GeS 2007 German e-Science

Available online at http://www.ges2007.de

Collaboration in and for e-Research: making the 'O' in virtual organisation work

Alex Voss[1], Rob Procter[1], Steffen Budweg[2] and Wolfgang Prinz[2]

[1]National Centre for e-Social Science, University of Manchester, United Kingdom
[2]Fraunhofer Institute for Applied Information Technology FIT, Sankt Augustin, Germany
{alex.voss,rob.procter}@ncess.ac.uk,
{steffen.budweg,wolfgang.prinz}@fit.fraunhofer.de

Abstract

Collaboration support for knowledge-intensive work such as e-Research is still very fragmented and collaboration across organisational and disciplinary boundaries is difficult to achieve. We sketch out a programme of research that will build on existing work in the areas of collaborative work environments and virtual research environments to overcome these problems by focusing on conceptual issues, (design) methodology and technology development.

1 Introduction

Working practices in knowledge intensive domains show a tendency to evolve from being centred around individual activities to work conducted in teams and further to community based efforts. A prime example is e-Research[1], where the notion of the "virtual organisation" organised around particular scientific collaborations spanning organisational (and often national) boundaries underpins a vision of a transformation of research practice. e-Research is by definition a collaborative activity that combines the abilities and resources of distributed groups of researchers in order to achieve research goals beyond individual researchers or local groups. Today, e-Research spans activities in physics (Schissel 2005), astronomy (Walton *et al.* 2006), crystallography (Coles *et al.* 2005), oceanography (Haines *et al.* 2006) and biomedical research (Goble *et al.* 2003) but also in econometrics (Peters *et al.* 2006) and archaeology (Clarke *et al.* 2005), to name a few of many examples. Often, e-Research not only spans geographical and organisational but also disciplinary boundaries. An example is the Integrative Biology project which aims to build multi-scale models spanning the molecular and cellular level to tissue, whole organs and their functioning in the organism (Lloyd *et al.* 2007).

Most researchers use common tools such as email or, increasingly, instant messaging and simple web-based tools such as wikis. Some groupware tools such as BSCW (Bentley *et al.* 1997) are also used, often offered as institutional collaboration platforms for the benefit of all their members, be they involved in research, teaching/learning (Appelt and Mambrey 1999, Budweg *et al.* 2006a) or administration. Some e-Research technologies have also been designed specifically to support collaboration, for example, the Access

[1] We follow the recent trend to speak about e-Research rather than using the term e-Science as we wish to explicitly include research activities outside the sciences, e.g. in arts and humanities.

Grid Toolkit (Childers 2000) while other tools such as storage resource brokers support collaboration implicitly through the data management support they provide. More recently, and building on the concept of a collaboratory (Finholt 2003, Olson *et al.* forthcoming), work has been undertaken to build integrated *virtual research environments*[2] (Fraser 2005, Borda *et al*. 2006, JISC 2006) with the aim of supporting collaboration across organisational and disciplinary boundaries over the whole research lifecycle.

However, it is probably fair to say that current collaborative tools (with the exception of email) are still not widely adopted, that they offer little interoperability and that they lack support for the integration of work activities within larger and dynamic contexts as envisioned by e-Research. They are therefore ill suited to building the shared spaces that are needed for research collaborations to thrive and for researchers to organise their daily work in a meaningful way that is organised around the work they do and the contacts they have with different collaborators in different contexts (Prinz *et al.* 2006). Consequently, building collaborative workspaces for research, be it in order to address a specific research question or to support research practices more generally, requires significant one-off effort because of the lack of interoperability between the individual components. In addition, the resulting fragile assemblages of different tools with different interaction styles and underlying models of collaboration often fail to produce useable and useful spaces for collaborative activity.

From a user's perspective, it is a common observation that collaboration support is currently not seamless and 'invisible' but requires a lot of attention in terms of agreeing the use of tools and appropriate ways of using them (Prinz *et al.* 2006). At the same time, research contexts are becoming more complex in terms of the number of collaborating researchers, the number of data sources and other resources, as well as the number of disciplinary and organisational commitments involved. Furthermore, it is increasingly recognised that (support for) collaboration in research involves complex institutionalised socio-technical arrangements and that the wider context of the social organisation of research is an important factor (Star and Ruhleder 1996, Lee, Dourish and Mark 2006, Hine 2006).

The vision of e-Research is that research collaborations are also highly dynamic, assembled 'on the fly' as needs and opportunities arise. The notion of a 'virtual organisation' is already well established and researchers are at the same time considering the use of social networking technologies developed under the Web 2.0 banner (O'Reilly 2005) to support even more dynamic *ad-hoc* collaborations[3]. These will require the constant re-negotiation of different work practices and usage conventions, as well as distributed tailoring and appropriation of the collaboration technologies involved. This corresponds to changes in work settings addressed by recent research on collaborative work environments like MOSAIC and ECOSPACE (Schaffers *et al*. 2006, Prinz *et al*. 2006) in their approach to supporting community-based work and facilitating *ad hoc* cooperation.

