Formative Evaluation of the JISC VRE Programme

The VRE1 Programme: achievements and lessons learnt

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The VRE formative evaluation team would like to thank all VRE1 project managers, user champions and end users who gave their time to inform this study.

Executive Summary

This report presents the achievements and lessons learnt from the 15 projects that participated in the VRE1 programme. Overall, the programme is judged as a success in meeting its original aims and objectives. In doing so the projects engaged (to a greater or lesser extent) their respective research communities in VRE development and implementation; conducted extensive user requirements analyses which provided the basis for the construction of various VRE configurations, including both large scale and lightweight, proof-of-concept demonstrators; identified functionality (in the form of tools and services) which met user requirements; and increased awareness of and stimulated discussion on VREs within the UK research community. Overall, the VRE1 Programme clearly demonstrated its potential to have a major impact on supporting and changing research practices in the academic community.

Specifically, the formative evaluation identified five main areas where the VRE1 projects contributed to collective learning as regards VREs. First, VRE1 projects can be seen as an emerging and expanding (but still rather hidden) community of practice. Either through the formal Programme meetings or informal contacts, the projects developed productive ongoing working relationships with each other. These were characterised by bilateral meetings, mutual help and assistance, and even resulted in formal partnerships for joint bids, e.g. in VRE2. Apart from these collaborations within the context of the VRE1 programme, most projects reached out to the wider academic and research community by undertaking a wide range of dissemination activities, including presenting at conferences and publishing in refereed journals. We see this emergent community of practice as a very valuable outcome of the programme and as a key mechanism for driving the programme forward. Consequently, we would strongly recommend that JISC help support and maintain this community as well as make it more directly “visible” to key stakeholders, e.g. HEIs.

Second, the VREs developed by the projects broadly relate to three types of socio-technical systems which are focused on: (i) Accessing and Combining Data and Computing Resources linked to the ability to work with dispersed data sources, across databases, applications and legacy systems; (ii) Online Collaboration in terms of facilitating the (a)synchronous combination of expertise of dispersed researchers as well as promoting collaborative writing; and (iii) Virtual Research Management which supports the whole research lifecycle and allows for the collecting and managing of institution-wide information.

Third, in developing their various VRE configurations, projects highlighted the potential of VREs to transform research praxis across disciplines and institutions. VREs have the potential to radically change research praxis across disciplines. As such VREs enhance the transparency and reliability of research processes which, in turn, can lead to a better understanding of the research question. Moreover, projects proved how VREs can contribute to data generation, e.g. by facilitating multi-site trials and experiments, and in some cases, even leading to greater speed and accuracy of data capture and analysis. At the same time, projects showed how

VREs can expand the boundaries of current research methods in a specific discipline as well as introduce new ways of doing research. In either case, the result has been both the generation of new knowledge and research paradigms. In addition to introducing a new way of conducting research, VREs also provide a different way of handling data and related documentation, thus making project management more effective.

An interesting finding from projects' experience is the way technology has been taken up by users or institutions in a number of novel and/or unexpected ways. This, in turn, also illustrated the dynamism of socio-technical systems developed by the projects, where the constant interaction between the technological artefacts and users can result in the latter claiming and adapting technology for their own needs and in new and unexpected ways. For example, the SAKAI platform is employed not only as an online collaboration but also as a research tool. Finally, a number of projects have also highlighted how VREs can be used to enhance the quality of teaching and training of students.

Fourth, projects viewed user engagement and involvement as both one of their key tasks and main achievements. Indeed, one important characteristic of all projects has been their conscious effort and success in clearly identifying and engaging their respective user communities at various stages of their project lifecycle. Although projects' view of users ranged from regarding them as co-participants in the design of technology to on-going collaborator to a source of data informing the technological development process, they all exerted a concerted effort in both identifying and analysing their respective user requirements and engaging them not only in the VRE project itself but also in longer-term relationships. Moreover, a number of projects adopted a participatory, iterative approach to technology design and development which, in turn, resulted in enhanced user development and increased take-up. Interestingly, some projects went well beyond their initial user base and engaged a number of other actors, not least institutions and even industry.

Fifth, the institutional challenge as regards involvement in and adoption of VREs by HEIs remains. Although the latter's awareness of VREs has increased significantly, not least due to the VRE1 projects, their institutional support and buy-in varies considerably. Path dependency issues, including legacy system compatibility, pre-existing VLEs/MLEs, lack of clarity as to the added value of VREs and interest in competing solutions, combined with the projects' relative lack of social marketing and strategic communications strategies lie at the heart of the HEIs' attitude. Even when the institutional support is strong, this does not necessarily translate into availability of resources, including funding.

In view of these findings our recommendation to JISC therefore is to scale up its work on VREs. Acting on the lessons from VRE 1, in particular those relating to the value of binding in users and institutions, will be crucial to ensure the success of this innovation.

