disparity between behavioral norms in Japanese culture, because the general principles of these research ethics are imported from the West. An example given by Akabayashi and Slingsby (2003) is the issue of organ donation. In the West, donor cards provide evidence of an individual's consent for organ donation. In contrast, Japanese society believes that the family has full autonomy over the patient's well-being, including withholding information about medical conditions from others. Therefore, although the patient has given consent for organ donation, the family has the final say on the organ donation.

Another example is in the field of stem cell research. Although this area of research could greatly benefit from international cooperation, collaboration between scientists of different countries is hampered by the divergence in national stem cell policies among nations (Mertes and Pennings 2009). Researchers in countries with restrictive stem cell policies will not be able to participate in forums and workshops that permit open discussion on stem cell research issues. These researchers fear that they might be prosecuted in their home country, as they will be seen as a traitor. According to Mertes and Pennings (2009), this calls for extraterritorial jurisdiction for freedom of research, where scientists and researchers should be able to freely engage in intellectual discourse on this area of research. Both scenarios illustrate the conflict between Western and Eastern values and culture.

Kass et al. (2003) highlighted the problem arising from e-research collaboration involving countries that have IRB review boards and countries that do not. Among the IRBs, they lack uniformity in the review process, thus creating uneven protection of human subjects and undermining the intent of the Common Rule. Both situations result in different expectations as to what is and is not appropriate. For example, requiring respondents to sign consent forms when a majority of the respondents could not read and write, or in another situation where verbal informed consent is more acceptable as opposed to written informed consent. The act of requiring researchers to meet standards set by Western-based ethical guidelines raises other issues, such as the appropriateness of the guidelines to the local contexts. Due to the increasing complexity of research, McWilliams et al. (2006) have proposed the establishment of an expert centralized IRB review via implementation of a national virtual IRB review system overseen by the Office for Human Research Protections (OHRP). This centralized review would enable expert review specific to the research, and would ensure consistency and uniformity in protection of human subjects. Since this is a centralized virtual system, IRB members will remain at their institutions while providing their expert review virtually, and will make information regarding monitoring and adverse-event reporting available online in real-time.

The previous examples demonstrate that there is a difference between Western and Eastern culture and values, and that adoption of Western-based research ethics might create controversy among researchers from both cultures. Embarking in e-research collaboration could create greater challenges. Again, it is the question of which and whose ethical guidelines and standards should be adopted. For example, not all nations have a Data Protection Act. Countries such as the United Kingdom and the European Union have established a common minimum standard of data privacy, which, among other things, stipulates that data gathered may be used only for the specific purpose for which it was collected and cannot be disclosed to other parties without consent.

Another issue that threatens e-research collaboration is the distortion of data. Transmitting data electronically across nations might cause distortions and omission of data. Researchers also cannot promise that confidential data will not be accessed during electronic transmission (Mann and Stewart 2000). This can be caused by technical glitches, including virus attacks or intrusion of unauthorized users or "hackers" who gain entry into a computer or computer network. Tampering of data by hackers or distortion of data during transmission may create problems of validity and reliability of the data gathered. Another ethical principle in research is confidentiality and privacy. Confidentiality in e-research collaboration involves research members' communication in e-mail discussion lists or other collaborative forums, sharing of data, and moderating their findings. In both cases, additional technical support is needed to elevate security of the ICT applications.

Besides elevating ICT security, another concern of ethical issues is that social networking's open and sharing character, as in e-research collaboration, could invite dangers. It could threaten security for both copyright and privacy (Braund 2008). As highlighted by Kralik et al. (2005), a large quantity of highly personal data is bundled into one electronic file, which can be e-mailed or stored on compact disk and mailed to co-researchers. It is the responsibility of all team members to trust each other and accept and uphold their ethical and moral responsibilities. They need to ensure that the data set is used only within the scope of its enabling ethics committee approval. Kralik et al. (2005) suggested establishing an intellectual property agreement between members of the research team as a measure to maintain researchers' vigilance.

Another concern in multinational research, especially that involving research subjects in developing countries, is the tendency of researchers to exploit vulnerable populations such as children (Vreeman et al. 2009). While informed consent is widely and legally accepted, children are generally not considered capable of informed consent and require adults to provide consent for them. In e-research, additional ethical challenges are raised when consent is obtained via e-mail from an adult representing the child rather than obtaining a hard copy of a written signature. Some may argue that this type of signature might not be legally accepted (Kralik et al. 2005). In the case of using children as participants, two ethical issues must be addressed. Firstly, how will a researcher be certain that the child has voluntarily given his or her consent to participate in the research? Secondly, the e-mail containing the informed consent, which does not have an authentic signature, is not legally binding. Even in cases where participants send the signed downloaded informed consent, there is an issue of whether the signature is of the participant.

The above ethical issues pertaining to e-research collaboration may seem numerous; however, several preventive measures can be taken. One measure outlined by Kralik et al. (2005) is a balance between a breach of confidentiality versus the likely prospect of personal gain. Many human research ethics pro forma mention risks "beyond those encountered in everyday life". In the context of e-research collaboration, confidentiality risk in using e-mail and discussion lists may be regarded as "everyday life" and can be viewed from the moral responsibility for the user rather than only as an ethical concern. Another measure is to increase security of the system by taking relevant technical steps, such as using secure socket layer (SSL) encryption in communication that uses e-mail lists (Kralik et al. 2005). SSL encryptions do not allow intermediate parties to tap the conversation, nor can they view the messages transmitted. This will make communication among research collaborators more secure.

5 Conclusion

There is no doubting the significant contribution of research collaboration in scientific research, and it has been enhanced with the innovation in ICT. Various features have enabled researchers to collaborate more effectively and efficiently. Unfortunately, the adoption of e-collaboration has created some ethical issues. These issues must be dealt with carefully. However, this opens the door for further debate of these issues so that the research community can move towards common consensus on the adoption of agreed standards of good practice. This is vital in ensuring the e-research collaboration gains trust and support from the public.

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The Coming "République des Lettres"

The Academic World and the Web 2.0 Risks and Challenges

Ana Dinescu

Abstract The chapter analyzes the ways in which the development of various social networking tools is influencing the academic world. There are threats and opportunities. The academics could benefit from the significant opportunities created by changing ideas. Working on a collaborative, real time on-line basis, increases the possibilities of exchanging ideas. However, the vast amount of literature available on the Internet is co-authored by non academics and is not "vetted" or subject to peer review. How valid are the theories and findings of such papers? This is a serious matter of concern. The future (for example, MyNetResearch) belongs to tools that facilitate dedicated research exploiting current social networking opportunities. The focus of this chapter is to discuss pertinent social networking tools and how they can be used at their best to stimulate collaborative research.

1 Introduction

In the corner of a pub, a normal-looking person is tapping on a laptop with Internet wireless connection, endowed with reliable anti-virus software and the last updated version of Word and Adobe Photoshop, storing from time to time the information on a memory stick. On the screen, a couple of windows are open, with texts waiting to be edited – many texts copy-pasted from the Internet or papers in various stages of refinement, including students' papers in process of evaluation. At regular intervals, he checks the e-mail address waiting the final confirmations and other organizational details for a forthcoming conference, as well as the most recent papers of the students. The article is advancing directly on the screen, after carefully inter-crossing references of articles and notes archived and carefully organised in

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easy-to-be-found computer folders. A rewritable CD is ready for the rapid transfer of some very important files, in addition to or the same as those already transferred on the memory stick. From time to time, the phone rings, reminding the user about a class or an incoming appointment with a Ph.D. student. Who is this person apparently so busy and multi-tasking? It is only an approximation (and not at all fully accurate description) of the mobile office and habits of the new era researcher.

At first sight, the person we are about to observe looks like any of us, in our Web 2.0 World, without prior clear external identification signs: he could be dressed casually or wearing an expensive suit; he could be found at the library or at the cafeteria next door. The borderlines – in terms of spaces accessed and the outside identification signs – between the world of the university and the normal world are fading away. What it is left?

Nowadays, it is extremely difficult, and not risk-free for the quality of the research as such, to keep you aware of a technique's potential. The image of the hermit-like scientist avoiding any interference from the outside world is becoming more and more obsolete. The differences continue to be stressed by the content of the information read, shared and produced. But the competitive advantage might prevail by the ways in which the e-tools are used for the purpose of producing and reproducing knowledge, the final aim of any serious academic research. Are the technical tools and the various opportunities set by the Internet – mostly blogs and social networks – contributing to the advancement and improvement of this complex process of knowledge? Or rather, by the extreme broadening of the target group – the so-called "democratization of science" – the quality of the scientific research is getting inferior and, sooner or later, will it be almost impossible to talk about high scientific standards that we knew? Not less important, the broad access to the writing channel which was previously exclusive is now available to almost everybody. Is this competition detrimental to serious research quality? Practically, anyone with an Internet connection is able to publish any kind of information on the web.

In this chapter, we will try to address a couple of questions on the influence of e-techniques on academic research. How are the modern Web 2.0 habits translated into the academic world? Is it conducive to academic research? How, and in what respects, the production of knowledge influenced the academic work and what new methods of sharing information is available to the researcher? Are these methods reliable? How could a perfectly e-literate academic contribute to maintaining the same standards of academic accuracy and accountability? And last, but not least, is it possible, as a researcher, to be non participative and still produce the same quality research using old fashioned techniques such as books and printed papers?

We attempt to provide insight for a researcher who has used older Web tools and applying professional academic standards to the research while simultaneously maintaining dialogue and collaborating with other researchers with similar interests. The unavoidable reality is that the rapid progress of digital media has seriously challenged the way we have done research. In the same way, the current methods of collaborative research (discussing with peers and forming relationships at conferences) is put under question by the new sources available, such as information distributed via Wikis, blogging and chat rooms (Schultz et al. 2007). But, we cannot yet talk about a confrontation between the old and the new, as the old and the new could collaborate, in the same spirit of dialogue we pointed out beforehand. In this section, we will evaluate the aspects related to the collaborative advantages offered by Web 2.0 techniques for the academic field, while addressing the risks of creating false knowledge and inappropriate conclusions on the basis of uncategorized information.

2 Wandering in the Library of Babel

In his short story "The Library of Babel" the Argentinean writer Jorge Luis Borges (2000) describes an infinite library, where the books are not organized following a central and unique criteria: it was possible to find in the library all the books ever written, in all the possible languages, organized randomly and without any purposive meanings. Comparatively, in the Internet world, the lack of organisation of the information, according to simple and universally available criteria is occurring hand-in-hand with the huge volume of information increasing progressively every single second. One of the consequences is the difficulty in clearly identifying the source of texts and sometimes the original authors. Now, we have many anonymous articles and assumed references. This is a limitation because the difference between and absolute truth and fiction can be a blur.

How the academic world – for centuries striving to be as selective as possible in its membership and disciplined by a self-imposed isolation, as a foundation of fundamental research – is positioning itself toward the Web 2.0 (or the Web 3.0 or potentially other Web.0) world? Rather than joining either the choir of the laments regretting the "good, old times" of the pure academic authenticity – to be read in some situations as the alienation from the ways in which real world is functioning – or the enthusiastic utopians of the new e-world – whose slogan could be sometimes resumed by the "surf – on the web – or you are dead" –, we will chose the moderate balanced position, based on a case-to-case analysis of the opportunities and threats of the most used digital media techniques. Our basic assumption is that on specific occasions, when the production and distribution of knowledge is concerned, these instruments considerably increase our academic chances and prospects. At the same time, we consider that the mindset of researchers are built in a world where the criteria and standards are set independently of the new technology trends.[1]

[1]We made the following experiment. We looked through the Google search engine after the following fragment of sentence: "influence of the internet on the academic habits". We obtained 1,140,000 results. Among them, the ready-made wiki.answers (wiki.answers is defined as: "Website that facilitates the answering of questions as well as allowing anyone to sign up and answer the questions of others. If you show exceptional skill, you might be recommended to be a supervisor, which allows to you to have the same power as a webmaster", see: http://www.wiki.answers.com, cited 18 March, 2009) Q.: What are the factors that influence study habits among high school student? A.: Factors influencing study habits among high school student are: socio economic, concentration, remembering, organising time, listening and taking notes, taking tests, motivation". It is an answer gave without further references and citations, attributed to a nickname. Could be

We want to mention that the application for contributing to this book and the constant dialogue concerning the structure and progress of the chapter was made on-line, as well as 90% of the documentation: identification of bibliography, download of articles, and purchase of the books necessary to cover the knowledge's gaps of the author on the matter. The dialogue for preparing this chapter was pursued exclusively via *MyNetResearch*, a social network designed exclusively for researchers and scientists on various domains, and via e-mail. The authors never met during the elaboration process of this book.

The quick development of the Internet-based tools and the growth of the social networks, mainly in the last 10 years, are extremely challenging for the academic world. The academic as well is adopting the Web 2.0 tools, including in areas traditionally not of public interest, as archaeology. This process is offering an impressive range of opportunities for widely spreading the results of the academic work to a well defined community of people interested, even if in some areas certain reticence still prevails (Samida 2006).