---

[2] We should note the related concepts of problem solving environments, cyber-environments and science gateways. For the purposes of this paper, we will use the term VRE as synonymous to or subsuming these other concepts.

[3] In principle, the notion of a VO captures these forms of collaboration as well but the tools and infrastructures we currently have for identity and rights management are still relatively heavyweight which means that most VOs are relatively static entities.

If we want to achieve the aim of e-Research as a dynamic assemblage of researchers and resources aimed at tackling research questions previously infeasible, then we need to effect a step-change in the way we facilitate and support collaboration in these new, dynamic work contexts. This involves building on a solid understanding of collaborative work activities in general, of research as a particular kind of activity and the specific practices that are involved in particular kinds of research. We therefore wish to sketch out a research programme that establishes a link between the communities working on virtual research environments and collaborative work environments and helps to ensure that emerging frameworks and components for collaboration are developed in a way that is not only consonant with the principles of user-centred design but also takes on board existing research in such areas as computer supported cooperative work or science and technology studies. A core issue to be addressed is the need to reconcile local practice, innovation and the need for flexibility with (inter-) organisational concerns, issues of (multi-)disciplinarity and technology supply side concerns such as economies of scale.

2 Collaboration Support

Today's collaboration support in many organisations is centred around email, corporate intranets and groupware systems or project-specific provision of groupware to support well-defined collaborations between project partners. As already mentioned, the provision of these tools and the resulting functionality are often very fragile and fragmented with little support for integration between the multiple different work contexts that individuals might be involved in. To overcome these limitations and to support work contexts that are increasingly dynamic and crossing organisational as well as disciplinary boundaries, researchers are working on platforms for integrated collaboration support. In this section we introduce work on collaborative work environments (e.g., Schaffers *et al*. 2006, Prinz *et al*. 2006) and virtual research environments (e.g., Fraser 2005, Lloyd *et al.* 2007, JISC 2006) before turning to our agenda of exploiting overlaps between these areas of research in the following sections.

2.1 Collaborative Work Environments

Collaborative work environments (CWEs) provide "the ability to collaborate over time and space, within and between organizations or communities […] to achieve flexibility by making best use of the knowledge and competences available" (Ballesteros 2006). One (popular) way of delivering this promise is through the provision of community portals. An example is the open Ami@Work community platform, offering members a central place and defined set of collaboration technologies such as Wikis, Blogs and BSCW Shared Workspaces. This can help create a common ground for cooperation and a pre-established shared tool-set, thereby reducing coordination overhead (which tool to use, for what purposes, and how). In portals, the requirement for the integration of different tools for complex tasks and lifecycles (e.g., collaboratively sharing and co-editing a word document prepared in a Wiki and announced in a Blog) can be realised by centralised integration efforts. The Ami@Work community platform, for example, provides single-sign-on, user profiles and identities shared across applications, and features for easy interconnection and linking of information and documents (Pallot *et al.* 2006). Nevertheless, the potential number of communities, portals and frameworks poses new challenges. It is unlikely that one portal will serve all cooperation partners' needs, so portals can only be a partial answer to the problem of fragmentation.

Many CWE projects build on the notion of changing work contexts, moving from individual to collective / team-based and finally community-based workplaces with an accompanying vision, that "[within a] few years, significant social, organisational and economical changes as well as a relentless technology evolution will dramatically change […] the way eProfessionals work and collaborate. People will no longer work according to chain production models but rather more as dynamically and spontaneously assembled groups of people working together in a collaboration mode, which means a seamless work to achieve common goals" (Pallot *et al.* 2006).