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1. INTRODUCTION

This is the second programme-level report produced as part of the formative evaluation of the JISC's first Virtual Research Environments (VRE) Programme. The VRE1 Programme started in April 2004 with the objective to explore how technologies and infrastructures developed for virtual learning environments can be exploited for the research community. The remit was ambitious, and the programme structure reflected this by allowing space for experimentation and genuinely different and innovative approaches to emerge. Between 2004 and 2007, the programme funded 15 projects to explore different elements of a VRE by deploying large-scale VRE demonstrators, identify functionalities of a VRE or develop demonstrators. In addition, the eReSS project was funded to help to identify suitable solutions for the interoperability of VRE tools, applications, and resources. A formative evaluation was to support the implementation of the VRE programme and individual projects, to help ensure that the intended goals of the programme were achieved.

After an initial progress report submitted early in 2006, this is the second programme-level report produced by the formative evaluation team. It comes at a time when the vast majority of projects funded by the VRE1 Programme have completed their work, and a successor group of four projects are developing their work under VRE2. Against this background, the main aims of this report are:

- To make sense, from a social science perspective, of the developments and achievements of the VRE1 Programme
- To surface the collective learning gains from the VRE1 Programme, focusing in particular around projects' experiences regarding institutional embedding, disciplinary embedding and execution of scholarly tasks
- To arrive at an overall assessment of the VRE Programme and its value to the UK Higher Education Community and to make recommendations to JISC relating to the VRE2 Programme and beyond

The report is organised by chapter in the following manner: **Chapter 2** provides an initial programme-level review of the VRE1 programme. **Chapter 3** explores the Programme's achievements by analysing the key outcomes from a socio-technical perspective. **Chapter 4** goes on to analyse the main lessons learnt from the research work under VRE1. In conclusion, **Chapter 5** offers an overall assessment of the VRE1 programme as a whole from the perspective of the formative evaluation and provides recommendations for the future.

2. THE VRE 1 PROGRAMME: OBJECTIVES AND APPROACHES

2.1. The VRE1 Programme and the formative evaluation

The VRE1 Programme emerged during a period of heightened interest in high-performance computing for scientific research and a growing awareness of the relevance of Virtual Learning Environment (VLE) and digital libraries technology for the research community.[1] Against this background, the aim of the Programme was to learn more about the potential and application of VREs in higher education. Specifically, the programme had three aims:

- Engaging the research community in building and deploying Virtual Research Environments (VREs);
- Providing a clear definition of what constitutes a VRE, its boundaries and how this function overlaps with other related technologies, e.g. Virtual Learning Environments, peer-to-peer applications and online collaboration software;
- Raising awareness and stimulating discussion on VREs within the UK research community.

Fifteen projects were funded to contribute to each of these aims, distributed across four distinct strands:

- *Strand I:* Larger scale projects to deploy VRE demonstrators based on existing frameworks (six projects);
- *Strand II:* Projects to identify functionality (in the form of tools and services developed in other projects) which has not hitherto been integrated into the existing framework architectures and to add such functionality to address clear user requirements (two projects);
- *Strand III:* Projects to develop and deploy lightweight, proof-of-concept VRE demonstrators appropriate to the needs and skills of specific communities (four projects);
- *Cross-strand* (three projects).

A list of these projects can be found in Annex 1 to this report.

In funding the 15 projects, JISC expected to achieve the following objectives [2]:

- Gain an increased understanding of the requirements of VREs to support decision making on future activities in this area;
- Produce tangible products and/or demonstrators of usable services & tools;
- Begin moving technologies into the wider community;
- Begin to change behaviours and cultures.

In addition, between 2006 and 2009 the e-Research Tools and Resources Interoperability project (eReSS) is to provide support to the VRE Programme by

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[1] See First Progress Report 2006, p. 7-8.

[2] See Formative Evaluation first progress report, p. 11.

helping to identify suitable solutions for the interoperability of Virtual Research Environment tools, applications, and resources.

To support the Programme's implementation, the VRE1 Programme also funded a formative evaluation which had four main aims:

- Assess how effectively the selected projects are meeting the aims of the programme;
- Identify common themes between projects where these exist;
- Identify gaps in the work currently being undertaken; and
- Contribute to raising awareness of the programme and stimulating discussion on Virtual Research Environments in the community.

The activities of the formative evaluation were organised in three phases to cover the duration of the VRE Programme. Phase 1 (August to December 2005) focused on familiarisation with the Programme and its projects and a needs analysis. The team visited all projects to speak with the key actors involved in the research and development work to gain an understanding of their activities. In addition, a mapping exercise took place where project plans were studied to map the intended activities against the Programme's aims and objectives. These research activities formed the basis of the first formative evaluation report and the consultancy support offered to projects. Phase 2 (January 2006 through to October 2006) focused on practical project support in the areas of user feedback, evaluation, community engagement, institutional embedding and exit and sustainability issues. On the basis of information gained from the initial visits, each project was offered two days' consultancy support/advice from a member of the project team and the team contributed to the design and running of the July 2006 Programme meeting. Phase 3 (November 2006 through to July 2007) explored the lessons learnt from the research work undertaken as part of VRE1, revolving in particular around issues of institutional embedding, disciplinary embedding and execution of scholarly tasks. Interviews were conducted with the project managers of each VRE1 project and several users or user champions were also interviewed. This report presents the results from this research.