The definition of research, according to Cambridge (on-line[2]) Dictionary is "a detailed study of a subject, especially in order to discover (new) information or reach a (new) understanding". E-research represents a variant of this new way to act, understand and create knowledge, using mostly – if not exclusively – the tools offered by the Internet. These tools are used for improving, expanding and developing the network of the researchers, as well as for gathering new information and pieces of knowledge on various topics and distributing it further to a wider audience.

In the long history of knowledge, the basic principle beyond the e-research is not entirely new and entirely revolutionary. "E-research did not emerge from a political vacuum. In many respects, it is a return to centuries-old principles of open science in response to challenges wrought by changes in technology and social policy, especially with regard to intellectual property" (Borgman 2007, p. 44).

At the level of the educational policies, this area of research is considered lately a political priority, getting significant subsidies from the part of the governments. OECD countries are investing significantly in the research capabilities and associated coordinating mechanisms. E-research is part of governmental strategies aiming to improve and support the initiatives dealing with Web 2.0 techniques. The majority of the universities with high reputation – as Oxford – already built their e-research centers and created at various levels (university, M.A.) open-distance courses where students rarely or never meet as the bulk of their education is conducted via webcams, e-mail or Internet chat rooms.

First of all, what it is different in this new phase of the history of knowledge, in comparison with (only) a couple of years ago, is a new sense we attribute to the notion of time. Through the Internet you can check any time and very rapidly the

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took into consideration for an academic research? Or it is rather an argument for relying first on the academic standards already in use for writing a scientific article?.

[2]http://dictionary.cambridge.org, cited 17 March, 2009.

resources of the library or to order on-line a book impossible to find locally. Your application for a scholarship is made more in full knowledge of the conditions offered – available on the internet or following e-mail discussion with people in charge – and on the basis of the library resources at your disposal. You could write and make the proper modifications of your texts instantly, including using – for the foreign languages – text Thesaurus and on-line dictionaries. After writing, the results of your works might be distributed immediately. Moreover, in a matter of minutes, it is possible to identify the persons sharing the same academic preoccupations, independently of their geographical location. Time is equally an important criterion at stake when you chose (or not) to get involved in various on-line approaches and interventions, as, for example, to open a personal webpage or to make corrections of articles not meeting the academic criteria or to comment on articles published on the web. At the same time, you need to dedicate a significant amount of time for maintaining your on-line virtual community, to find people with similar interests and to identify the proper network according to your academic and scientific interests. The new universal skills an academic should appropriate are the ability to interact rapidly in instant conversations, as the permanent refinement of the searching word categories, in order to increase the chances to obtain the required information.

One important issue facing the academic research is the problem of the sources of reference. Previously, in order to get a proper documentation for an academic paper, the depository of knowledge was the library, the printed book, with known, academically confirmed authors, recognized as such by the academic community. The occurrence of getting trapped in superficial and inaccurate works was strictly limited, because the entrance certificate in the world of the knowledge, through the written word, was itself exclusivist and at least double-checked – by an academic title leading to an academic position in an university or a scientifically certified research centre. What you have now, in the era of Internet, is a huge amount of information with more or less known or confirmed authors – taking into account also the possibility of not using a real name and building a fake biography, including by introducing fake credentials. The materials you might find on-line could be erroneous, incomplete, outdated, biased or unsuitable for a serious academic research. Or simply the result of a copy-paste plagiarism initiative not detectable at the first sight, despite the sophisticated programs already designed in this aim.

The researcher, owner of diploma issued by a certified and accredited university center, is now becoming aware of the increasing competition of people able to use – and misuse – the freedom of expression on the net. The traditional publishing was based on "quality-control" criteria, with various levels of scrutiny before the final publication, while today anyone can publish virtually anything. Wikipedia, the anonymous Encyclopaedia is updated at every second by (mostly) anonymous/nick-named authors whose professional qualification is almost impossible to certify (Jones 2008). The outcome of their work is sometimes doubtful and subjective – when addressing current political or historical issues, for example –, but it is the first to appear at a preliminary search on the Internet. For a novice academic or student lacking the basic criteria and a previous knowledge, using such a source could affect the quality of the research. How could you counter the "amateurism"? negatively. The immediate reaction is important. Once a certified scholar is discovering false and inappropriate information, he might instantly access Wikipedia – given the accessibility system of posting – and make the required corrections. In this way, his action is serving the scientific accuracy. Afterwards, it is possible to monitor and control the additional modifications and intervene accordingly for making the proper corrections.

3 To Be or Not to Be in the Network

Another area concerning the new topics of interest for the researcher is represented by the social network sites. According to Boyd and Ellison (2007): "We define social network sites as web-based services that allow individuals to (1) construct a public or semi-public profile within a bounded system, (2) articulate a list of other users with whom they share a connection, and (3) view and traverse their list of connections and those made by others within the system. The nature and nomenclature of these connections may vary from site to site". What makes a social network site unique is by allowing individuals to meet strangers, but rather by enabling users to articulate and make visible their social networks. The www is offering various possible platforms for making research possible and strengthening the academic community. In the same way, there arises a series of questions and concerns related to privacy and limits of disclosure of personal information (Tufekci 2008). To the same degree, because exclusively – or mostly – centered on individual profiles, they could be a useful tool in self-promotion. Does a researcher need this? As long as he has something to say and knowledge to share, the answer is yes. In comparison with an anonymous websurfer, an academic is transparent in all the e-proceedings. (Though this does not preclude the academic hiding behind a nickname to attack contrary views of other academics.)

Some of the social platforms themselves surged as networks aimed for academics or students only, as is the case with *Facebook* which began in early 2004 as a Harvard-only SNS, later gradually expanding to include categories of age, gender or professional backgrounds (Boyd and Ellison 2007). For the members of the academic community, *Facebook* is offering the opportunity to create the own thematic group – including with restricted-membership, acquired on-invitation only. As well, you could share with your "Friends" or group, links of common-interest, articles, you could invite and distribute invitations for events, with an estimated audience (as long as the people invited have the opportunity to give an answer choosing whether "Yes", "No" or "Maybe" they will attend a given event). Via www.academic.edu – a network of academics organised across university categories – your academic articles could be uploaded instantly on *Facebook* and shared with your connections.

In fact, the social networks are developing and rapidly expanding the opportunities set shortly after the diversification of the Internet use. Only a couple of years back in time, before the current dramatic evolution of social networks, it was very easy for an academic to set up a *yahoo* discussion group on a specific theme. The coordinator of the group was selecting and accepting the members, moderate the messages and distribute useful information regarding upcoming conferences, call for publication, or scholarships. Those who were "in" were able to network and exchange information on various topics of interest, including requesting collaboration on projects or practical information for ground researches. These communications tools are still available, but their use is progressively decreasing, as other tools – are offering appropriate instruments to the needs of academics.

In addition, there are developed social networks strictly dedicated to the academic community members. *MyNetResearch* is designed as an academic network only, together with other nets as *Epernicus*, *Scispace.net, Academic.edu* or *Mendeley*.

What makes *MyNetResearch* different and, in our opinion, the fittest tool, by now, for academic collaboration, resides in its core concept. It was launched relatively recent, in May 2008, and most probably needs a more intensive campaign of advertising, including on the social networks platforms, in order to gather as much people interested as possible, not yet acknowledging its existence and the opportunities offered. Not a business network – as *LinkedIn* – or a social network – as *Facebook* – it is dedicated exclusively to academics and researchers across the world. The target is very well defined and, in comparison with the social networks, the academics have the advantage – on a free or paid membership basis – to seize opportunities within their very narrow area of interest. The framework in itself is common to a big majority of networks of this kind – forums, blogs possibility to enter in contact with people you know or you don't but with whom you share the same interests – but the content is fit only for those interested in academic research. Beyond the opportunity to search or submit jobs, to share ideas on the forums, you have the chance to find grants and other peers interested to take part at a project and write together the application and required documentation. This last feature is extremely important as it is going beyond the role of a platform for collaboration, but made possible the collaboration itself and encourages the exchange of ideas of an extremely wider scale, whatever the geographical location. In terms of academic freedom and ways to increase knowledge, it is, we believe, an extremely important step forward. In the process of preparation publication of an article, you have the "Bibliography Creator" option, allowing an easy set-up of your bibliography list, according to various writing style requirements. The criteria set for finding another academic researcher in your field of study are very strict and, thus, a greater opportunity to find what you are looking for. In other words, you win time and you are in the right place for reaching your academic goals; a system to report e-mails received as *spam* or *abusive* is limiting – eliminating it is almost impossible – the risks of unwanted correspondence while setting the standards of the required ethics. And, if you want to be part of this network – because it is free at a certain level and is trendy to be part of as many networks as possible, looking for friends, business partners, school friends or even a date, the chances to find an opportunity in this direction are almost zero. The search criteria for a peer academic review are rigorous and offer a high probability to obtain the expected results more rapidly according to: Research Interests, Teaching Interests, Geographical Region, Published Journals, Grants Awarded, and Additional Language. The information shared are varying from the articles on various domains – according to the usual review and publication policy, avoiding the temptations of amateurship – to exchange ideas on the forums – the newest feature of the network, introduced in the first half of 2009 – about the advantages and disadvantages of the academic research or tutorials for choosing a PhD topic. What will be needed in the future will be a more pro-active attitude from the part of the participants in this network, to share more ideas and results of their researches, in finding fellow researchers and going beyond the various kind of borders.

H-Net (www.h-net.msu.edu) is, according to its own presentation, "an international consortium of scholars and teachers who creates and coordinates Internet networks with the common objective of advancing teaching and research in the arts, humanities and social sciences". It enjoys the membership of over 100,000 subscribers from more than 90 countries, with sections related to *Book Reviews*, *Announcements* about coming conferences, *Call for Papers*, *Fellowships*, *Academic Jobs* all over the world. In comparison with the standard social networks, these special-targeted tools are expanding the possibilities of finding appropriate individuals to share valuable information and preoccupations, starting from the exclusive interest for developing and increasing the value of knowledge.

Another opportunity is offered by *LinkedIn*, designed as a tool for professionals from various domains, specifically those who know each other in the real world and are interested in maintaining a certain level of exchange regarding common topics, including events of common interest. You could set up your group, start discussions or networking for getting the best professional opportunities, make announcements about coming conferences or other professional events, and share information about the books read. There is room for academics too, but the possibilities to share information and maintain a permanent academic dialogue are still limited, as the primary target-group of this network is represented by the business community.

Twitter is almost the last new comer – by now, May 2009 – on the list of opportunities offered to the scientist to share results. Scientific reviews, newspapers and public institutions already opened their accounts here, announcing to their followers information about articles and up-to-date news. What a scientist could do, in the word limit of 140 bytes of length allowed by Twitter is to announce a conference, or an event or simply post information and a link about a study and results relevant to the group of "followers". It represents a way to inform about your activity and it could be an occasion, among others, to advertise yourself and the results of your work.

The *Feed* option offered by the majority of the websites could be beneficial for the scientists as well, offering the opportunity to get updated with information in real time about new reports in his or her relevant area of interest or new blog posts. In addition, the prospect to be connected to up-to-date information about topics of interest is made possible by the various news alert tailored according to selected key-words. In this case, new abilities are at stake, as long as the accurate selection of the wording is a guarantee of acquiring the suitable information. The searching abilities have to be improved constantly, as the access to valuable information is dependent to a great extent by the choice of the searching engines or specialized directories. An impressive number of documents are now part of the "deep Web". According to Bergman (2001), "Searching on the Internet today can be compared to dragging a net across the surface of the ocean. While a great deal may be caught in the net, there is still a wealth of information that is deep, and therefore unused. The reason is simple. Most of the Web's information is buried far down on dynamically generated sites, and standard engines never find it". He evaluated the extent of "deep Web" to near 550 billion individual documents, in comparison to one billion as contained of the "surface Web".

Another category in this new virtual world is made up by the networks devoted to books, as *Shelfari* or *ANobii*, where it is possible share with other people your reading preferences and to write book reviews. The same could be done on *Amazon.com*. In this area, the competition is among people who read as a hobby and those who read as a professional duty and write accordingly, respecting the principles of critical thinking. How do you reach an audience with a sophisticated language and various references unknown to the most part of the readers? Is it a worthy cause or pointless pursuit?

The increase degree of collaboration is rapidly expanding thanks to the Internet. Before the Web 2.0, there were millions of academic events taking part in various points of the Globe; nobody was able to hear about if not in the same geographical area . In an asynchronous way, nowadays, a researcher could at least find out the last discussions on the area of interest, he could find a program, and even be able to send a presentation and post a video presentation, when because of various reasons s/he is unable to participate in person. The chats with experts are playing almost the same role, to offer to a wider audience the opportunity to converse and to ask questions directly.

The vast majority of people, academics or not, are not able to travel too much, for personal, financial and other reasons. Through on-line the museums or open sources tools, the Internet is allowing open access to various archives of documents and digital photos. Even 3D and with a high degree of adaptability in terms of getting the maximum degree of visibility, it will never replace the pleasure to be in a museum. But, when we cannot enjoy this pleasure, we still could have access to knowledge and, at least when it is necessary, we are able to check certain detailed information on-the-spot. Using the Internet is, in this case, the most accessible and time affordable opportunity.