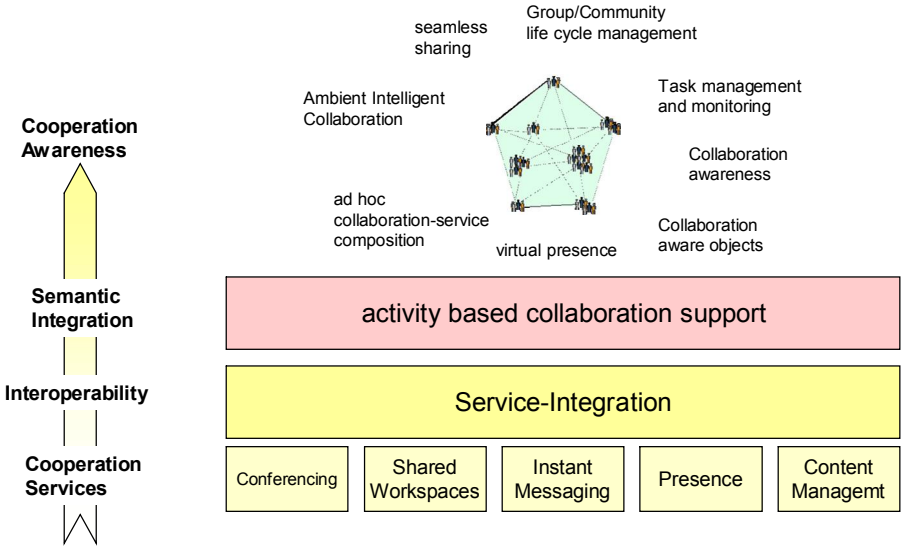

Figure 1: Cooperation Aware Environments (Prinz *et al.* 2006)

The EU-funded Ecospace Integrated Project (Prinz *et al.*2006*)* aims to develop appropriate collaboration support for these contexts including architecture, implemented collaboration middleware & services as well as extensions to existing collaboration tools and new collaboration tools integrating both asynchronous and synchronous aspects. This collaboration environment will enable knowledge workers to network and form groups and professional virtual communities, stimulating creativity and innovation while increasing productivity. The design activities will be informed through the use of three living labs[4] and experiment results for different business sectors, driven by industry partners and applied research.

Demonstrations and training material as well as a body of documented experience and methodological know-how gained in their application domains will be used to disseminate findings and inform the development of a collaboration platform reference architecture and corresponding 'upperware'. These will enable the interplay and interoperability of collaboration services and tools in a collaboration environment as well as business process management, mobile and wearable computing. Results will be contributed to standards and will foster the seamless cooperation of users within and between organizations, teams and communities. Ultimately, the aim is to develop a vital community that adopts the results of ECOSPACE and continues to extend them according to their needs using a developer's forum provided at the project web-site. In this way, sustainability of the project's outcomes will be ensured and wider uptake of the technologies and standards encouraged.

[4] http://www.openlivinglabs.org

2.2 Virtual Research Environments

As e-Research technologies mature and are taken up in routine practice, the question arises how their use can be supported through collaborative environments supporting wider research processes rather than merely individual tasks. Building on earlier work on collaboratories (Finholt 2003, Bos *et al*. 2007), virtual research environments (VREs) have been built to explore this issue. VREs are defined as:

> "[a] set of online tools, systems and processes interoperating to facilitate or enhance the research process within and without institutional boundaries. […] This means VREs will help individual researchers manage the increasingly complex range of tasks involved in doing research. In addition they will facilitate collaboration among communities of researchers, often across disciplinary and national boundaries. The research processes that a VRE will support include: resource discovery, data collection, data analysis, simulation, collaboration, communication, publishing, research administration, and project management. Through the use of common standards, VREs will link with the broad digital context within which they sit, ensuring compatibility with other key systems such as those of research funders" (Borda *et al*. 2006, p. 3).

Note that the definition explicitly mentions elements such as research administration and project management that are part and parcel of research activities but do not often appear in the published literature. On the technical side there are strong drivers to link VREs with other (institutional) systems such as administration systems and virtual learning environments (*ibid*. p. 6). It is the breadth of this vision that sets VREs apart from earlier activities which were much more focused on solving *specific* problems arising from particular scientific collaborations.

There is currently much debate about ways in which the e-Research community might benefit from and expand upon ideas developed around community platforms such as MySpace or Connotea, collectively often referred to as Web 2.0 (O'Reilly 2005). For example, myExperiment is an effort to build a community platform for users of scientific workflow systems (Goderis, Li and Goble 2006), allowing them to share, discover and use workflows. The aim is to extend the scope of myExperiment over time to include adaptations to the specific needs of other disciplines such as chemistry, social science and astronomy. This aim is underpinned by an understanding that there are similar needs in different disciplines that relate to the need to manage the reuse of artefacts (such as workflows) and to provide a space for research communities to develop and foster collaboration in a flexible, tailorable environment.

As the needs of researchers are constantly changing and difficult to predict, it is unlikely that VREs can be built and produced as single applications in the same way as virtual learning environments are today being installed in many higher and further education institutions (Fraser 2005). Rather, it is more likely that components making up a VRE will be implemented at a number of different levels, for example as (part of) supporting infrastructures at a national level, within universities or other research institutions or at a disciplinary level. These components and wider infrastructures will then need to be *configured* to support specific projects or networks of collaboration around particular research topics or scientific challenges.