2.2. Research and Development work under VRE1

2.2.1. The 'value added' of VRE1 funding

The VRE Programme presented the UK academic community with a unique opportunity to develop nascent research ideas. A range of consequences followed from the funding:

A primary consequence of the VRE funding was that it was instrumental for most projects in facilitating their research and development work. As a project manager reported, without VRE1 "we would have sat around and have lots of ideas, but there would have been no implementation". Another project manager mentioned that the technology would not have developed "for a long time". In the views of another, "we would have been fumbling our way forward, we really needed the support of VRE1". A fourth project manager also considered that progress would have been "slower, less focused, less generic".

VRE1 funding also had a range of secondary consequences. For example, a number of projects reported it helped accelerate and deepen particular elements of their development work and accelerated the process of user testing. As a corollary, this process further assisted in gaining an in-depth understanding of users' needs and requirements. In particular, the SAKAI education research project reported that without the VRE1 funds there would have been a "less well developed understanding of research requirements; SAKAI would have continued to develop, but we wouldn't have the same level of user engagement or confidence in the VRE concept or in the specifics of the SAKAI platform. We'd be pitching a VLE with untested VRE functions to new users, rather than something with full VRE user accounts."

2.2.2. Methods and approaches used

Projects adopted different approaches to software development and user involvement. Data from interviews and project reports indicates that these approaches were broadly aligned with the following kinds of models.[3]

Table 2-1: Software development models used in the VRE1 Programme

Development model	Short description	Project example
Participatory design	Participatory design is an approach to design that attempts to actively involve the end users in the design process to help ensure that the product designed meets their needs and is usable. http://en.wikipedia.org/wiki/Participatory_design	CORE
Co-operative design	Involving designers and users on an equal footing. (North American term for participatory design.) www.nada.kth.se/~yngve/CD-PD-OH.html	IBVRE
Co-realisation	Orientation to technology production that develops out of a principled synthesis of ethnomethodology and participatory design. It moves the locus of design and development activities into workplace settings where technologies will be used. www.inf.ed.ac.uk/publications/report/0648.html	MEMETIC
XP (eXtreme Programming)	Extreme Programming (or XP) is a software engineering methodology, the most prominent of several agile software development methodologies. Proponents of XP regard ongoing changes to requirements as a natural, inescapable aspect of software development. Proponents also believe that being able to adapt to changing requirements at any point during the project lifecycle is a more realistic approach than attempting to define requirements at the start of a project and then attempting to control any changes.	CSAGE

[3] Definitions added by the formative evaluation team.

Development model	Short description	Project example
	http://en.wikipedia.org/wiki/Extreme_Programming	
Incremental approach / iterative design	The basic idea behind iterative enhancement is to develop a software system incrementally, allowing the developer to take advantage of what was being learned during the development of earlier, incremental, deliverable versions of the system. http://en.wikipedia.org/wiki/Iterative_and_incremental_development	BVREH ELVI
Waterfall software lifecycle model	The waterfall model is a software development model in which development is seen as flowing steadily through the phases of requirements analysis, design, implementation, testing (validation), integration, and maintenance. http://en.wikipedia.org/wiki/Waterfall_model	EVIE
(Rapid) prototyping	Prototyping is the process of quickly putting together a working model (a prototype) in order to test various aspects of a design, illustrate ideas or features and gather early user feedback. http://en.wikipedia.org/wiki/Prototyping	SAKAI Education Research
Spiral development methodology (modified)	The spiral model is a software development process combining elements of both design and prototyping-in-stages, in an effort to combine advantages of top-down and bottom-up concepts. http://en.wikipedia.org/wiki/Spiral_model	History of Political Discourse
Agile programming	Agile software development is a conceptual framework for undertaking software engineering projects that embraces and promotes evolutionary change throughout the entire life-cycle of the project. http://en.wikipedia.org/wiki/Agile_software_development	SAKAI Portal Demonstrator