The challenges rose by the Web 2.0 are addressing as well the overall packaging of academic works. For example, if the presentations are distributed through *google.docs* application, you could even attach a short movie and make an illustrative selection of photos. The risk is that once you post it – for free – on the web, your information is not protected by any copyright and patent guarantee. Anybody could further use it and distribute it cost free, including under its own name, without any additional responsibility. The good news is that they are in use in various software programs designed to detect plagiarism, many of them already employed on a daily basis by universities and academic centres as well as by edition houses and academic journals. So, at least, the professional and made-for-profit use is significantly limited.

The same could be available for the system of the *Scholars* (http://scholar.google.com) and *Books* (http://books.google.com) sections from *Google*. The books and documents are digitalized, you could access parts of it, but for the full content you need to order them, including on-line – case in which an academic must have a minimum literacy in terms of Internet on-line financial operations. Of course, in many cases, only parts of a book could be studied – the sections available for free – and this possibility could encourage the mental lethargy. A book "read" as such could be inserted in the bibliography of a paper, or of a book, and this misuse is quite difficult if not impossible to be detected easily, if a face-to-face detailed discussion about the content of the book is not possible.

On *Flickr* it is offered the opportunity to share pictures significant for presenting certain aspects of the research, mainly in areas as arts, but not exclusively limited to it. In areas such as biology, medicine or archaeology, ethnography or anthropology (to mention only very few of them), posting pictures on specific topics could be beneficial for the research and the mention of the copyright is allowed. The same is available for *youtube*, by sharing movies and on-line presentations of speeches at various conferences, or videos and scientific movies.

4 Collaboration Without Borders

The people-to-people connection is easier and cost-free and this extended affordability is weighting the quality and intensity of the academic networks as well. *Skype* offers the option to connect for free and the majority of messenger systems provide the opportunity of discussions between two or more persons through voice-system or web-cams, in addition to the already classical writing chats.

Also, the Internet is shifting the hierarchies: it might be easier today for a student or junior researcher to address, in mediated-communication, a Ph.D. or a well-known scholar. The bulk of university professors and respected academics set their own Internet webpage, with references, CVs, e-mail address, presentations of activities and excerpts, or even full articles. Those interested are able to contact and discuss various common topics, as well as to look for academic advices. In this way, personal and academic decisions are easier to take and the time is not working against, but turned into an ally, as long as it is achievable to take a decision in a dramatically shorter period of time, based on detailed and right-from-the source information.

The quality and the coverage area of the research could be improved through by using various tools offered by the Internet. The utility value of the Web 2.0 tools is evident in the domain of human sciences, mainly in areas where the field and quantitative research are representing the core validity of the hypothesis. The results of the research could be distributed, at various stages of the investigation, via blogs – the new faces of the usual research diaries – a wider sample could be reached by e-mail or videoconferencing interviews, with subjects easily identified in common discussion groups. With the help of Internet tools – more or less cost free, as *Survey Monkey* – www.surveymonkey.com, or *Zoomerang* – www.zoomerang.com – it is less difficult today to set up a questionnaire and to cover a wide area of answers. The packages of qualitative data could be codified more easily thanks to special designated packages, as NVivo, XSight or ATLAS.ti. At the same time, we cannot neglect the ethical problems arising when it is about the agreement to use e-mails, as privacy is concerned and the consent of both parties involved in the dialogue should be given before delivering certain information for a wider audience (Murthy 2008). Another element you should take into consideration when starting such a project is the risk of receiving answers from people without appropriate academic qualifications, and with an identity impossible to certify. For the general economy of the theme, it could alter the basic details and further on, the general conclusions of the study. These are some aspects we must be aware of when choosing these tools.

Another chance made accessible by the new environment is related to the on-line courses and e-learning methods. You could learn now in the best schools and obtain the study diploma, in exchange or not, of a fee thanks to the distance learning system. One of the disadvantages is the lack of face-to-face contact with students, an important part of the pedagogical habits and a litmus test for any real-world teacher. On the other side, you have unlimited space – through the discussion forums – for openly sharing information and resources and creating, and thus, creating the sense of a community. MIT made available 1,900 e-learning classes, on a wide area of academic topics. Specialist or not, you have the opportunity to access tones of information, academically certified, with no registration fee. It will not prompt you to automatically obtain a diploma to a highly respected world university, but it will offer valuable information, right from the authorized source. On-line courses are used on a large scale from academia to international organizations aiming to train its members (Bélanger 2008).

The architecture of an article or of a research paper, and the compulsory references you need to include changed as well, without altering the basis for transmitting information and knowledge. The changes are aimed to increase the collaboration and exchanges between persons sharing similar interests and preoccupations, academics or simply people interested in a specific topic. In order to make possible a further contact for, possibly, additional information, you must provide an e-mail address. Also, the references are not only books and articles, but equally electronic sources. You should mention the last check of the webpage – day, month, and year, if possible – because any interventions and changes could occur on-line and you should specify the recent “historical” moment you accessed the aforementioned information. Also, by using the hyperlinks the reader has direct access to the sources, some of them opening various doors towards other information and knowledge-based facts. The Internet practices should influence a stylistic change and may increase the pace of sharing and writing information, without altering the content and the quality of the information transmitted.

Last but not least, our reading habits are subject to change: You read an article, you agree or not with the author or you have supplementary information or need clarifications of certain aspects. As long as you have the contact details of the author, you could instantly send an e-mail explaining your issue or approach. If the article is available on a website – newspapers or blog – it is possible to make an intervention on- the-spot through the comments section and in addition, you could instantly find people sharing similar preoccupations. The books are not only to be read, but could also be listened and watched and the printed material could be added with video and image content. The attention is becoming more and more distributive and the general structure of the written text adapted to various supports to conform to these new changes in perception.

You could do and write everything you are interested in on your own blog or your own website, deciding by yourself the length and the comments and the visual presentation of your works. The only essential requirement is an e-mail account, as everything is tailored in a technically affordable way. What are the effects of this democratization of science? In the academic world, it is rather the critical approach and the quick analysis of a certain statement, turned or not into another autonomous article, aiming to challenge the current focus. They are affordable (Graves 2007) and easily accessible and could potentially enjoy a broader category of readers, for free, something not possible in the case of academic articles and elite reviews. The information posted varies from political science information, to ongoing archaeological excavations[3] (Samida 2006). The blog could host an academic diary or any other information related to personal and academic references, the choice of the information posted being exclusively the author's (Gurak and Antonijevic 2008).

But, the general criteria followed in editing and posting the information remain the same – research quality and scientific accountability. The variables are the framework and the opportunities offered. The system of anonymous referees is to be kept as well for the on-line environment, for the on-line reviews or applications for conferences.

5 Conclusion

In conclusion, is it better to go back in the library and cut any connection with the Internet? Not exactly. Digital techniques represent intrusion and there still could be resistance. But the internet is a tool that has to be taken advantage of. You could make yourself the proper corrections – all you need is a Wikipedia Internet account. A comprehension of Web 2.0 is essential. Further, an academic blog or webpage

[3]http://www.catalhoyuk.com/, cited 17 March, 2009.

can allow the possibility of publishing findings quickly and at minimal cost without undesired waste of time.

The success (or not) of enhanced research productivity is contingent on the answers to the following questions: to what extent will the academic habits be influenced by the new Web 2.0 or Web 3.0? What are the challenges for the ways in which we address and produce knowledge? For the moment, the answers are not unequivocal. Historically, what we possibly will do in this very specific period of time is to gather and document a given situation. The answers are contingent on technological developments in the future.

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E-Research Collaboration and the Free-Rider Problem: Communication Solutions to Social Dilemmas in Computer Mediated Research Collaborations

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Abstract Collaborative scientific projects can be considered public goods dilemmas. This is a particular type of social dilemma, where short-term immediate self-interests are at odds with long-term collective benefits. Perhaps the best known solution to the free-rider problem in social dilemmas is communication between participants prior to making contributions to the public good. However, there is research to suggest that people contribute less to public goods while communicating on-line before the dilemma, as opposed to face-to-face discussion. This chapter will discuss why computer-mediated mediums of communication are less effective at improving cooperation amongst collaborators (e.g., lack of social cues to examine the credibility of commitment, less leadership, and poorer monitoring of other's behavior) and propose several means for addressing this challenge to on-line collaborations (e.g., video-conference, telephone communication, prior face-to-face interactions, frequent coordinated communications, and reputation evaluations).

1 Introduction

Zarelda, a political scientist, is preparing a grant proposal on the topic of communication and conflict resolution. She understands that the best approach to studying this relationship is via multiple perspectives and methods across disciplines. She joins an online research community (e.g., MyNetResearch) with hopes of finding three potential collaborators. Zarelda finds three interested scholars and sends an email outlining the work for each individual, emphasizing the grant is due in 2 months. One week before the deadline, Zarelda notices that two of her collaborators

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are not fulfilling their promised contribution to the project. Instead, their work is cursory and contains several errors. In the end, Zarelda feels frustrated, has a poor grant prepared for her project, and later the grant is rejected.

The problems experienced by Zarelda may be common to internet collaborations. Certainly, it is exciting that the internet is making possible communication between scholars across nations and disciplines, without ever meeting collaborators face-to-face. Such collaborations are a welcomed change, but there are some challenges unique to these internet collaborations. Although Zarelda's problem with others' lack of effort can occur in any collaborative research project, it may be that the problem is more profound in the context of internet collaborations. In particular, internet collaborations may often fall prey to the free-rider problem – which occurs when individuals put less effort towards a research project, and free-ride on the efforts of their collaborators.

All collaborative research projects can be considered a social dilemma. A social dilemma occurs when immediate self-interest conflicts with long-term collective interest (Kollock 1998). For example, in Zarelda's research project, it is in the others' self-interest to allocate less time and effort reading, writing, and thinking about the current project, and to spend their time and effort otherwise, all the while free-riding on the efforts of their collaborators. However, if all group members behave this way, then everyone fails to gain the collective benefit (e.g., a quality grant proposal). Much research in the social sciences has attempted to understand and resolve the free-rider problem. Examining this research, one factor emerges supreme in resolving the problem: communication.

Much research supports the general conclusion that communication before the dilemma enhances cooperation amongst group members in the dilemma (Dawes et al. 1977; Kerr et al. 1997; Orbell et al. 1988; for review see, Balliet 2010). However, there is also research that suggests face-to-face communication is more effective than other forms of communication, e.g., written messages, email, or chat groups (Balliet 2010; Bos et al. 2009; Frohlich and Oppenheimer 1998; Rocco 1998). This poses a particular problem for internet collaborations. While these collaborations may still pose a social dilemma, the means of communication in these social interactions are less effective in resolving the free-rider problem. In the following, I will briefly address the relevance of social dilemmas to internet research collaboration, discuss theory and research on the effects of communication in social dilemmas, outline the particular shortcomings of communication during internet collaborations, and lastly overview potential solutions to these challenges.

2 Social Dilemmas and E-Research: The Free-Rider Problem

Internet research collaborations can be classified as a public goods dilemma, a type of social dilemma. The public good in this context is the research output, e.g., a grant or publication. The publication is dependent on group members allocating time, effort, and resources to the project. This is a social dilemma, because it is in each individual's self-interest to not contribute to the project, but to reap the rewards of the research output. However, if all members act this way, then there is no collective reward of research output. This is known as the free-rider problem and has been studied across disciplines in the social sciences. In fact, many social problems are public goods dilemmas, e.g., building a road, support for social programs, and donations to public television or radio. Some of these problems are easily solved by restructuring the rewards and punishments of non-contribution, e.g., a tax system. However, such formal systems are often not in place while we interact with others on collaborative research projects. To our benefit, research has provided many alternative solutions to the free-rider problem.

The free-rider problem can be addressed, broadly speaking, by either motivational solutions or structural solutions (Kollock 1998). Motivational solutions (e.g., the formation of group identity) appeal to an individual's concern for others outcomes in social dilemmas, while structural solutions (e.g., punishment) involve changing the rules and outcomes in the social dilemma. In fact, research has identified several motivational and structural solutions to social dilemmas. For example, it is well known that free-riding increases in larger groups (Kollock 1998), and therefore a structural solution to a dilemma can be reducing the group size. A project leader for an internet research project may be sensitive to this and only add additional collaborators to a project as needed. Other methods might simultaneously provide a motivational and structural solution to the dilemma, e.g., communication. Indeed, communication could be a particularly useful strategy for E-researchers to resolve the social dilemma of online research collaboration. It is well known that communication prior to a social dilemma reduces free-riding in the dilemma (Deutsch 1958; Balliet 2010). However, face-to-face discussion is more effective at reducing free-riding compared to written or computer-mediated communications (Balliet 2010). This could pose a particular problem to resolving the social dilemma of online research collaborations. To understand the limits of communication affecting free-riding in the online environment, we must consider both theory and research on communication in social dilemmas.