3 Designing for Collaboration in e-Research

Collaboration has always been at the heart of the e-Science vision (Jirotka *et al.* 2006), to the extent that it has almost been taken for granted that research

is a collaborative activity and that collaboration is desirable and useful. Some recent studies have started to unpack the role that collaboration plays and have observed that research practices are not simply and unreservedly collaborative and open but that researchers are quite deliberate and careful about just when and who they share and collaborate with (Carlson and Anderson 2006). Instead of treating collaborative behaviour as a given, we need to start to unpack the different ways in which researchers make choices about collaboration and just what collaboration might mean in a particular context. The question is how environments for research can be designed so as to facilitate and support the formation and work of virtual organisations addressing complex research questions. Clearly, this process needs to be shaped in a way that allows designers and users to attend to the working practices involved and to the ways in which these change as research progresses (Carusi and Jirotka 2006).

The increased emphasis on sharing of resources and reuse of data and artefacts such as workflows or scientific software raises issues of ensuring their provenance and quality as well as security, confidentiality and appropriate use. As previous work on the use of electronic records in healthcare has shown, these issues are intimately tied in with peoples' *working practices*, located in an organisational and regulatory *context* (Hardstone *et al.* 2004, Martin *et al.* 2007) and that therefore development of support for such work needs to be attentive to these matters (Hartswood *et al.* 2005). For example, the secondary use of such data brings with it additional problems of consent and confidentiality but also has to deal with the inherent problems of making sure that record keeping practices and the use of records are sufficiently aligned (Hardstone *et al.* 2004, Geddes *et al*. 2006). This is just one example of how design of collaboration support for e-Research needs to be attentive to the specific practices involved and the organisational contexts in which e-Research takes place.

We would argue that the specific circumstances of and practices involved in research make it necessary to establish a reflexive tie between the normally separate activities of design and use (Voss 2006). Such a tie needs to exist both at the local level where support of specific research endeavours is the key concern, at the institutional level where decisions are made about the institutional support of research IT and at the level of the formation and shaping of (multi-)disciplinary research communities. Drawing on studies from the areas of computer supported cooperative work and participatory design may help us to formulate a systems development approach that will support local research practices while at the same time being attentive to how these fit in with generic technical architectures and global infrastructures. For example, Büscher et al. (forthcoming) point to the "deeply consequential relationships between use and software architectural design" and develop an approach to distilling local innovation into generic architectures and more generally applicable component parts. We would argue that the development of virtual research environments needs to be underpinned as much by sound architectural principles as by an understanding of collaborative practices in e-Research and that much can be gained by aligning this development with wider developments in the area of collaborative work environments and the tradition of computer supported cooperative work and participatory design.

4 VREs and CWEs

As research is a particular kind of work, similar to other kinds in some respects but different in others, virtual research environments can be seen as special cases of collaborative work environments. However, it would seem that the development of VREs is progressing independently of the develop-

ment of CWEs and that the communities involved in these projects overlap only very partially. This is not to say that there is no exchange but it is our impression that collaborations are opportunistic and contingent rather than strategically arranged. There is a real danger here not only that effort is duplicated but also that valuable lessons learned over many years in the field of computer supported cooperative work are ignored in the development of cooperation support for e-Research. These lessons relate to general findings about work as a socially organised activity, to the design of collaboration support and to the ways in which technology development can be informed and driven by an understanding of collaborative work practices. Our aim is to sketch out and provide strategies for exploiting this overlap for the benefit of both projects. We can roughly characterise them as being related to conceptual issues, methodology and technology, each of which we will discuss in turn.

4.1 Conceptual Issues

The way we conceive of work and the concepts we use to describe its features has an important impact on how we go about designing collaboration support for innovative work contexts. For example, we might want to look at extracting general lessons from studies of risks in scientific collaborations (Olson *et al*. forthcoming) and use them to inform the debate about collaborative work environments and the way we might go about setting up communities of distributed knowledge workers. A taxonomy of collaboration environments, populated with examples of efforts that have been successful might help us understand what good practice is in this area as well as to disseminate this understanding. An excellent example of such a resource is the Science of Collaboratories database of successful e-Research environments or collaboratories (Bos *et al*. 2007).

Based on such common ground, we can also start exploring the differences in conceptualisations of social structures in VRE and CWE research as well as the relationship between the visions involved and real-world experiences. For example, a study of FBIRN, a large-scale multi-organisation scientific collaboration (Lee, Dourish and Mark 2006) suggests that local contexts and organisational alignments are still of crucial importance to the way in which work gets done. This is despite the emphasis placed in conceptualisations of e-Research on inter-organisational work in "virtual organisations". When we consider similar statements about work within collaborative work environments, can we assume that these individuals will be divorced from such organisational contexts? Will this be true for the majority or at least a significant minority of workers? Or do we need to treat organisational alignments as one in a number of factors?