3. WHAT DID THE PROGRAMME ACHIEVE?

3.1. VRE1 as a community of practice

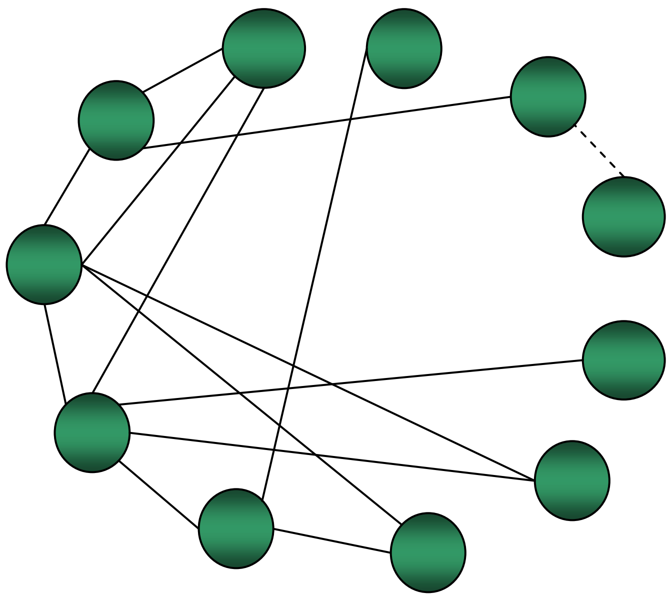
VRE1 projects developed productive working relationships with each other. As part of the VRE1 Programme, programme management and the 15 projects met bi-annually at a total of three Programme meetings (July 2005, January 2006 and July 2006). The formal agendas offered projects an opportunity to learn about each other's work and get support for particular issues of their research and development work. However, projects gained most from these meetings by making full use of the opportunities to build and foster relationships and create powerful links with other projects and project actors. Thus, programme meetings assisted projects:

- To meet up and to get to know other project teams;
- To share information about their work, areas they are struggling with and 'contextual issues' (such as ethical, social and legal issues);
- And to help progress their work by getting suggestions from other projects about technologies they are developing or through some of the programme activities.

Programme meetings were also opportunities for projects to pick up informally what was on JISC's agenda for the development of VREs.

Importantly, projects also developed ongoing working relationships with each other outside these formal meeting settings. These relationships are depicted schematically in Figure 3-1: Links between VRE1 Projects below.

Figure 3-1: Links between VRE1 Projects



Four factors appear to have facilitated the creation of these links:

- Institutional proximity (i.e. where several projects were based at the same HEI as was the case in Oxford);
- Where projects used the same technology (e.g. the SAKAI or the MEMETIC toolkit);
- Where projects belonged to the same discipline (e.g. the Humanities projects);
- Where projects shared an interest in a particular aspect of the VRE programme (e.g. links developed between projects who shared an interest in research collaboration).

Many of these relationships were characterised by informal alliances which involved cross-site meetings, mutual help and assistance and in some cases led to more formal alliances for VRE2, which had concrete outcomes in the form of successful VRE2 bids. In particular, these relationships were instrumental in:

- *Sharing experience*. Learning from each others' experiences of applying particular development methods and using this learning for their own development work during VRE1. For instance, the ELVI project presented their findings on user engagement at a workshop at Oxford University.

- *Offering mutual help and assistance*. Feeding into each others' research, for instance by attending scoping workshops. For instance, representatives from the BVREH project attended the workshop organised by the Political Discourse project to kick off the eText forum which uses the project's VRE technology.

- *Providing a sounding board for VRE research*. Several VRE1 projects organised periodic meetings with each other. The three Oxford projects, for instance, organised "occasional meetings to discuss progress and find out more about each project."[4] The SAKAI Education Research project and the Political Discourse projects also met up periodically "to present our work to them and vice versa".

- *Building strategic alliances.* In order to develop joint bids for the VRE2 Programme, usually towards the end of the programme and occasionally after project work had been completed. Examples include MEMETIC and IUGO, the Political Discourse project and SAKAI Portal Development.

The experiences of Programme meetings and other interactions between projects indicate that the Programme and its stakeholders succeeded in contributing to the construction of an emergent 'community of practice' around virtual research environments.[5] We would argue that the development of this emergent, and in some

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[4] BVREH completion report.

[5] According to Wenger, a community of practice is a group 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 on an ongoing basis. (…) These people don't necessarily work together every day, but they meet because they find value in their interactions. As they spend time together, they typically share information, insight and advice. They help each other solve problems. They ponder common issues, explore ideas, and act as sounding boards."*

ways hidden, community of practice had powerful impacts for the programme and the actors involved.

3.2. Reaching out to the wider academic community

VRE1 projects have not only focused on working with other actors within the Programme, but have also undertaken a wide variety of dissemination activities. The chart below shows the type and proportion of dissemination activities undertaken by projects[6].