3 Communication and Cooperation: Why Does Communication Matter?

Deutsch (1958) initially found that allowing participants to briefly discuss the social dilemma greatly enhanced cooperation, compared to a no discussion condition. Since his seminal work, several researchers have replicated and extended these findings to many types of social dilemmas, including public goods dilemmas (Dawes et al. 1977; Kerr et al. 1997; Orbell et al. 1988). Indeed, as supported by a meta-analyses of 45 studies, communication has a strong positive effect

($d = 1.01$) on cooperation in social dilemmas, compared to no communication (Balliet 2010). Researchers have proposed several alternative explanations for the effect of communication on cooperation, e.g., a better understanding of the dilemma, enhanced group identity, more positive expectations of cooperation from others, and making salient a norm of promise keeping or a benevolent norm of cooperation (Kerr et al. 1997). Perhaps the most supported explanation has been that communication provokes a norm that guides cooperative behavior. A norm is a rule that guides behavior that is not supported by any type of formal sanctioning system (Bicchieri and Lev-On 2007). For example, Bicchieri (2002) proposes discussion makes salient the social norm of promise keeping. Specifically, this norm is thought to direct behavior only when people expect others to cooperate in the dilemma. In line with this perspective, Orbell et al. (1988) found that groups with leaders that pushed the agenda of getting everyone to make promises were more likely to keep those promises. Bicchieri (2002) refers to promise keeping as a social norm, which implies that the norm only directs behavior in a social context, when others are able to evaluate one's behavior according to the norm.

Kerr et al. (1997), however, provide some evidence that the norm that guides behavior is not a social norm. Instead, it can be a personal norm that directs behavior. This would have important implications, because a social norm might only be followed when participants have a chance to be observed and sanctioned by their group members. However, there is no need for the monitoring or sanctioning of behavior directed by personal norms, since people will likely self sanction themselves, e.g., feelings of guilt, if they violate their own personal norms. If discussion induces a personal norm, then people should be just as willing to donate to a public good after discussion regardless if their donation is anonymous or non-anonymous. Kerr et al. (1997) observed contributions to a public goods dilemma when participants were either randomly assigned to a no-discussion/anonymous, discussion/anonymous, or discussion/non-anonymous condition. While discussion still increased cooperation, relative to the no-discussion condition, there was no statistical difference in contribution between the discussion/anonymous and discussion/non-anonymous conditions. Therefore, the norm of promise keeping may be a personal norm that individuals adhere to regardless of the potential social sanctions for norm violations. As we will see below, this may have important implications for understanding how communication in the online social dilemma of collaborative research projects can be used to reduce the free-rider problem.

Given that prior research supports a norm-based perspective on the effects of communication on cooperation in social dilemmas (Bicchieri 2002; Biel and Thogersen 2007; Kerr et al. 1997), I will anchor on this perspective while considering some specific challenges faced by online research collaborators and some potential solutions to these problems. Indeed, research does suggest that more troubles may arise regarding the free-rider problem in online communication domains, relative to more traditional forms of collaboration (Rocco 1998).

4 Computer-Mediated Communication: Specific Challenges to Social Dilemmas

Research on communication in social dilemmas has manipulated communication as either face-to-face discussion or written messages, e.g., written notes or via computer. In fact, a dearth of research has systematically compared these two types of communication. The few studies conducted on this topic have resulted in inconsistent findings. Some research finds that face-to-face discussion increases cooperation, relative to email or written messages (Bos et al. 2009; Frohlich and Oppenheimer 1998; Rocco 1998). However, other work finds that there is little to no difference between these two types of communication (Zheng et al. 2008, 2009). In a meta-analytic review of the effect of communication on cooperation in social dilemmas, Balliet (2010) found that face-to-face discussion had a much stronger positive effect on cooperation, relative to written notes or other forms of computer-mediated written messages. There are four reasons why face-to-face discussion results in less free-riding than written computer-mediated communication.

Bicchieri and Lev-On (2007) suggest that in face-to-face discussion the social norm of promise keeping is more salient, relative to other computer-mediated forms of communication, which lack some of the situational features that make salient the norm of promise keeping. They cite a lack of leadership during online communication as an important difference that can affect the norm of promise keeping. Orbell et al. (1988) found that groups with a strong leader who encouraged others to make promises were most successful in reducing free-riding behavior. However, it should be noted that these studies were conducted with strangers and no group was assigned a leader. During research collaborations, the principle investigator often takes leadership responsibility. However, there may still be circumstances when a leader is less clearly defined in online collaborative projects, e.g., when the principle investigator lacks leadership skills. The benefits of leadership overlap with the second reason online communication during social dilemmas results in greater free-riding: That there is often a lack of punishment for free-riding behavior in the online environment.

There is evidence and theory to suggest that discussion can either elicit a personal (Kerr et al. 1997) or social norm (Bicchieri 2002; Biel and Thogersen 2007). If a social norm occurs, then this social norm would be more likely to direct behavior when there is some type of monitoring and sanctioning system for behavior. Indeed, there is evidence that the opportunity to observe and punish other's choices in social dilemmas adds to the effectiveness of communication (Ostrom et al. 1992). While, Ostrom et al. (1992) find that discussion alone does enhance cooperation, relative to no discussion, in a social dilemma, allowing participants to punish free-riders increases cooperation levels beyond cooperation levels when only discussion is allowed. Therefore, the relative ineffectiveness of online communication in resolving social dilemmas might be in part due to a lack of an effective monitoring and punishing of free-riding behavior. It may be useful to monitor other's behavior, but are there cues that we can use to predict when a person is likely to cooperate or free-ride? Research on the sight, sound, and touch of others suggests that these stimuli may carry important information relevant to assessing another's commitment to a group project.

A third difference between face-to-face discussion and computer mediated communication is due to the lack of important information provided by the physical presence of our collaborators. Bicchieri (2002) suggests that the norm of promise keeping will only direct behavior when there is adequate information that the other's will also cooperate in the dilemma. Therefore, people do not blindly adhere to this norm and may scan the environment for cues relevant to assessing the credibility of their group members commitments to cooperate. Some of these cues that are used to examine the credibility of another's intention to cooperate may be non-verbal communication. In many forms of online communication, there is a lack of important non-verbal social cues available, e.g., facial expressions, eye gaze, tone of voice, and body posture. Kurzban (2001) discovered two non-verbal social messages, oblique eye gaze and touch, both increased contribution to a public good. In fact, only being able to see the other in the dilemma can increase cooperative behavior (Boone et al. 2008; Wichman 1970). Moreover, Wichman (1970) found while only hearing the other can raise cooperation to levels observed in conditions when individuals are able to both see and hear the other, simply seeing the other still slightly increases cooperation relative to a control condition. Therefore, the absence of seeing and hearing the other in computer-mediated communication may equate to less information in assessing the credibility of others commitments to the project. Without this information, people may be less inclined to expect their group members to cooperate and therefore will be less likely to direct their behavior according to the norm of promise keeping.

There are also other, more practical, differences between online communication and face-to-face discussion that might explain the differences between the effectiveness of these two types of communication. It is well known that face-to-face communication can be more dynamic and fluid than some forms of electronic computer-mediated communication. The dynamics of face-to-face discussion may allow individuals to more accurately address the important issues and concerns raised in social dilemmas (Rocco and Warglien 1996). If communication occurs via messages being sent back and forth between individuals (e.g., a chat group), key issues may be lost and the group may not sustain discussion of the most pressing issues to each individual. Therefore, face-to-face discussion may simply promote more cooperation in social dilemmas, compared to computer mediated forms of communication, because it (1) allows for better leadership, (2) enables a more effective monitoring and punishment system of non-cooperative behavior, (3) provides non-verbal cues to assess other group members intentions, and/or (4) it has more established rules directing the conversion that allows each members primary concerns to be addressed.

5 Solutions to Overcoming the Problems of Computer-mediated Communication

The above research and theory clearly outline a problem for researchers involved in online collaborative research projects. The communication that occurs online is simply less effective at reducing free-riding behavior. However, there are a few steps that can be taken to circumvent this problem. These solutions include (1) using a mixture of communication mediums, (2) frequent coordinated meetings to discuss research progress, and (3) integrated punishment and reputation-building mechanisms in online collaborative research forums. The merits of these solutions will be considered in turn.

Communication Medium. Of course, recommending researchers to have a face-to-face discussion prior to online research collaborations may contradict the benefits of these projects. However, there are few reasons to suggest that it does not and some alternative approaches can side-step this concern. First, it is imperative that researchers coordinate their efforts, because a lack of coordination may result in greater effort spent on a project, relative to if each researcher were to conduct the project on their own (Finkel et al. 2006). Therefore, in the absence of sound coordination and planning it might be counterproductive to engage in online research collaborations. With this in mind, the benefits of online research collaboration may only come at a cost of establishing alternative means of communication prior to effective online collaboration. Second, there are alternative means of communication that are relatively costless, but still as effective as face-to-face discussions in reducing free-riding behavior.

To start, the gold standard of communication in social dilemmas is face-to-face discussion. Rocco (1998) observed the decisions of people in a six-person social dilemma when participants were either allowed to communicate using electronic mail or with face-to-face discussion. Rocco found that the electronic mail condition resulted in substantially greater amounts of free-riding, a phenomenon she termed “electronic opportunism”. However, in a second study, Rocco found that if the group was allowed to socialize for a brief period prior to electronic communication in the social dilemma, then there was a relative reduction in free-riding behavior. These results are promising because they suggest that an initial meeting prior to engaging in a long-term online collaborative project will help reduce free-riding while interacting online. These face-to-face discussions could be coordinated by attending similar conferences or taking advantage of grants. However, one of the main benefits of online research collaboration is that it reduces a need for the expense of meeting face-to-face. The few studies systematically examining the effects of different communication mediums on free-riding in social dilemmas finds that video conferencing and telephone communication may reduce free-riding, compared to emails or written messages.

Bos et al. (2009) find that individuals allowed to have a videoconference during the social dilemma was statistically more cooperative, compared to when participants communicated in an internet chat room. Moreover, the videoconference condition was just as cooperative as a face-to-face discussion condition. Also, the videoconference and face-to-face discussion groups reported greater trust of the other two members of their group, relative to the chat room condition. Brosig et al. (2001) also find that a videoconference, while being not statistically different than a face-to-face discussion condition, resulted in greater cooperation than a no communication condition. However, these researchers did not compare videoconference to an alternative computer-mediated form of written communication. Taken together, these results suggest that a videoconference, which is easily coordinated given the accessibility of the current technology, can be a successful alternative communication medium, especially while coordinating the initial efforts on a project.

Is telephone communication more effective at reducing the free-rider problem compared to text chat or email? Jensen et al. (2008) suggest that it is. In their research, dyads were asked to make several decisions in a social dilemma while being randomly assigned to one of four communication conditions: no communication, text chat, text-to-voice, and discussion via speakerphone. They found that a speakerphone resulted in greater levels of cooperation relative to both the text chat and no discussion conditions. However, the text-to-voice condition resulted in only marginally significantly more cooperation compared to the no communication condition. These data give credibility to the effectiveness of telephone communication in reducing free-riding behavior. These data also highlight the necessity of hearing the other's voice. Again, this study is not exceptionally clear if text-to-voice technology will help in reducing the free-rider problem. Importantly, this condition did not result in statistically less free-riding behavior than the text chat condition.

The studies mentioned above highlight two forms of communication that may reduce the free-rider problem: videoconferencing and telephone. These forms of communication might best be utilized at the beginning of collaborative research projects. Afterwards, it might be most cost effective to continue online discussions via email or chat rooms. However, it might be best to come back to these other successful forms of communication periodically during the ongoing project.

Sub-Project Goals and Monitoring Progress. In a meta-analysis, Balliet (2009) found that there was not a statistical difference in levels of free-riding behavior between having communication only prior to the dilemma and communication allowed during the dilemma. However, these findings may be relatively limited to the context of laboratory studies, which only last an hour and so might not capture the dynamics of long-term collaboration projects. There are a few reasons to suspect that the establishment of sub-goals and periodic meetings via videoconference or telephone will increase collaborative effort in achieving project goals. To begin, frequent online meetings will enable an assessment of current progress and may bring to light any lack of effort by specific group members. These meetings may affect free-riders in two ways. First, Miettinen and Suetens (2008) find that individuals who made promises to cooperate in a social dilemma, but then later defect, tended to feel guilt in response to learning that their partner cooperated. Therefore, not only will frequent meetings enable an assessment of progress towards group goals, but may also motivate others who have failed to deliver their promised component of the project to increase subsequent efforts. Guilt has been associated with prosocial motivations in much prior research and would likely promote subsequent cooperation (Ketelaar and Au 2003).

Periodic meetings using videoconference or telephone may also help prevent free-riding behavior by allowing individuals to express their reasons for free-riding behavior. Often individuals do have the intentions to cooperate on a project, but various circumstances may arise to prevent them from working on a project, e.g., a sick family member and other pressing work obligations. If other group members perceive the lack of effort as intentional, this may result in a spread of free-riding amongst other group members. However, research demonstrates that if individuals intend to cooperate and external circumstances prevent them from doing so, then communication reduces the spread of free-riding behavior, relative to when no communication occurs between group members (Tazelaar et al. 2004). Therefore, periodic group meetings will help prevent the spread of free-riding behavior in a collaborative group if individuals perceived as free-riders are able to provide adequate reasons why they were unable to act on their cooperative intentions and promises.