Building upon these understandings will be essential for collaborative technologies to be easily *embedded* within social arrangements and wider socio-technical contexts, be *transparent* in the sense that their use does not require a lengthy setup process and have a *reach* beyond individual projects or activities and beyond individual institutional contexts: that is, to embody infrastructural qualities (Star and Ruhleder 1996). Such an arrangement would mean that use is *learned* as part of membership, i.e., taken for granted within a community of practice, would involve established *conventions of practice*, build on an *installed base* and the technology would become *visible only upon breakdown* (*ibid.*), i.e., it would normally be seen-but-unnoticed. Building systems and use practices that acquire these properties is still a challenging task and we need to gain a better understanding of what factors further or hinder the emergence of an infrastructure.

For example, Olson *et al*. (2002) have suggested the related concepts of collaboration readiness, collaboration infrastructure readiness and collabora-

tion technology readiness as a means to guiding our understanding of the factors that further or hinder collaboration. An example of a factor relating to collaboration readiness is the issue of whether established rules for data sharing exist within a community. Collaboration infrastructure readiness relates to questions about the operational environment of collaboration environments such as the existence of high-bandwidth multicast networks for multiparty video conferencing or the availability of technical support. Finally, collaboration technology readiness relates to the question of skills and experiences that individual researchers have with collaboration support tools. Depending on where we locate the barriers to uptake, different kinds of responses will be necessary to address issues falling into one or more of these categories.

4.2 Methodology: User-Designer Relations and Innovation

There is a need for technological innovation and a developing understanding of the changes in modern workplaces to progress hand in hand if we want to develop technologies that will turn out to be useful, usable and socially beneficial. Technology push (often dominant in e-Research) needs to be balanced with application pull and reflection on the changes made to the working practices of researchers. A user-centric approach is crucial here if we do not wish to disenfranchise researchers who may feel that their work is being reshaped by technologists who understand very little of it and do not share the concerns of the research communities for what constitutes good practice.

We will discuss various approaches to practically addressing these issues by creating particular forms of relationships between technology design and use, allowing local innovation to be distilled into more generally applicable components that fit in with a generic open architecture for collaboration support. It is paramount to avoid the design fallacy (Williams, Stewart and Slack 2005), i.e., the notion that building ever more knowledge about users and use *into* designed artefacts is going to lead to more useable and useful systems and wider uptake. Requirements are moving targets as contexts and work practices are continuously evolving. This is especially true in research where innovation is part of the game rather than an occasional exception. This does not mean that traditional methods of requirements gathering like the use of workplace studies, focus groups or user surveys do not have a role to play but they need to be complemented with at least an element of ongoing engagement that is aimed at supporting the innovative uses that occur only after the initial design of technologies is completed and artefacts get used in anger in real-world settings (Voss *et al*. 2000, Törpel *et al*. 2003).

Corealisation (Hartswood *et al*. 2007, Voss 2006) is one approach that aims to provide a suitable orientation to design as an ongoing activity involving not only professional designers and other IT professionals but, crucially, all people playing a part in the overall socio-technical ensemble of which IT is a part. In e-Research, a related strategy that has been pursued is "embedding" researchers in the design team[5] or designers in research teams. Another approach developed within the area of CSCW and palpable computing is the use of facilitation as a way of exploring innovative uses of technology in real-world settings, on a routine basis or in the form of scenarios played out in the field (Büscher *et al*. forthcoming). The strength of these approaches is that they foster a long-term engagement between technologists and users to explore possible designs and their uses in real-world contexts.

[5] This requires buying researchers out of their normal duties as well as finding ways to ensure that their involvement in e-Research can be recognised within existing (academic) career structures.

While the use of facilitators in traditional work contexts is quite well explored as, e.g., user-advocates (Klöckner *et al.* 1995; Pankoke-Babatz *et al.* 1997; Mambrey *et al.* 1998) in participatory design or technology-use mediators (Orlikowski *et al*. 1995; Bansler & Havn 2003) in organisational studies, further research is needed for inter-organisational or community-based settings. The distributed nature of such contexts makes it necessary to think about new ways of supporting the collaborative appropriation of otherwise general-purpose media, e.g., by using the collaboration technologies itself for the mediating processes (Budweg *et al.* 2006b).[6]

4.3 Technology

Many VREs are built as portals that allow web-based access to various resources as well as providing collaboration support. The existence of a recognised standard (JSR 168) makes it possible not only to select from a wide range of development tools and supporting technologies but also potentially enables the resulting VRE components to be traded and integrated in institutional portal environments using the same standards. However, JSR 168 provides for integration only at the level of the presentation layer, allowing different, independently developed *portlets* to be displayed together in a web browser, coexisting but not interoperating. This leaves the coordination and integration between different portlets which is needed in many contexts unaddressed. One reason why the Sakai virtual learning environment[7] is quite attractive as a development platform for VREs is that it provides APIs for a closer integration and coordinated existence of components. It is becoming increasingly apparent that what is needed is an underlying framework that can bind together independently developed collaboration tools as we move from scenarios where these merely co-exist to integrated environments.