Figure 3-2: Type of dissemination undertaken under the VRE1 Programme

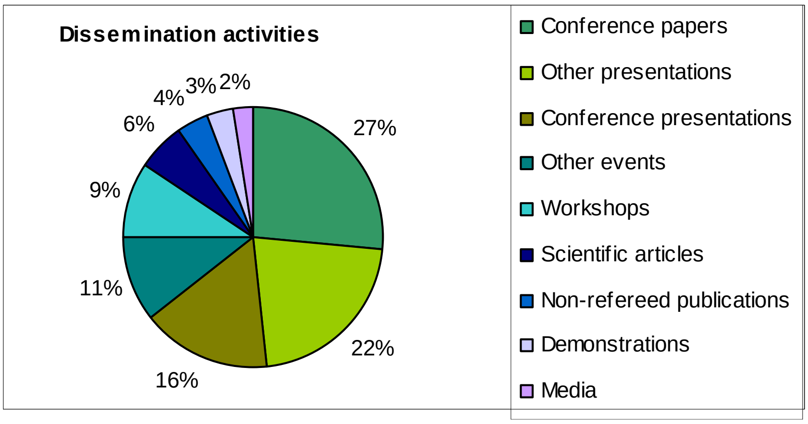

Figure 3-2 above indicates that presenting papers or work at conferences has been the most popular type of dissemination activity. Projects participated in a variety of conferences, though in terms of frequency of attendance the most popular ones were:

- The UK eScience All Hands Meetings (20 per cent of conferences attended),
- The Digital Resources for the Humanities and Arts (11 per cent of conferences attended) and
- The eSocial Science conferences (8 per cent of all conferences attended).

Together, these three events represent nearly 40 per cent of all conferences attended by VRE1 projects between 2005 and 2007.

Overall, the conferences attended can be broadly grouped into three categories:

- Conferences related to 'pure' computer science (such as the Access Grid Retreat, Conference on the Design of Cooperative Systems, the Workshop on Middleware for Grid Computing or the International Conference on Systems Science, Conference on the Design of Co-operative Systems, Conference on Human Factors in Computing Systems) – representing approximately one third of conferences attended.
- eScience conferences (such as the international e-social science conference; NCeSS Annual Conference, the IEEE Enterprise Computing Conference,

6 As listed in projects' final and completion reports. At the time of writing, the reports of three projects were not yet available; the data is therefore valid for 12 out of the 15 projects. Wherever possible, projects' own classification of activities was employed.

ELeGI Conference on Advanced Learning Technologies) – representing approximately half of all conferences attended;

- Domain specific conferences (such as the Annual Conference of the British Educational Research Association; the European Association of Research Managers and Administrators) – representing approximately one sixth of conferences attended.

Another main method of disseminating information about project work was for members of project teams to give presentations at events other than conferences or workshops (22 per cent of the Programme's dissemination activities). These 'other events' include:

- The VRE Programme meetings for which projects developed posters, gave presentations and demonstrations of their work.
- Intra-institutional events, such as public seminars or presentations to representatives of the HEI administration.
- Inter-institutional seminars and informal talks as well as training events.

Two projects in particular, undertook conscious efforts to go one step further and systematically marketed their technologies to potential users. The CSAGE project was particularly pro-active and has undertaken "over 80 events ranging from very small one-to-one meetings to presentations at 500+ auditoriums, each trying to present work, or test pieces with the aim of giving a vision of future use."[7] Another example for conscious and tailored marketing efforts is the SAKAI Education Research project. Drawing on social marketing and engagement techniques, this VRE project made strong efforts to reach out to different user constituents: "we decided from the outset that we were going to talk to educational researchers themselves, the JISC community and the e-social science community."

A brief review of VRE 1 project sites in September 2007 indicated that the majority were easily accessible and usable across a range of browser platforms. However, accessibility is also about communicative clarity to a wide range of target audiences who may be interested in utilising findings, data and tools in their own work. A number of project websites were not available, from either the main JISC VRE website or at the project specific URL. There was also evidence that key internal projects links were down within one or two project sites (e.g. presentations). On occasion, it can also be challenging for the user to discern precisely what type of outputs have actually been produced by projects. And in the case of projects where demonstrators, tools or prototypes are deliverables these are sometimes not available or remain in development. Project websites are a primary vehicle for marketing, communications and dissemination, not only for existing user communities but for engaging potential new users as well. It would seem that the websites of VRE projects have an untapped potential to be used for these purposes. For instance:

- Project websites could offer a brief and easy to read introductory account of the project and the added value that the project provides to researchers and academics or other specific target user groups.

[7] CSAGE Final Report

- In the case of downloadable prototypes, software and demonstrators there could be also be an emphasis on straightforwardly written user manuals and instructions. Use of video walkthroughs or other visual media could also augment usability and take up.
- The design and content of websites should also be considered with respect to the overarching social marketing and communications strategy for the project and its objectives.