Besides using telephone or videoconference to update progress, blogs and email may be an efficient, cost effective alternative to monitoring progress towards group goals. Using these computer-mediated methods of communication for updating progress has a few advantages. First, not all members need to be present at the same time. This may be especially important in the case of international collaborations. Second, since they require less time, effort, and coordination, a more frequent schedule of updates can be utilized to monitor progress. For example, a group of collaborators may make an agreement to update a blog at the end of each week detailing their progress on the project. This strategy will raise awareness of any individual who begins to free-ride and reduce effort. If this is the case, then the threat of punishment and/or impacting the reputation of the free-rider may increase their level of cooperation.

Punishment and Reputation. Another possible means for improving cooperation in online research collaborations is by excluding free-riders from group projects and being able to assign reputation points to fellow researchers. As some prior research demonstrates, communication combined with a possibility for punishment results in greater levels of cooperation compared to only communication or punishment alone (Ostrom et al. 1992). It might be that simply including an option for project leaders to drop non-contributors from projects may be enough to motivate project members to engage effort. However, prior research has found that the threat of being excluded from a group can have negative psychological effects on those potentially being ostracized (Richman and Leary 2009), and this can lead to even less cooperation during subsequent interactions (Twenge et al. 2007). Therefore, the exclusion, or even the threat of exclusion, of free-riders is recommended as the last option.

More importantly, online research collaboration forums can allow researchers to explicitly evaluate the past performance of their collaborators, which is then tagged to their collaborators profile, thereby enabling the development of reputations, and this is known to increase levels of cooperation (Milinski et al. 2002). For example, MyNetResearch allows researchers to evaluate their collaborators on a scale from 1 to 10 (with 1 = to the most negative evaluation and 10 = the most positive evaluation). These evaluation scores can be averaged over time. In fact, just the awareness of a possible negative evaluation can motivate free-riders to cooperate (De Cremer and Bakker 2003). Therefore, allowing people to systematically share information about their collaborators, and so impact their collaborator's reputation, can facilitate cooperation amongst group members. Also, this can be a mechanism that enables other researchers to avoid interactions with collaborators who have defected on previous projects.

Written online communication may not be as effective in resolving the free-rider problem of online research collaboration, but all hope is not lost. As shown above, surveying the literature on communication and cooperation in social dilemmas makes several suggestions regarding how to sustain cooperative collaborative relationships. First, using alternative means of communication (e.g., videoconferencing and telephone) capitalize on some of the shortcomings of online communication. The alternative communication mediums both enable the dynamic rule-based communication that occurs in face-to-face discussion and make available social cues to assess others intentions to cooperate. By using these communication mediums periodically marking progress throughout the research project, this may provide better oversight of others efforts and allow for collaborators to provide reasons for their failures to meet deadlines. Lastly, the establishment of a mechanism that enables individuals to develop reputations in online research forums can enhance cooperative efforts and allow other's to avoid interactions with free-riders. Taken together, these strategies should help researchers overcome the limitations of written online communication in resolving the public goods dilemma of collaborative research projects.

6 Conclusion

The promising benefits of online research collaboration are met with additional challenges – one in particular is the exacerbation of the free-rider problem in the public goods dilemma of research collaboration. Although, communication is one of the most effective situational features of social dilemmas that can enhance cooperation, there is evidence to suggest that online communication, compared to face-to-face discussion, is less effective at resolving the free-rider problem. The lack of effectiveness of online communication may be due to a lack of leadership, less effective monitoring and punishing of free-riding behavior, fewer non-verbal social cues to assess the credibility of others commitments, and/or the lack to norms guiding an effective discussion of the dilemma. To overcome this challenge, it is suggested that researchers consider video conferencing, telephone, and periodic project meetings assessing progress using these forms of communication, in lieu of always using email or online chat as the medium of communication. Research forums facilitating online research collaboration can also consider integrating reputation-building mechanisms that monitor past behavior of collaborators. Applying these strategies should decrease subsequent free-rider behavior and encourage cooperative productive research collaborations.

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Knowledge Sharing by Web 2.0 in Real Estate and Construction Discipline

Rita Yi Man Li

Abstract Gone are the days when face-to-face was the only means to share knowledge. The birth of Web 2.0 allowed both the internet users and website owners to share their knowledge rapidly. Inspite of all the advantages brought by these new technologies, not all the people in real estate and construction discipline use Web 2.0. This book chapter has two major objectives: (1) review the use of Web 2.0 technology for knowledge sharing, and (2) discuss the reasons for the resistance and the benefits.

1 Introduction

The rising tide of internet users stimulated web designers to develop better online resources. Quite a number of tools are developed nowadays to enhance the interactivity of the World Wide Web. While Facebook has its origin in 2004, others such as wikis dated from the mid-1990s (Myhill et al. 2009). The revolutionary technological breakthrough of Web 2.0 has turned a new page on knowledge sharing. The importance of traditional ways of knowledge sharing methods such as face-to-face contact, letter-writing, phone calls, all but disappeared in the 1990s with the birth of the internet revolution. The new millennium marks the commencement of "co-authorship" of knowledge by internet users. Authoritarian web content can no longer satisfy the needs of hungry knowledge seekers.

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2 Web 2.0

The term “Web 2.0” is not new and has been around for 5 years (Tredinnick 2006). Since O’Reilly coined the term “Web 2.0” in 2004, numerous definitions of Web 2.0 have proliferated (Myhill et al. 2009). The commencement of the age of Web 2.0 overturned the traditional mode of publishing in Web 1.0: control of content in websites no longer lies in the hands of web owners but all the internet users. Technologies facilitate the extraction, use and reuse of data and information in a flexible manner, Information services have become more dynamic and sensitive to users’ actions. Web 2.0, generally speaking, is the product of real use, application and need, not the idealized use concerned solely by the website owner. Characterized by the kind of trust built between website owners and other internet users, user-participation in Web 2.0 created a new pool of information sources.

It reflects collective use by all the internet users over time, rather than reflecting the website owner’s preferred view. (Tredinnick 2006). Although Web 2.0 is not particularly new or novel (Myhill et al. 2009), literature on Web 2.0 in academic research is still limited.

Tim O’Reilly (2005)) suggests that the true test of a Web 2.0 service relies on an amalgamation of some or all of the following features:

1. Control over unique, hard-to-recreate data sources that get richer as more people use them
2. Connect collective intelligence
3. Cost-effective scalability services, but not packaged software
4. Lightweight user interfaces, development and business models
5. Web users are co-developers
6. Software is used above the level of a single device (Myhill et al. 2009)

Differences between Web 1.0 and 2.0 can be found in Fig. 1.

Web 1.0	Web 2.0
Double Click	Google AdSense
Akamai	BitTorrent
mp3.com	Napster
publishing	Participation
personal websites	Blogging
page views	cost per click
screen scraping	web services
Content management	Wikis management system
Taxonomy	Folksonomy
Britannica Encyclopedia	Wikipedia
Ofoto	Flickr

Fig. 1 Web 1.0 and Web 2.0 (O’Reilly 2005)

3 Knowledge and Knowledge Sharing

A mixture of values amalgamating social context, experience and expert insight gives rise to Knowledge. Generally speaking, knowledge can be classified as tacit and explicit. Tacit knowledge is acquired by the act of copying and explicit knowledge is acquired through rules and guidelines in codified form (Lin and Lee 2004). The concepts of tacit and explicit knowledge highlight one important fact, namely, that the process of knowledge-information transformation is a matter of codification (Tredinnick 2006). Absorbed by the members of organizations and societies, understanding and knowledge is demonstrated by members' acts (Dulaimi 2007). Conceptualized as a complex process, knowledge is the product of people's interpretation on how things work based on the elaboration of previous experiences in memory. New experiences are constructed or evaluated by using previous experiences as a base. In fact, personal constructs are the parameters used by a person to describe the conceptual structure of their environment derived from past experience and to interpret new experiences in terms of existing structures (Waitt and Head 2002).

Knowledge sharing is an indispensable element for individuals to learn (Li and Poon 2009). Knowledge sharing refers to the process of ideas or thinking refining and modifying based on past experiences. Knowledge sharing is different from but related to communication (Tredinnick 2006). Presuming knowledge owner and sharer co-exists, knowledge owners externalize their knowledge and knowledge sharers internalize knowledge. Such processes need not be conscious; many circumstances involve unconscious acts and the knowledge externalizers might not have an intention to share what he knows. For example, assume a man cooking in the kitchen; his son observe this and learns how to cook. This man may not have intention to teach his son, but he shared his knowledge successfully with the acquiree (Li and Poon 2009). To accomplish knowledge sharing, knowledge reconstruction is required. Knowledge can be shared by traditional face-to-face interactions as well as synchronous and asynchronous communication by electronic media (Tredinnick 2006). People may share knowledge because they share similar interests and engage in similar activities thus acquiring the similar skills. (Soneryd 2004).

To achieve the goal of effective knowledge sharing, "people" and "technology" are the two major elements. Previous research on knowledge management has recognized the importance of E-tools as an important knowledge sharing facilitator. Knowledge exchange among stakeholders generates new knowledge which can improve their capability in turn. The process of, learning thinking sharing and knowing has a reciprocity relationship. While the act of knowledge sharing and creation lead to knowledge appreciation, knowledge depreciates when (1) knowledge becomes obsolete; (2) knowledge owners fail to share their knowledge before they meet their receivers; (3) sharing activities occurs among a small circle of people and the rest do not know (Yang 2007). Although it seems easy to share knowledge, it is often difficult to motivate those knowledge owners to externalize their own knowledge due to various barrier (Li and Poon 2009). The digital era nowadays has not only bought us to a new environment, it also provides an alternative way to share knowledge in a much more rapid way and destroy the geographical location barrier effectively (Li and Poon 2009).

4 Web 2.0 Technologies

Characterized by open communication, authority decentralization, and the freedom to share and re-use Web content, many new technologies have emerged under the Web 2.0 umbrella, e.g. really simple syndication (RSS), wikis, blogs, AJAX and API programming, streaming media, open source software, user driven ratings among others (Barsky 2006).

4.1 Blogs

Probably the oldest form of Web 2.0, weblog appeared initially in the mid 1980s as the simplest way of web publishing (Tredinnick 2006). The number of blog users has increased dramatically from a few hundred in 1999 to 29 million in 2006. Initially used as online diaries, such as Xanga, Yahoo Blog, Showhappy etc, it gradually became an information platform for knowledge sharing because of its ease and low cost in information publishing. The chat boxes available on blog allows readers to input their own thought and idea immediately after they read the passage, and makes it interactive and participative in nature (Tredinnick 2006). Some of the professors and lecturers in real estate and construction discipline have already put their blog as one of the major means in sharing the knowledge in alternative ways, e.g. Dr. Edward Yiu from The University of Hong Kong shares the latest development in real estate development in his blog in http://hk.myblog.yahoo.com/ecyyiu, Dr. Christopher Preece from International Islamic University Malaysia has written blog on quantity surveying issue in http://www.christopherpreece.blogspot.com.

The popularity of blog in knowledge sharing can be explained by its convenience. Blog software usually contains built-in templates; bloggers do not need to have prior knowledge on HTML coding to create their own web pages. Those have learnt how to write and design web pages on their own, will also know they need to apply for space on the internet. Even though popular servers such as Yahoo! has provided free space to their subscribers, all the web designers have to spend their valuable time on applying for a space. After deciding the username, password, title and template for the blog, a profile of the writer can also be created. The birth of the blog not only signifies a new age in knowledge sharing, it also brings in a new dimension on how to locate people with similar interests. A survey conducted in January 2005 by Pew Internet and American Life Project indicated that less than one-third of Internet users read blogs in 2005; however, within a year, 58% more people wrote blogs (Barsky 2006).

4.2 Wikis

Emphasis on participation is even more evident in wiki. Similar to blog, Wikis are a simplified means of web publishing (Tredinnick 2006). A wiki is a good means to provide collaborative web pages where all the users can contribute or modify content. As they have open access philosophy, wikis are susceptible to "virtual vandalism" in absence of controlled membership. Therefore, many wiki websites have membership and editorial systems to guard against unauthorized rabble-rousing or controversial content specially designed to provoke comment, or the so-called "trolling" act. Some web sites, e.g. wetpaint (www.wetpaint.com), provide a costless and convenient way of establishing a collaborative wiki website where individuals are invited to contribute and build their own group-orientated content (Myhill et al. 2009). Supported by open-source software, Wiki relies on server-side processing capabilities to convert the content into HTML. Unlike blog, wiki supports the creation of full-scale websites with its combination of authoring tools, audit trails and templates. The central idea of wiki is a tool which aims at achieving the goal of collaborative authoring. Wikis allow users to edit the web pages they browse: power to edit and update information is left to users. Public wikis such as Wikipedia (http://www.wikipedia.org) have demonstrated how this approach benefits information resources creation and management, resulting in stable and credible content (Tredinnick 2006). Real estate Wiki (http://www.realestatewiki.com), for example, provides an effective means to share knowledge via question and answer by home purchasers, sellers or even mortgage providers.