In addition, we should not forget that the Web and its standards were not originally designed to support complex applications but were rather meant to facilitate the relatively coarse-grained process of document transfer. Mobile applications required, e.g., in the context of archaeological excavations (Clarke *et al*. 2005) or high-bandwidth VRE environments supporting large scale synchronous collaborations (Childers 2000) make it necessary to complement browser-based tools and to provide for integration between different modes of access to a VRE. One issue this raises is the dynamic transition between synchronous and asynchronous collaboration (e.g., Buckingham Shum *et al.* 2006) and the interplay between and integration of scientific applications and collaborative environments.

The aim of the ECOSPACE project to produce collaboration upperware and services to enable seamless and instant collaboration within communities is very consonant with approaches taken in e-Research, especially service oriented approaches adopted in the Grid community. What is important, though, is to ensure that the solutions chosen at the middleware and upperware layers are compatible or can be adapted. For example, strategies will be needed to provide federated authentication and authorisation mechanisms that integrate well with back-end identity and user profile management systems run by institutions or resource providers. The selection and use of standards as well as awareness of existing work are important elements that can be achieved through initiatives such as the e-Framework (Olivier, Roberts and Blinco 2005) and the eReSS study of standards used in JISC VRE projects (eReSS 2006).

---

[6] See Carusi and Jirotka (2006) for an overview of user engagement practices employed in the recent UK JISC VRE programme.

[7] http://sakaiproject.org/

5 Conclusions

Achieving the e-Research vision requires a step-change in the way we facilitate and support collaboration. We have argued that forging a link between communities working on CREs and VREs is valuable for ensuring that the emerging collaboration frameworks and components upon which the e-Research will depend are developed in ways that are consistent with the principles of user-centred design and also capitalise on existing findings from socio-technically-oriented research in relevant fields such as computer supported cooperative work.

Acknowledgements

This research was funded by the UK Economic and Social Sciences Research Council through the National Centre for e-Social Science, the Engineering and Physical Sciences Research Council through the e-Science Institute and as well as the European Union and the ECOSPACE consortium through the ECOSPACE project.

References

1. Appelt, W. and Mambrey, P. (1999). Experiences with the BSCW Shared Workspace System as the Backbone of a Virtual Learning Environment for Students. *Proceedings of the World Conference on Educational Multimedia, Hypermedia and Telecommunications ED-MEDIA 99*, Seattle, USA.
2. Ballesteros, I.L. (ed.) (2006). *Workshop Report on Collaborative Environments in the Future Enterprise*. European Commission, March.
3. Bansler, J. and Havn, E. (2003). Technology-use mediation – Making Sense of Electronic Communication in an Organizational Context. *Proceedings of GROUP 2003*, Sanibel Island, Florida, USA: pp. 135-143.
4. Bentley, R., Appelt, W., Busbach. U., Hinrichs, E., Kerr, D., Sikkel, S., Trevor, J. and Woetzel, G. (1997). Basic Support for Cooperative Work on the World Wide Web, in *International Journal of Human-Computer Studies* 46(6): Special issue on Innovative Applications of the World Wide Web, p. 827-846, June.
5. Borda, A., *et al.* (2006). *Report of the Working Group on Virtual Research Communities for the OST e-Infrastructure Steering Group*. London, UK, Office of Science and Technology, 46pp.
6. Bos, N., Zimmermann, A., Olson, J., Yew, J., Yerkie, J., Dahl, E., Olson, G. (2007). From shared databases to communities of practice: A taxonomy of collaboratories. *Journal of Computer-Mediated Communication*, 12(2), article 16. http://jcmc.indiana.edu/vol12/issue2/bos.html
7. Buckingham Shum, S., *et al.* (2006). Memetic: From Meeting Memory to Virtual Ethnography & Distributed Video Analysis. *Proceedings of the 2nd International Conference on e-Social Science*, Manchester.
8. Budweg, S., Fischer, J.E., Mambrey, P., Pankoke-Babatz, U. (2006). Kommunikative Vernetzung in der universitären Lehre. Konferenz Mensch & Computer 2006. Gelsenkirchen, September. München: Oldenbourg Verlag
9. Budweg, S., Törpel, B., Burtschick, H.-J., Pipek, V. and Poschen, M. (2006). Contributing to Functionality – The Case of a Network of Union Educators. In: *IRIS Association: Proccedings of the 29th Information Systems Research Seminar in Scandinavia,* August 12-15, Helsingoer, Denmark
10. Büscher M., Christensen M., Hansen K.M., Mogensen P. and Shapiro D. (forthcoming). Bottom-up, top-down? Connecting software architecture design with use. In Voß, A., Hartswood, M., Ho, K., Procter, R., Rouncefield, M., Slack, R. and Büscher, M. (eds.) *Configuring user-designer relations: Interdisciplinary perspectives*. Springer Verlag,.
11. Carlson, S. and Anderson, B. (2006). e-Enabling Data: Potential impacts on methods and expertise. *Proceedings of the 2nd International Conference on e-Social Science*. Manchester, UK.