Two further observations can be made relating to the dissemination activities carried out under the VRE1 Programme:

- Through the activities of a few projects the VRE programme has achieved media coverage, hence potentially reaching a wider audience beyond academic peers. The CORE, CSAGE and MEMETIC projects have published articles for the Times Higher Education supplement and ISME has an article in preparation for New Scientist Magazine. Furthermore, OGHAM has featured in the BBC Radio 4 series 'The Material World'.
- Across the programme, at the time of submission of final reports a total of 12 refereed articles were mentioned as dissemination outputs (a list of these can be found in Annex 2 of this report). This figure is likely to reflect the ongoing nature of research and development work, which for most projects has only recently finished. It is therefore possible that over the coming months such articles that have been recently published or submitted will appear in a range of periodicals including computing, education, management science, linguistics and health. The SAKAI Education research project was particularly pro-active in the submission of refereed articles, as was the SAKAI portal demonstrator project.

3.3. Three emerging socio-technical systems

The outcomes of the 15 projects can be broadly categorised as relating to (i) technology *per se*; (ii) user involvement; (iii) improved collaboration; (iv) enhanced research process(es); (v) software; (vi) partnerships and (vii) publications, etc. With many projects typically achieving multiple outcomes simultaneously. As a result, most projects managed to fulfil all or part of the key characteristics of a VRE as defined by JISC. Occasionally, outcomes have even exceeded what was originally envisaged. The Cheshire 3 project, for example, went beyond identifying VRE functionality to develop a prototype VRE which is attracting interest from industry. The CORE project reports that the team "thought we were doing proof-of-concept, whereas the surgeons started using the CORE tools for demonstration purposes", A further example is the History of Political Discourse project (cross-strand) which found itself going beyond prototyping or demonstrating a VRE to actually implementing and disseminating a VRE amongst humanities scholars and students.

The VRE technologies developed can be productively categorised from a socio-technical perspective. In this report we understand the socio-technical system as follows: a systemic relationship and dialogue between the user and the technology artefact in the wider context of the work environment.

From this perspective, our data analysis allows projects to be characterised in terms of three types of socio-technical systems:

- **Accessing and combining data and computing resources**, such as ISME, CORE, SAKAI.
- **Online collaboration**, e.g. IBVRE, OGHAM, Political Discourse, etc.
- Providing the virtual environment, tools and services for **virtual research management**, e.g. EVIE, ELVI.

In the following sections below we present each of these socio-technical systems as manifested in the various project-related configurations.

Table 3-1: Summary of socio-technical systems and key features

Socio-technical system	Key feature	Project examples
Accessing and Combining Data and Computing Resources	Working with dispersed data sources, across databases, applications and legacy systems	ISME, CHESHIRE 3, MEMETIC, CORE, IBVRE, OGHAM, IUGO
Online Collaboration	Facilitating the (a)synchronous combination of expertise of dispersed researchers	CSAGE, IBVRE, ISME, ISME, CORE, MEMETIC, OGHAM, SAKAI Portal demonstrator, SAKAI Education, BVREH, Political Discourse.
Virtual Research Management	• Supporting the whole research lifecycle • Collecting and managing Information • Crossing inter-departmental boundaries	ELVI, EVIE

3.3.1. Accessing and Combining Data and Computing Resources

This socio-technical system focuses on accessing and combining data and computer resources, allowing researchers to work with dispersed data sources and across databases, applications and legacy systems. This, in turn, enables them to access a wealth of data situated in dispersed locations, variety of databases, and/or legacy applications, all of which would otherwise be either challenging or time-consuming to retrieve. This e-enabled resource recovery is further combined with an ability to both link various datasets and databases as well as conducting searches across databases and sites. The outcomes of the data search can also be archived for future reference. Consequently, part of the research lifecycle can be enhanced in terms of increased efficiency in resource retrieval and analysis, and more comprehensive scope in data gathering and elicitation.

The GROWL project, for instance, built a lightweight toolkit which allows heritage applications (written in Fortran, C and C++) to be integrated into the Grid to allow scientists "to access the power of remote computing systems and access large datasets in a seamless way."[8] ISME developed a prototype VRE which allows

[8] GROWL final report, p. 3

distributed teams of material scientists and engineers to use multiple sources of archived data in order to collaborate on enquiry-based experiments. In a similar vein, CHESHIRE 3 produced a number of user-oriented information and collaboration tools, which facilitate use of and collaboration over distributed and diverse digital resources. In particular, its Fab4 browser was developed as a model to support collaboration by academic communities across diverse data types, including spontaneous distributed annotations across diverse document formats. In addition, it developed access and resource discovery tools, including a range of flexible digital library services; system support for access to large data collections; and distributed information management services. For example, provision of the annotation system for the collaborative analysis of text by CHESHIRE 3 can, according to one user, "be of particular use to academics and researchers who wish to undertake collaborative research."

On the other hand, the SAKAI VRE for Educational Research project developed a cross-tool and cross-site search tool in order to facilitate retrieval of information from dispersed data sources and databases. Currently, the TLRP projects are using different tools in different ways, collecting research data and engaging research participants through SAKAI. As one user pointed out, "SAKAI has been really beneficial in providing a central storage space for projects, literature reviews, project management, discussions, research data, central storage space".