4.3 RSS feeds (Really Simple Syndication)

RSS is a way of making web content by means of content feeds, consisting of XML marked-up files. RSS usually combines the lead paragraph, or a summary of an article published on the web or on a blog and hyperlink them back to their source (Tredinnick 2006). An RSS feed provides an unobtrusive means of updating web content. By clicking on the relevant link, users will receive the latest information updated from the publisher. RSS is a common, effective and rapid means of spreading news and is highly suitable to update researchers with regard to search for their research funding. The Dubai Real Estate (http://rss-dubai.com/blogs/index.php/Real-estate) for example. provides RSS feeds on a variety of aspects of its new residential development project which includes payment methods and facilities provided by the dwelling developers. RSS is also the major method adopted by the UK Research Funding Councils (http://www.rcuk.ac.uk) in sharing news (Myhill et al. 2009).

4.4 Professional Web-Based Communities

Developed as an important means for amassing organizing and disseminating knowledge, professional web-based communities collect individual pieces of knowledge to become a "pool of knowledge". Pooling of knowledge and experiences among group members can provide more choices on both decision making and problem solving. Web-based communities can also be treated as a kind of social networking behavior which enables participants to participate actively within the process of knowledge creation and communication. By way of this, people can meet others with similar interests around the globe. Besides, web-based communities can resolve the problem of geographical location effectively (Li and Poon 2009). It can be accessed by notebook computers or even mobile phones with web services. Whether you are sitting in the dark corner of the coffee shop, noisy underground transport, or quiet study room, you are welcome to get access to these web based communities easily. Group creators and members of the group members in Facebook can share video chips and photos, post a question on discuss board or even invite people within the group for collaboration (Li and Poon 2009). Facebook (http://www.facebook.com), one of the most famous social websites, allows individuals to select and join a group of people with similar interests. There are more than 140 million members in the world with a Facebook Account. Compared to traditional email group lists, this method is on-going and multidirectional. A single user can share and match personal profiles and subsequently become part of a wide range of different user groups (Myhill et al. 2009). Table 1 and Table 2 provide some sample usage on real estate and construction by Youtube and Facebook.

Table 1 Communities in Youtube

Name of the videos	Target audience	Website
U.S. Builders Group Safety Training 09	Builder	http://www.youtube.com/watch?v=_7gTRVDJK94
OSHA 30-Hour for Construction	Builders	http://www.youtube.com/watch?v=gX_jBqju0zg
Module 2 Lecture-1 Role of Material in Construction	Construction practitioners	http://www.youtube.com/watch?v=R2dNp5tLni0
Module 3 Lecture -1 Concrete: Material	Construction students	http://www.youtube.com/watch?v=uPAE2ZcFdo4
Real Estate Bubbles and California's Economic Growth	Real Estate students	http://www.youtube.com/watch?v=uyOWuczlJCA

Table 2 Communities in Facebook

Name of the group	Target audience	Website
Professional Networking	Real estate professionals in the industry	http://www.facebook.com/group.php?gid=9642713439
Construction safety	Construction safety practitioners	http://www.facebook.com/s.php?ref=search&init=q&q=construction%20safety&sid=2ae715893c12ba9dde83e754e518eb7b#/group.php?sid=2ae715893c12ba9dde83e754e518eb7b&gid=12787725326&ref=search
Construction Management Researchers	Researchers in construction management	(http://www.facebook.com/ext/share.php?sid=15576086035&h=HuGrn&u=qsTWm
International Real Estate	Real Estate Investors	http://www.facebook.com/group.php?gid=18428627696
Taylor & Francis Built Environment Books	Built environment readers	http://www.facebook.com/ext/share.php?sid=15576086035&h=HuGrn&u=qsTWm
Dubai Real Estate	Dubai real estate investors	http://www.facebook.com/ext/share.php?sid=15576086035&h=HuGrn&u=qsTWm
Malaysia and Singapore Real Estate	Investors in Malaysia and Singapore	http://www.facebook.com/group.php?sid=b7be0d11cb8b90786551cb9f79a91c20&gid=25761649624&ref=search#/group.php?sid=ca1f59f91676bb445ef9ac5f6632bccd&gid=21745378000&ref=search

Professional web based communities not only provide convenience to practitioners. Emery's study shows that there is proliferation on using Web 2.0 as a tool for research collaboration, partnerships and secure funding (Myhill et al. 2009). As the emerging "Google generation" is native to Web 2.0 (more than 80% of the 18- to 24-year-old generation in the United States visit social network sites), it is expected that Web 2.0 will become a more popular knowledge sharing tool in the academic arena (Myhill et al. 2009). Groups which are designed to help real estate and construction researchers to assimilate and dissimilate information grow steadily, e.g. MyNetResearch (http://www.mynetresearch.com) provides blogs, forums, toolbox, RSS feeds to users for knowledge sharing. Diigo (http://www.diigo.com) provides icons such as "people like me" where members can find somebody on web that have similar interests or search by tags to locate people. The "Collaborative Research Platform" also shares research findings. A project team can also be created to pool relevant resources and thoughts together. Elsevier's 2Collab (http://www.2collab.com) also provides a platform to researchers to rate and comment on research papers (Myhill et al. 2009). Other networks in yahoo e.g. Property Research Forum (http://finance.groups.yahoo.com/group/propertyresearchforum), and Co-operative Network for Building Researchers (http://tech.groups.yahoo.com/group/cnbr-l) provide a platform for the exchange of related ideas and dissemination of information like conference and workshop announcements, "call for papers", vacancies, journal and book launches, research studentships, fellowships and awards opportunities, CPD programmes and courses etc.

5 Resistance to Use Web 2.0 in Knowledge Sharing

No part of any institutional change happens on an island unto itself: changes in one part call for changes in every other part of the institution (Watson 1971). Entering into the digital era, more and more people are becoming acquainted with Web 2.0. Yet the number of users in Web 2.0 for real estate and construction knowledge sharing is still limited. In fact, it is in the nature of human beings to resist change (Li and Poon 2009). Most learning theorists hold the assumption that, unless the situation changes noticeably, organisms will continue to act according to their accustomed way (Watson 1971). What then are the major reasons behind the resistance to change? Some studies show that younger persons are generally more ready for change than are those who have acquired property, skills, or prestige in the older age. More cosmopolitan individuals who have a wider variety of contacts and experiences are usually more open-minded to change; those more isolated and provincial resist because they have little room for imagining a new way of working or living (Watson 1971). Others find that misunderstanding, fear of unsatisfactory outcome and failure are the major reasons which resist change. In view of resistance to change, various solutions are suggested by different writers, e.g. education, coercion, political support, manipulation and discussion (Li and Poon 2009). A much more detail solution can be found in Table 3.

Table 3 Five "Wh" question in reducing resistance to share knowledge by Web 2.0 (Watson 1971)

"Wh"question	Resistance will be less if...
Who brings changes?	1. People feel that the project is their own, but not devised and operated by outsiders, e.g. all the members should have equal opportunities in sharing and receiving new notices but not the web owners monopolizes the whole process. 2. The project is supported by top officials, e.g. Head of the Universities Departments.
What kind of change?	1. Participants perceive the change as reducing their burdens, e.g. the provisions of instant massagers' services can reduce researchers' financial burden in making distant phone calls. 2. The project is in line with values and ideals which have long been acknowledged by participants, e.g. there should be rules to inform every potential participants about the use of these Web 2.0 tools before they become members. 3. The program offers the kind of new experience which interests participants, e.g. the chatroom services provided in online communities save researchers' money in flying from one place to discuss research. 4. The participants feel that their autonomy and their security are not threatened, e.g. members' personal information should be kept confidential.
How is the changes bought about?	1. Participants have joined in diagnostic efforts leading them to agree on the basic problem and to feel its importance, e.g. all the participants are given equal opportunities in voicing out their opinions and receiving information. 2. The project is adopted by consensual group decision, e.g. members are encouraged to raise any useful suggestions to the Web 2.0 tools owners and the tools owners should be open-minded to accept these suggestions. 3. Proponents are able to empathize with opponents, e.g. the opponents should not use improper words towards ideas which go against their beliefs. 4. It is recognized that innovations are likely to be misunderstood and misinterpreted, and if provision is made for feedback of perceptions of the project and for further clarification as needed, e.g. many online communities provide an email of the owners concerning any enquiries.
"Wh"question	Resistance will be less if...
How is the changes bought about?	5. Participants experience support trust, acceptance, and confidence in their relations with one another, e.g. the participants are willing to help each others on providing useful. 6. The project is kept open to revision and reconsideration if experience indicates that changes would be desirable, e.g. all the participants can voice out their suggestions for improvements to the Web 2.0 tools owners at anytime.

6 Motivations in Sharing Knowledge by Web 2.0

Knowledge management practices is similar to the act of one opening up other's head, scoop out knowledge and reproduce it (Tredinnick 2006). Motivating people to share their knowledge is a can of worms in many people's mind, not to mention by way of new technology as Web 2.0. There are various methods in traditional motivation theories which can enhance knowledge sharing, namely, incentive schemes, awards and penalty (Chua 2003).

6.1 Theory X

McGreqor pin points two distinct theories on human behavior based on Theory X and Theory Y. Theorist X followers opine that men have to be directed, forced and threatened with penalty – they are not self motivated and disciplinary actions are necessary for achieving goals. Yet, some researchers are of the view that penalty tends to be ineffective due to possible delay or if it is too mild in nature (Li and Poon 2007, 2009). Others argue that minimal supervision is already good enough to ensure the organization members follow what they are told to do so (Li and Poon 2009). Following Theory X, the major motivation in adopting Web 2.0 for safety knowledge comes from the high penalty in not using it. Such "penalty" does not have to be a monetary penalty. It can be the delay in obtaining information etc. To motivate researchers to use more research tools online, the website owners, such as MyNetRearch can provide a brief account on how many new pieces of information on *call for papers*; *grants* etc were posted every month. Co-operative Network Building Researchers (http://tech.groups.yahoo.com/group/cnbr-l/), one of the largest online construction research groups, has listed out the number of pieces of news each month. Non-members know how much information they have not obtained should they not join the groups. Moreover, it has also listed clearly the number of participants in this group. Outsiders can also know the number of possible audience should they post a new message.

6.2 Theory Y

In sharp contrast, Theory Y shows another polar case on human behavior. Followers believe that men are responsible (Li and Poon 2009), they perceive work as natural as rest. External threat of punishment are not the only means for achieving goals or any objectives (Li and Poon 2007). A suitable working environment is sufficient to motivate people towards the goal set by the organizations. As humans enjoy being treated like a valuable member in society, trust is the basic precondition for communication, communal and open learning. While a climate of trust is necessary in knowledge sharing within an organization (Dulaimi 2007), similar atmosphere is also necessary in Using Web 2.0. To avoid any misuse in the online communities, the website owners have to state clearly the consequences of bad behavior. Resulting in trust being built between the pools of users.

Skeptics, however, argue that theory X and Y represent two extreme polar cases which very likely did not exist in the real world; a combination of the two theories is more likely to offer good motivation administration solution (Li and Poon 2007).

6.3 Need's Theory

Maslow suggests that human conduct is motivated by five classes of needs: physiological, safety, love, esteem and self-actualization. People try to satisfy one need first and then move forward to another need. After fulfilling the needs on basic needs such as food, water and sex, people start to think about ways how to build a secure environment and finally, they will need self-fulfillment (Li and Poon 2007). To motivate researchers to share their knowledge, they might need to satisfy their basic need first, i.e. employment before talking about any knowledge sharing concept etc. In some online communities, for example, MyNetResearch (ttp://www.mynetresearch.com/Jobs/SearchJob.aspx), Co-operative Network Building Researchers (http://tech.groups.yahoo.com/group/cnbr-l/) allows members to post all the openings in the Universities.

Needs theory has been criticized heavily for its strict hypothesis on the needs ladder, Cole (2004) comments that empirical observations on such organized movement up the needs ladder does not usually realize in reality (Cole 2004). Others concur that the theory has failed to provide an explanation on how behavior can be affected within the hierarchy. In any case, however, it proves its value at the present high technology times. Maslow's theory indicates that motivation for knowledge work comes from his three highest hierarchical levels. Needs theory imply that the motivation behind knowledge owners on sharing the knowledge by Web 2.0 does not lie on monetary gain or improvement in social relationships but on their goal to attain self-actualization (Li and Poon 2009) (Fig. 2).

6.4 Vroom's Expectancy Theory

While Maslow suggests that achievement is related to the need for inherent fulfillment. Vroom visualises that the likelihood of one particular behavior is determined by the perceived relationship between an action and outcome the outcome of

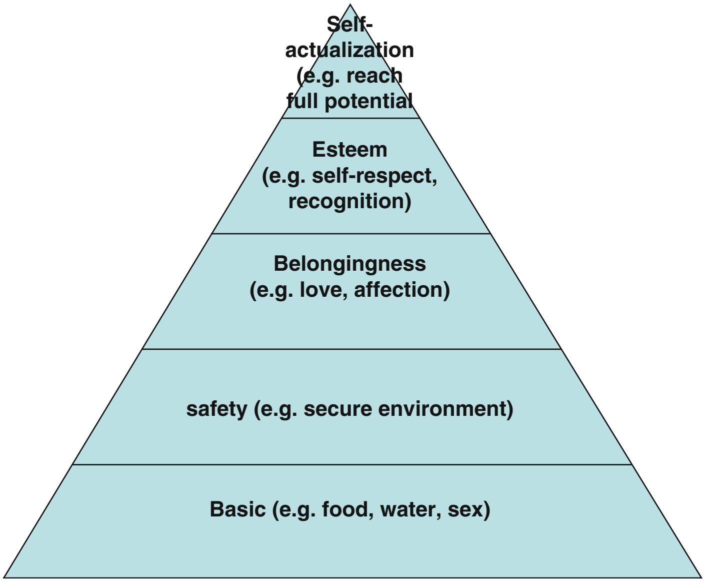

Fig. 2 Needs theory pyramid (Hendriks 1999)

an action (Li and Poon 2007). There are three major components in Expectancy theory: Expectancy, instrumentality and Valence (Cole 2004).