12. Carusi, A. and Jirotka, M. (2006). Building Virtual Research Environments and User Engagement. *Proceedings of the 2nd International Conference on e-Social Science*. Manchester, UK.
13. Childers, L., Disz, T., Olson, R., Papka, M.E., Stevens, R., Udeshi, T. (2000). Access Grid: Immersive Group-to-Group Collaborative Visualization. *Proceedings of the 4th International Immersive Projection Technology Workshop.*
14. Clarke, A., Eckardt, H., Fulford, M., Rains, M and Tootell, K. (2005). Silchester Roman Town. The Insula IX 'Town Life' Project: The Late Roman Archaeology. (http://www.silchester.reading.ac.uk/later)
15. Coles, S. *et al.* (2005). The 'end to end' crystallographic experiment in an e-Science environment: From conception to publication. *UK e-Science All Hands Meeting*, Nottingham, UK, 19-23 September.
16. *eReSS Study Initial phase report: Standards and technologies in the VRE domain*. September 2006. http://www.hull.ac.uk/esig/eress.html
17. Finholt, T.A. (2003). Collaboratories as a New Form of Scientific Organization. *Economics of Innovation and New Technology* 12(1), pp. 5-25.
18. Fraser, M.A. (2005). Virtual Research Environments: Overview and Activity. *Ariadne* 44, July.
19. Geddes, J., *et al*. (2006). Designing for e-Health: Recurring Scenarios in Developing Grid-based Medical Imaging Systems. Proceedings of the HealthGrid Conference, Valencia , June 7th-9th.
20. Goble, C.A., Pettifer, S., Stevens, R. and Greenhalgh, C. (2003). Knowledge Integration: In silico Experiments in Bioinformatics. Foster, I. and Kesselman, C. (eds.) *The Grid: Blueprint for a New Computing Infrastructure*, 2nd edition, Morgan Kaufman, November.
21. Goderis, A., Li, P. and Goble, C. (2006). Workflow discovery: the problem, a case study from e-Science and a graph-based solution. *IEEE International Conference on Web Services (ICWS'06)*, 2006. pp. 312-319.
22. Haines, K., Blower, J., Liu, C. and Santokhee, A. (2006). Delivering NCOF operational marine data through the Internet. *Proceedings of the IMarEst World Maritime Technology Conference* 6-10 March.
23. Hardstone, G., Hartswood, M., Procter, R., Slack, R., Voss, A. and Rees, G. (2004). Supporting Informality: team working and integrated care records. *Proceedings of the 2004 ACM Conference on Computer Supported Cooperative Work*. Chicago, pp. 142-151.
24. Hartswood, M., Procter, R., Rouncefield, M, Slack, R. and Voss, A. (2007). Co-realisation: Evolving IT Artefacts by Design. In Ackerman, M., Erickson, T. and Halverson, C. (Eds.) Evolving Information Artefacts, Springer.
25. Hartswood, M., Jirotka, M., Procter, R., Slack, R., Voss, A. and Lloyd, S. (2005). Working IT out in e-Science: Experiences of requirements capture in a HealthGrid project. *Proceedings of HealthGrid*.
26. Hine, C.M. (ed.) (2006). *New Infrastructures for Knowledge Production*. Information Science Publishing.
27. Jirotka, M., Procter, R., Rodden, T. and Bowker, G.C. (2006). Special Issue: Collaboration in e-Research. *Computer Supported Cooperative Work* 15, pp. 251-255.
28. JISC. (2006). *Virtual Research Environments Programme: Phase 2 Roadmap*. http://www.jisc.ac.uk/uploaded_documents/JISC-BP-VRE-v1-07-AB.pdf (accessed 30.03.2007)
29. Klöckner, K., Mambrey, P., Sohlenkamp, M. and Prinz, W. (1995). POLITeam – Bridging the gap between Bonn and Berlin for and with the users. In: Marmolin, H. et al. (Eds.) *Proceedings of the Fourth European Conference on Computer-Supported Cooperative Work*. Dordrecht, NL: Kluwer, pp. 17-32
30. Lee, C.P., Dourish, P. and Mark, G. (2006). The Human Infrastructure of Cyberinfrastructure. *Proceedings of the Conference on Computer Supported Cooperative Work*, Banff, Canada, pp. 483-492.
31. Lloyd, S. *et al.* (2007). Integrative Biology — the challenges of developing a collaborative research environment for heart and cancer modelling. *Future Generation Computer Systems* 23, pp. 457-465
32. Mambrey, P., Mark, G., & Pankoke-Babatz, U. (1998). User Advocacy in Participatory Design: Designer's Experiences with a New Communication Channel. *Computer Supported Cooperative Work* 7, pp. 291-313.