Moreover, within this context VREs allow for **the capture and archiving of data** which could otherwise be at risk of loss e.g. recording distributed meetings and conferences, including parallel session discussions. Meetings, seminars, workshops recorded in this way can be accessed and searched after the event, and thus themselves be employed as a resource, e.g. for those not having been able to attend. MEMETIC has produced a flexible and robust software toolkit that is capable of supporting a number of research-based scenarios. For example, Access Grid videoconferences are no longer restricted only to those who can attend live, but can be recorded and replayed using VCR-style controls, or via the novel indexing and navigation tools offered in the project's Meeting Replay tool. The Political Discourse project team working with MEMETIC technologies, have also begun recording seminars. These recordings can provide the basis for constructing an **archive** of recorded and edited meetings, presentations and lectures to be used as a resource by MA students and the VRE Research Group participants. Similarly, IUGO produced open source and faceted browser software, which enables the integration of web-based content (and references to non web-based content), related to individual conferences and individual sessions within conferences. The information that can be accessed in that way can be used as a resource for interested parties, e.g. academics, researchers, students, etc. Given IUGO's focus on the audio visual storage of conference and research event data, this can potentially provide added value to existing services. As a potential user and VRE2 alliance partner reported, IUGO could provide "a whole new and added value dimension to their conference database which is currently just a listing of events and dates and short hyperlinked descriptions e.g. the ability potentially to retrieve actual recordings of presentations in audio and video and search within a conference". In addition, wikis are also beginning to be used for storing written material. For example, the Virtual Research Group run by the Political Discourse project uses Sakai's wiki tool, among others, for pooling resources and quotations.

VREs can also contribute to **data generation**, for instance by facilitating multi-site trials (CORE) and experiments (ISME). Specifically, VREs allow for a different way of handling data and doing experiments, while making people more aware of data management issues (IBVRE, ISME). They also have the potential for greater speed in data capture and handling. For example, in the OGHAM project VRE tools enable data recovery and capture in the field, i.e. at the archaeological Silchester site.

3.3.2. Online collaboration

Online collaboration is a socio-technical system that is characterised by its ability to facilitate the synchronous and asynchronous combination of expertise of dispersed researchers. Asynchronous collaboration concerns online events for which all participants are not necessarily required to be logged in or active at the same time. They can access the information and add their comments/contribution in a self-paced way and when most convenient to them. Such online collaboration supports both online interaction and independence as to when the researcher engages with the community. In contrast, synchronous collaboration involves the simultaneous online presence and contribution of participants. It brings together in real time people based on different locations, so that they collaborate, (e.g. in experiments/trials), as well as attend virtual meetings and seminars.

A number of projects were aimed at **facilitating the (a)synchronous combination of expertise of dispersed researchers** through visualisation technologies, including real-time visualisation technologies such as the Access Grid. These included Political Discourse, IBVRE, ISME, MEMETIC and CSAGE For example, the historians participating in the eText forum run by the Political Discourse project, based in different institutions and having different expertise, pursued their interest in collaboration by running a series of Access Grid seminars to discuss the term commonwealth. Similarly, the ISME project developed a prototype Grid-enabled VRE which enables materials scientists based in different locations to collaborate on experiments (using multiple sources of archived data). Its common shared workspace with Access Grid tools used on the web portal allows researchers to visualise results from their experiments via the multimedia resource, while the team can 'meet' together bringing their own data and modelling predictions in order to discuss and develop an evolving experimental strategy. CSAGE has allowed a choreographer to use stereoscopic viewing and a virtual 3D installation to perform art with distributed participants. On the other hand, the OGHAM project facilitated people's access to a wireless network and broadband *in situ*, i.e. at the archaeological site itself, thus making it possible for people to communicate direcly with base, which was viewed as a marked increase in efficiency .

In a similar vein, the SAKAI Portal Demonstrator project has developed tools for SAKAI, including an online meeting/Video-Conferencing (AGORA) and a Blogger tool which aims to enhance online collaboration. The services and tools of the CORE project (such as templates for data analysis) also allow orthopaedic surgeons, as the key target community, to work collaboratively in setting up a multi-centred medical trial; collating the findings; analysing the findings; and developing either an academic publication or a set of training materials.

VREs can also promote both **collaborative writing** and the faster turnaround of scholarly publications. For example, the OGHAM project team found the development of a virtual collaborative research environment invaluable for the preparation of materials for publication and the further development of research.

3.3.3. Virtual Research Management

The third socio-technical system which emerged from the VRE1 Programme encompasses whole institutions and research lifecycles. EVIE and ELVI developed virtual research management tools which **support the whole research lifecycle** from identifying funding opportunities and collaborators, to proposal writing to setting up budgets, to producing financial and management information, to report writing and publications.