1. Expectancy refers to the degree in which an increase in attempts will lead to better performance.
2. Instrumentality refers to an improved performance which leads to a specific outcome.
3. Valence implies when an individual realizes that his performance will lead to a better outcome, the more motivated an individual will be (Cole 2004).

Expectation theorists propose that force = expectancy x instrumentality x valence (Chiang and Jang 2007). In view of this, to motivate people to use Web 2.0 as knowledge sharing method, the aforementioned three criteria has to be met.

Although the theory has been regarded as one of the most important motivation theory, some researchers criticize the construct validity of mechanism of the captioned theory (Chiang and Jang 2007).

7 Conclusion

World Wide Web has saved the time span of knowledge sharing and shortened the distance between knowledge owner and receiver. Proliferation of Web 2.0 websites such as Blog, RSS, Professional Web Based Communities have overturned the authoritarian control and one way knowledge sharing situation and greatly increased the interactivity between various internet users. In spite of all the advantages, not all the people are willing to change. What are the possible ways to motivate people to use Web 2.0? Theory X implies that people use Web 2.0 in fear of losing any timely information. Theory Y suggests that the climate of trust is the major motivator in knowledge sharing. Needs theorists concur that self-actualization is a more important source of motivation than monetary gains from their act. Finally, Expectation theorists concede expectancy, instrumentality and valence is the major driving force. To build a successful Web 2.0 knowledge sharing base, the aforementioned criteria have to be observed. In view of improvement in computer education all over the world, it is expected that Web 2.0 will become more popular than traditional face-to-face knowledge sharing method among real estate and construction researchers.

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Creation of Social Capital in a Web Based Virtual Research Environment

Murugan Anandarajan and Bay Arinze

Abstract This chapter investigates the emergence of Web technologies and their role in developing social capital needed for effective research collaborations. It proposes a theoretical framework to understand how virtual collaborative teams are created in such environments and how they affect the development of social capital. Furthermore it examines features and properties of Web technologies that facilitate the creation of social capital required for the successful research collaborations.

As researchers increasingly turn to the Web to gain further efficiencies in their research and national economies depend more on research to compete in the global economy, it is increasingly important to understand how to create improved tools that will boost research efficiencies. Information and communications technologies (ICT) and the Web in particular, offer new opportunities in this regard. A framework for creating social capital is essential for understanding how these networks function, as we argue, and this framework will make such web-based research more effective and efficient over time.

1 Introduction

The popular image of the eccentric genius at work alone on a research project is becoming a thing of the past. Indeed in the last several decades, collaborative research has become the norm. Research indicates that greater numbers of researchers are collaborating on research projects to gain access to larger pools of knowledge, skill sets and resources, with a greater potential of successful outcomes (Deeter-Schmelz and Ramsey 2003). In the last few years, advancements in Information and Communication Technology (ICT) have led to the rapid growth of

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Internet-facilitated virtual collaborative research teams (Anandarajan 2010). In fact, the NSF has awarded funding to over 700 research projects relating to virtual infrastructures over the last 8 years.

A virtual collaborative research team is a group of researchers who work across time, space, and organizational boundaries, with links enhanced by ICT to create knowledge. While the use of this team structure has grown in recent years, concerns have arisen about networks of relationships that help individuals work effectively being sustained in teams whose members are physically dispersed (Prusak and Chohen 2001). In addition, according to Nonaka and Takeuchi (1995), knowledge creation is a social process undertaken by individuals that generally begins with sharing tacit knowledge in order to derive group-level norms, processes and goals as the basis for successful collaboration. This is referred to as social capital and provides the conditions that are necessary for the informational and collaborative processes in the creation of knowledge (Nahapiet and Ghoshal 1998). Thus, social capital is a vital component of collaborative research.

Unfortunately, research has shown that social capital within virtual teams is often quite inadequate, leading to poor outcomes. This failure has been attributed to the lean media characteristics of ICT used in virtual settings (DePaulo and Friedman 1998). In addition, research by Huysman and Wulf (2006), Olson and Olson (2000), Cohen and Prusak (2001) among others, conclude that ICT-based virtual teams impede the emergence of social capital at the group level.

To date, there has been little rigorous empirical work on the role of Web 2.0 technologies on virtual research collaboration (Anandarajan 2010). In addition, there has been no theoretical work on the social and rich media characteristics of Web 2.0 technologies and their impact on the development of social capital. One only has to examine such examples as Facebook and Linkedin to understand how the latest Internet technologies have led to the creation of social capital in corporate networks. These social networks have dramatically reduced the barriers and obstacles that hinder people from interacting with each other across the world through their rich media. As Duffy (2010) points out, Web 2.0 technologies have begun to emerge in research collaboration. However, the role of this technology on the social development is not yet known.

2 e-Research Collaborative Networks

A variety of e-collaborative networks have emerged during the last years as a result of the research challenges faced by both industry and academia. The manifestations collaborative networks include, virtual team breeding environments, professional virtual community, e-science virtual labs, among others. Regardless of the various manifestations the fundamental component of a collaborative network is a virtual team. A virtual team is defined as an association/cluster/network of independent individuals, sometimes across organizations, which come together and share resources

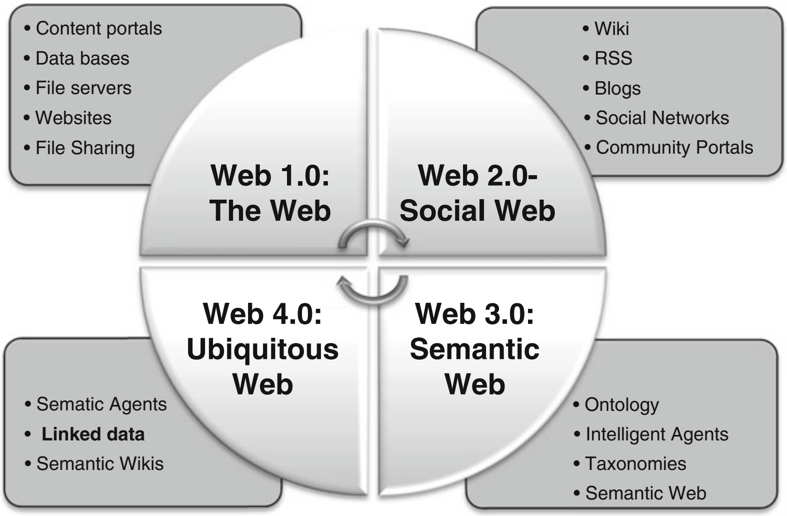

Fig. 1 Evolution of Web technologies

and skills to achieve a common goal, such as preparing a grant proposal (Camarinha-Matos and Afsarmanesh 2005).

The evolution of Web technologies has changed the characteristics of features and functionality of the e-research collaborative networks. As can be seen in Fig. 1, the first stage, Web 1.0 was about sharing information using search engines, enterprise portals, research websites online databases and file servers. Collaboration amongst researchers however, was similar to the pre-Internet era, in that researchers collaborated primarily with their immediate circle of colleagues and known acquaintances (in what we call "*collaborations of convenience*"). Internet-based resources were used primarily as a medium of communication and storage.

In the next generation of the Internet, commonly referred to as Web 2.0, researchers began sharing knowledge in personal online spaces such as wikis, blogs, community portals, and RSS feeds. These web 2.0 technologies enabled researchers to publish information in small, discrete notes in real time, in contrast to large, carefully-organized online databases of the first generation Internet. In addition, Web 2.0 increased the researchers range and reach of access to potential collaborative partners.

The third stage of the Internet, Web 3.0, was about representing meanings, connecting knowledge. In addition to the content, semantic technologies gives the internet a knowledge space, i.e., it can represent meanings and knowledge as well. Semantic webs encompass a broad range of knowledge representation and reasoning capabilities including tags, dictionaries, taxonomies, pattern detection, ontology, and model based inferencing.

Web 4.0 builds upon all previous stages of the Internet growth, from the concept of collaborative portals, semantic technologies and ontologies, to linked data.

This evolution of the Web focuses on best practices for publishing and deploying data on the web, with the emphasis data interconnections, interrelationships and context useful to both humans and machine agents.

3 The Role of Social Capital in Collaborative Research

Collaborative research projects involve ill-structured, open-ended and often interdependent tasks (Olson and Olson 2000). Such tasks are typically knowledge-intensive and require the sharing of explicit, as well as tacit knowledge (Nonaka and Takeuchi 1995). The sharing of such tacit knowledge requires rich and extensive social interactions on the individual level. Team members have to learn to collaborate and to establish a shared conceptual framework in order to engage in knowledge-intensive tasks (Levine and Moreland 1991).

In addition, collaborative research is inherently interdisciplinary in nature, and as such, researchers in virtual teams are likely to have different perceptions of the world and approaches to problem solving. Thus, as they engage in complex tasks, they have to find a shared cognitive basis for their collaborative work. They have to learn to communicate more effectively by developing a better understanding of how each member uses language, the categories that are important to them, the heuristics they employ, and the forms of verbal and nonverbal shorthand and codes they use (Nohria and Eccles 1992). In other words, they must learn to navigate and work together within ad-hoc social structures.

Social capital refers to the capabilities of such teams to act collaboratively, involving such issues as trust, shared cognitive models and the ability to process complex information. Social capital theory examines the inherent value of social structures. At a group level, social capital is defined as the value of social structures in facilitating social action. From a collaborative perspective, social networks serve as valuable resources that enable individuals to work in groups to undertake complex actions like knowledge creation (Nahapiet and Ghoshal 1998). Thus, social capital complements human capital by taking into account the social fabric among these individuals that facilitates effective collaboration.

Edwards and Foley (1998) indicate that social capital is not as easily available to all, as other forms of capital are. It cannot just be purchased or directly exchanged with other forms of capital. Factors limiting access include geographic factors and social isolation. This highlights the problems that face virtual collaborative teams that are separated by distance, time, norms, and culture.

Nahapiet and Ghoshal (1998) identified three dimensions of social capital: the structural, the relational and the cognitive dimension. The pertinent definitions and related constructs are shown in Table 1.

Drawing from this multidimensional view of social capital, the benefits of social capital are twofold, namely informational and collaborative. Individuals can access information through their social, often informal relationships, and teams are able to process information effectively when they possess sufficient social capital,

Table 1 Dimensions and constructs of social capital

Dimension	Definition	Constructs
Structural	Comprises the connections between individuals of a social group (Adler and Kwon 2002)	Social ties Information exchange Network density (Reagans and Zuckerman 2001)
Relational	Willingness of people to act together by subordinating their individual desires to group objectives (Leana and van Buren 1999)	Trust Norms (Nahapiet and Ghoshal 1998) Obligations
Cognitive	Ability of people to act together and comprises aspects of shared understanding (Nahapiet and Ghoshal 1998) and collective goal orientation (Leana and van Buren 1999)	Social shared mental models Shared reference (Clark and Brennan 1991) Mutual knowledge (Cramton 2001)

especially in the relational and cognitive dimensions. Collaborative benefits of social capital also relate to the willingness and ability of group members to act together. This collaborative ability results from group closure, trust, norms and a shared group understanding. Hence, social capital provides the conditions that are necessary for the informational and collaborative processes in the creation of knowledge (Nahapiet and Ghoshal 1998).

4 Web 2.0 Virtual Collaborative Research Environment and Virtual Teams

Using the media-rich functionality, the Web 2.0 Virtual Collaborative Research Environment (VCRE) can aid researchers in virtual teams to develop social capital in three ways: *Research Awareness, Research Networking* and *Research Management*. Table 2 summarizes the functionality of Web 2.0 VCREs and ways they contribute towards developing social capital.

In summary, Web 2.0 technologies provide researchers with a range of ICT features which range in media richness, that increase the range and reach of researchers' access to new potential collaborative partners and provide teams with research management tools. Virtual teams can be formed dynamically and on-demand in a suitable virtual collaborative research environment, namely, a Web 2.0 Virtual Collaborative Research Environment (VCRE).