33. Martin, D., Hartswood, M., Slack, R. and Voss, A. (2006). Achieving Dependability in the Configuration, Integration and testing of Healthcare Technologies. *Computer Supported Cooperative Work* 15(5-6), December, pp. 467-499.
34. Olivier, B., Roberts, T. and Blinco, K. (2005). *The e-Framework for Education and Research: An Overview*. July. http://www.e-framework.org
35. Olson, G.M., Teasley, S., Bietz, M.J. and Cogburn, D.L. (2002). Collaboratories to Support Distributed Science: The Example of International HIV/AIDS Research. *Proceedings of the 2002 Annual Conference of the South African Institute of Computer Scientists and Information Technologists*. pp. 44-51.
36. Olson, J.S., Hofer, E., Bos, N., Zimmerman, A., Olson, G.M., Cooney, D., & Faniel, I. (forthcoming) A theory of remote scientific collaboration (TORSC). In G.M. Olson, A. Zimmerman & N. Bos (eds.), *Science on the Internet*. Cambridge, MA: MIT Press.
37. O'Reilly, T. (2005). *What Is Web 2.0: Design Patterns and Business Models for the Next Generation of Software*. Available at: http://www.oreillynet.com/go/web2, (accessed 05.12.2006).
38. Orlikowski, W.J., Yates, J., Okamura, K. and Fujimoto, M. (1995). *Shaping electronic communication: the metastructuring of technology in the context of use*, Organization Science 6 (4), pp. 423-444.
39. Pallot, M., Ruland, R., Traykov, S., Kristensen, K. (2006). Integrating Shared Workspace, Wiki and Blog Technologies to Support Interpersonal Knowledge Connection, *Proceedings of the 12th International Conference on Concurrent Enterprising, ICE'2006*, Milan, Italy.
40. Pankoke-Babatz, U., Mark, G., and Klöckner, K. (1997). Design in the PoliTeam Project: Evaluating User Needs through Real Work Practice. *Design of Interactive Systems Conference DIS '97*, Amsterdam. ACM, pp. 277-287.
41. Peters, S., Ekin, P., LeBlanc, A., Clark, K., Pickles, S. Grid Enabled Data Fusion for Calculating Poverty Measures. *Proceedings of the UK e-Science All Hands Meeting*, Nottingham, UK, 18.-21. September 2006.
42. Prinz, W., Löh, H., Pallot, M., Schaffers, H., Skarmeta, A., Decker, S. (2006). ECOSPACE – Towards an Integrated Collaboration Space for eProfessionals. *Proceedings of the 2nd International Conference on Collaborative Computing: Networking, Applications and Worksharing*, Atlanta, November.
43. Schaffers, H., Brodt, T., Pallot, M., Prinz, W. (2006). *The Future Workplace - Perspectives on Mobile and Collaborative Working*, Telematica Instituut, The Netherlands.
44. Schissel, D.P. (2005). Grid Computing and collaboration technology in support of fusion energy sciences. *Physics of Plasmas* 12, 058104-1.
45. Star, S.L, Ruhleder, K. (1996). Steps Toward an Ecology of Infrastructure: Design and Access for Large Information Spaces. *Information Systems Research* 7(1), March. pp. 111-134.
46. Törpel, B., Pipek, V. & Rittenbruch, M. (2003). Creating heterogeneity. Evolving Use of Groupware in a service network. In: Andriessen, E., Heeren, E., Hettinga, M. & Wulf, V. (eds.) *Computer Supported Cooperative, special issue on "Evolving Use of Groupware"*, 12(4), pp. 381-409.
47. Voss, A., Procter, R. and Williams, R. (2000). Innovation in Use: Interleaving day-to-day operation and systems development. Cherkasky, T., Greenbaum, J., Mambery, P. (eds.) *Proceedings of the Participatory Design Conference*.
48. Voss, A. (2006). *Co-realisation: A Radical Respecification of the Working Division of Labour in Systems Development*. Unpublished PhD Thesis, School of Informatics, University of Edinburgh.
49. Walton, N.A., Dalla, S., Gonzalez-Solarez, E., Richards, A. and Tedds, J. (2006). AstroGrid: A place for your science. *Astronomy & Geophysics*, 47(3), pp. 22-24.
50. Williams, R., Stewart, J. and Slack, R. (2005). *Social Learning in Technological Innovation: Experimenting with Information and Communication Technologies*. Edward Elgar.