A *Web 2.0 Virtual Collaborative Research Environment (Web 2.0-VCRE)* can be defined as an association/cluster/network of individuals/teams/organizations (members), adopting common operating principles and infrastructures, with the main goal of creating temporary alliances to share skills or core competencies in order to solve a research problem. This environment provides an integrated architecture to interconnect all the potential stakeholders of collaborative research. Typically, the

Table 2 Functionality in Web 2.0 virtual collaborative research environments and their potential impact on the development of virtual teams' social capital

	Activities	Web 2.0 functionality	Potential impact on social capital
Research awareness	Learn about new ideas, opportunities work done by other researchers, etc.	Blogs, wikis, forums, RSS feeds etc	Structural social capital Cognitive social capital
Research networking	Formation of a collaboration team	Social networking tools, chat rooms etc	Structural social capital Relational social capital
Research management	Managing the team's research collaboration	Dashboards, Task management, Version Management etc	Cognitive social capital

members of a Web 2.0 Virtual Collaborative Research Environment can include: (a) public and private research centers (b) universities, and (c) government institutions. Thus, members of Web 2.0-VCRE's can find and collaborate with other members, regardless of disciplines, institutions, sectors and countries, in independent virtual research teams.

5 Dynamic Life Cycle of a Virtual Collaborative Research Team

A review of the virtual environment literature (indicates that there are four major factors that influence the life cycle of a virtual team. These are *spirit, structural, process,* and *outcomes*. These factors and related literature are summarized in Table 3.

These four factors form the basis of a three-stage process research model of a virtual team within the Web 2.0-VCRE. The first stage is the *Establishment* of the virtual team, where individual members initiate the use of the Web 2.0-VCRE. According to DeSanctis and Poole's Adaptive Structuration Theory (AST), in a purposeful socio-technical system, such as Web 2.0-VCRE, external structures such as collaborative goals, power factors and individual aptitude reflect the *spirit of the environment*. In the case of the Web 2.0-VCRE, this would be a reflection on how researchers should act, interpret the features, and fill in the gaps in the procedures that are not explicitly specified (DeSanctis and Poole 1994).

Based on a literature review, research goals can be classified into four categories: *skill, cognitive, affective* and *meta-cognitive* (Anderson and Sosniak 1994). Skill goals focus on imparting procedural knowledge or know-how, cognitive goals focus on building broader domain knowledge in a subject area, and affective goals focus on enhancing the level to which the researcher is immersed in the collaborative research efforts (Gupta and Bostrom 2008).

Table 3 Factors that influence the dynamic life-cycle of a virtual collaborative research teams

Factors	Variables	References
Spirit	Research collaboration goals:	
	Skill: Imparting procedural knowledge	Gupta and Bostrom (2008)
	Cognitive: Building broader domain knowledge in the research area	Gupta and Bostrom (2008)
	Affective: Enhancing the researcher's ability to get immersed in the research	Gupta and Bostrom (2008)
	Meta-cognitive: Understanding one's own information processing procedures	Gupta and Bostrom (2008)
	Power structure:	
	Governance structure: Rules that govern collaborative behaviors and relationships	
	Dependency: Degree to which researchers are linked in a way that provides some benefit to the collaborating researcher	Johnson and Johnson (1999)
	Leadership: likelihood of leadership emerging when ICT is used for research collaboration	Huber (1984)
	Conflict management: Whether interactions are orderly or chaotic and lead to shifts in viewpoints	Dennis et al. (2001)
	Atmosphere: Relative formal or informal nature of interaction among the team members	Dennis et al. (2001)
	Individual aptitude	
	Motivation: Direction, intensity and persistence of collaborative behavior	
	Self efficacy: Person's judgment of their capability to perform a certain task	Compeau et al. (2005)
	Other traits: Gender, Race etc	Bandura (2001)
Structural	Information communication technology:	
	Research awareness	Duffy (2010), Zaman (2010)
	Research networking	
	Research management	
Process	Social capital	
	Structural: Comprises the connections between individuals of a social group (Adler and Kwon 2002).	Social Ties, Information Exchange, Network Density (Reagans and Zuckerman 2001)
	Relational: Willingness of people to act together by subordinating their individual desires to group objectives (Leana and van Buren 1999)	Trust, Norms (Nahapiet and Ghoshal 1998) Obligations
	Cognitive: Ability of people to act together and comprises aspects of shared understanding (Nahapiet and Ghoshal 1998) and collective goal orientation (Leana and van Buren 1999)	Social shared mental models, Shared reference (Clark and Brennan 1991), Mutual knowledge (Cramton 2001)
Outcomes	Task time, team quality and collaboration satisfaction	Efficiency, Effectiveness, quality of work, overall satisfaction

The power structure factor is central to the critical theory literature in both education and information systems literature. Power structure includes the following dimensions; governance structure, leadership, dependency, conflict management and atmosphere. Aptitudes are the initial states and abilities of persons that influence behavior, given specific conditions (Ackerman et al. 1999). The AST literature however, has paid little attention to these individual differences. Aptitudes can be broadly distinguished into two categories: motivation and cognitive abilities. Motivation to collaborate is the direction, intensity, and persistence of collaborative directed behavior.

The second stage of the research model is where the virtual team members go through a process of *virtuality*. The concept of virtuality captures the idea that virtual teams can experience different levels of being distributed. Cohen and Gibson (2003) argue that the virtuality of a team is the function of the level of geographical dispersion among team members as well as the degree to which team members use ICT to accomplish their goals. Virtuality enables social capital. In this chapter, we examine the *Information Communication Technology Structures*, which are embodied by the Web 2.0-VCRE. A review of the previous literature on the effectiveness of ICT in collaboration has shown that the use of technology has not had successful outcomes. However, the literature did not include Web 2.0 technologies, which are characterized by their rich media networking capabilities. In this study, the structural ICT features include; *research awareness features, research networking features,* and *research collaboration management features*.

Web 2.0-VCREs are not simply a technical foundation to substitute for a real-world business counterpart, but an entity that exists in our ontological and epistemological recognitions. Its ontological meaning encourages membership in associated organizations and its epistemology enhances the social realization of being a member of virtual organization. For example, social capital creation among members explains a new phenomenon of the virtual environment. We argue that members of virtual teams within a Web 2.0-VCRE setting can build social capital in each stage of the model of the through the use of Web 2.0-VCRE features. In other words these Web 2.0 features serve as an alternative way of compensating for the lack of a means of building social capital in the traditional ICT as identified in the past literature.

In addition, Web 2.0 VCREs can moderate the relationship between social capital and outcome factors. In this environment, Web 2.0 technologies are utilized in every aspect of the collaboration process (research awareness, networking and management) among the virtual team members. Web 2.0-VCREs not only refer to technology use but also the embedded circumstances normally attached to the use, such as the separation of space among members.

In the final stage of the process model, the *outcomes* of the virtual team become streamlined in terms of fluidity and flexibility. In this stage, team members understand the values of Web 2.0-VCRE and see the outcomes of the research collaboration. These outcomes include task time, team quality, and collaboration satisfaction.

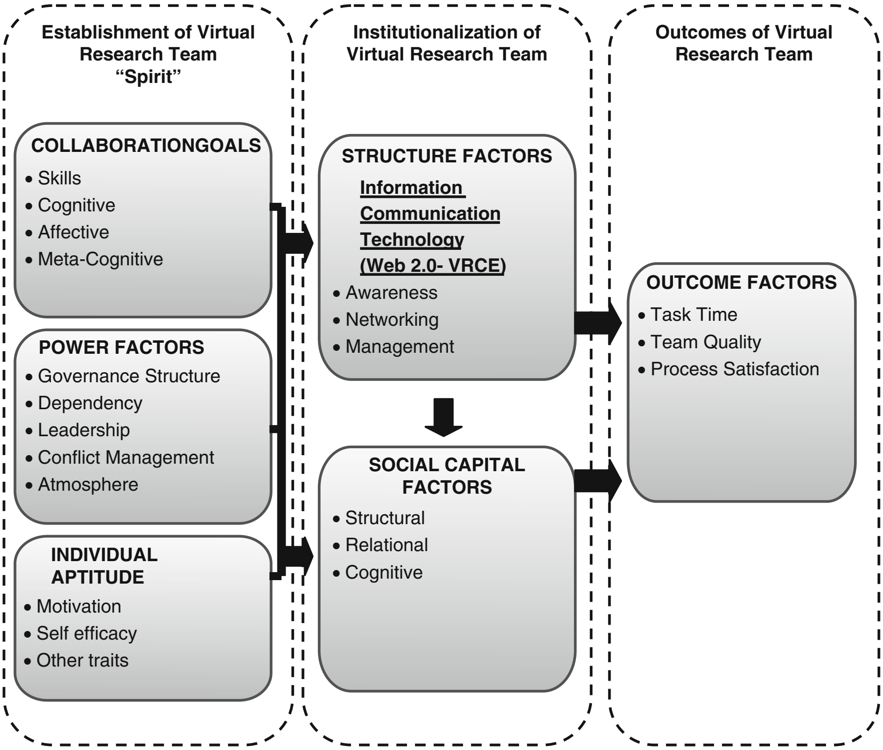

Fig. 2 Factors that influence the life-cycle of a virtual team

Based on the above discussion we propose the following research questions:

1. The virtual research collaborative teams' overall spirit influences the use of the functionality of the Web 2.0-VCRE and social capital.
2. The level of usage of the Web 2.0-VCRE functionality will impact the rate of development of social capital in the virtual team. i.e., the lower the use of the media rich functionality, the lower the team's social capital development and vice-versa.
3. The level of use of Web 2.0-VCRE functionality has a direct impact on the outcomes of the virtual research team. In addition, the level of use of the Web 2.0-VCRE moderates the relationship between the social capital factors and virtual team outcome factors (Fig. 2).

6 Discussion

Future research studies will obtain valuable insights into, and empirical data about the role of ICT in the development of social capital virtual research teams. While the subject of social capital is better explored in traditional forms of collaboration and groupwork, it is unexplored in Web 2.0 based virtual teams. In addition, there has been little theoretical work on the social and rich media characteristics of Web 2.0 technologies and their impact on the development of social capital.

Further research studies will aid in better understanding the mechanisms of social capital development in Web 2.0-VCREs and how they differ from non-Web 2.0 VCRE settings. The results will assist research institutions seeking to increase the positive outcomes of their virtual collaborative teams using Web 2.0-VCREs. It dovetails with the increasing distributed nature of research and the proliferation of virtual infrastructures, which already host tens of thousands of researchers globally.

A better understanding the emergent behaviors in VCREs is an important need as new social networks are created for use in the social and business realms. With Facebook achieving an unprecedented membership of over 350 million users, and many other networks registering millions of users globally, Web 2.0-based computing is the new wave of information systems.

Increasingly, organizations of all types are looking to build and use virtual research infrastructures. However, while the tools or building blocks of such infrastructures exist in the form of social network toolsets, the deeper understanding of how socially intelligent networking takes place within VCREs is nonexistent.

The importance of VCREs emanates from the vast amounts spent on research annually ($370 billion spent by the United States in 2007) and the multiplier effect of such research spending on the wider economy. In addition, it is understood that collaborative research produces synergies that demonstrate that in the knowledge economy, the whole is more than the sum of its parts.

The use of VCREs goes beyond the tools and features of social networks to discover the mechanisms by which social capital is created in such virtual teams. The intentional incorporation of such tools in the design of VCREs will make for more effective systems that increase their users' research productivity. This study thus focuses on the use of such VCREs, with the added benefit of using one of the largest available research networks as a test bed for the study.

7 Summary

Collaborative research has become the norm over the last several decades, and organizations of all kinds are looking for ways to extend their research effectiveness through collaboration. This has led to the rapid growth of Internet-facilitated virtual collaborative research teams and online communities. Knowledge creation is fundamentally a social process that involves individuals sharing tacit knowledge in order to derive a group-level understanding as the basis for successful collaboration. This implies the existence of social capital, that is, the value of connections and cooperation created in networks of social human relationships.

To date, scant research has examined the impact of Internet-based technologies on virtual relationship-building. Facebook's 350+ million members underline how Internet technologies have led to the creation of social capital in networks. These

Web 2.0-based networks have dramatically lowered the barriers that hinder people from interacting with each other. The impacts of these technologies have begun to extend to research collaboration.

This chapter has discussed how *Web 2.0 Virtual Collaborative Research Environments* (Web 2.0 VRCEs) help to develop social capital needed for effective research collaborations in virtual teams. It proposes a theoretical framework to understand how virtual teams are created in Web 2.0 Research Collaboration Environments and how Web 2.0 environments can impact the development of social capital needed for successful research collaborations.

Future research studies based on the framework described here will shed light on how social capital is generated in the fast-expanding world of virtual research environments and how it affects research productivity outcomes. They will assist researchers to, for the first time, gain insights into the mechanisms of socially intelligent computing in Web 2.0 VCREs and their impact on social capital among various types of researchers. Given the rapid rise of social networking in general and more specifically, in research communities, it is important to gain an understanding of how social capital is generated in such communities and how that affects the research collaboration process and related outcomes.

The results of such studies will also include design recommendations for developers and managers of new Web 2.0 VCREs in both academia and industry. According to the NSF, the research enterprise in the United States was valued at $370 billion in 2007. he importance of research as a national priority cannot be overstated as a determinant of national economic competitiveness in the new global economy. If we assume that increasing amounts of research will occur in VCREs, then a better understanding of these environments and the process of creating social capital among their researchers will be vital to advancing the US research enterprise.

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Index