For example, ELVI's research 'digital dashboard' is one web page which provides access to a range of personalised channels, e.g. research activity channel, Project Monitoring, Financial Management channel, Targeted Funding Opportunities channel, Research News-Feeds, Collaboration tools, Virtual Library facilities etc. Alternatively, EVIE's RSS channel presents at-a-glance funding alerts to researchers.

Such comprehensive institution-wide systems can be instrumental in **collecting and managing information** for both academic and administrative purposes. For example, the ELVI's research activity channel provides access to research activity data for academics, school managers and administrators, faculty heads, and senior management. The channel presents tables of data regarding research outputs (Publications, Research Funding, Student Supervision and Esteem Indicators) by the University's academics, and enables the user to drill down into the details of those outputs by clicking on the numbers within the table. In terms of its main benefits the research activity channel enables access to a wealth of data about the University's research. So far, it is mainly used for preparation of the University's RAE submission, but it is hoped that it could also become a powerful tool for encouraging collaboration by enabling academics to explore the research interests of colleagues throughout the University.

Moreover, the project finances channel is the other important channel on the ELVI's research dashboard, since academics, School Management and Central Support need easy access to financial data for their projects. Some of its main benefits include easier access to project finances which assists academics in managing their finances. At the same time, however, problems and deficits are highlighted earlier.

Another effect of such "holistic" institutional VREs is that they contribute to the **crossing of inter-departmental boundaries** between university departments as well as between the latter and the university's administration. This, in turn, can promote a deeper awareness of other departments' interest and focus of work as well as deepen one's understanding of what other departments actually do (and for the administration, contribute to the institution's reputation and viability). Consequently, opportunities for enhanced collaboration can also present themselves across the university. For example, ELVI's Research Activity channel offers information on publications, supervisions (PhD, MSc), funding, "esteem" indicators, any individual working in the University/School/Faculty, staff lists by school/faculty, etc. The ultimate aim is to use the research activity channel to find out what other schools are doing, what funding is available and what other people are doing. As a result, collaboration opportunities can be identified more easily.

Overall, such VREs can result in greatly improved research processes and related management; increased transparency; improved communication flows between different departments/disciplines and between these and the University's administration; enhanced collaboration; more effective workflow planning, organisation and better informed decision-making.

3.4. A potential for radically changing research praxis

VREs also have the potential to radically change research praxis across disciplines.

Firstly, the OGHAM project showed the dramatic potential of VREs for the field of archaeology. Here, VREs can close the gap between research steps (data collection, inputting of information into a database, analysis and publication) and therefore speed up the research process from data capture to publication. The OGHAM VRE facilitates this in particular through an on-site wireless network and computing facilities. These facilities enable researchers to add their find data and manual sketches directly into the IADB database. Off-site or remote members of the project team are in turn able to see what is happening on-site very quickly and incrementally and to offer their interpretation of the work. The project's virtual collaborative research environment then allows researchers to collaborate on preparing material for publication. The project produced a collaboratively written article which, according to the project manager, has gone into publication much quicker than could have been previously envisaged. This fast turnaround from data capture to publication could not have been possible prior to the VRE.

VREs further **enhance the transparency and reliability of research processes** which, in turn, can lead to a better understanding of the research question. IBVRE users commented that thanks to VREs, ideas are reproducible, which assists in ensuring consistency of the experiment set-up, which includes automated and appropriate checks. This assists research practitioners in conducting more carefully controlled experiments and hence help facilitates "better science". The ISME project developed tools that refined the remote experimental steering process, created a shared workspace and aided distributed visualisation in a VRE that is used by dispersed teams of researchers, e.g. instrument scientists and materials scientists in a transparent and robust manner. In addition, the fact that ISME enables supervisors to remotely oversee experiments conducted by students and suggest improvements/corrections, as appropriate, enhances the transparency (and thus reliability and validity) of the experiment. As a result, students benefit from improved training and support structures, whilst the likelihood of mistakes and lost experiments is minimised.

Second as a result of VRE-enabled online collaboration, VREs can **expand the boundaries of current research methods**, whilst at the same time **introduce new ways of doing research**. Indeed, one key outcome of a number of projects has been the way their varied VRE configurations have either expanded the boundaries of current research methods in a specific discipline, and/or initiated new ways of doing research. In either case, the result has been both the generation of new knowledge and research paradigms. For example, in the ISME project the Mobile Access Grid technology used for remote experiment steering changed the way the remote advisor perceives the whole experiment. Here the Access Grid can be employed as an alternative way to assist and steer an experiment. Moreover, one can, using a legacy application developed by the Open University, undertake virtual experiments. The service in question provides the researchers with a simulation tool of the experiments at the remote site and can be used either prior to their visit to the facility to learn the experimental process and/or even on-site in case any problems arise. The project also allows experimenters to seek and secure (remote) expert advice to assist problem solving. According to the project's final report, VREs offer totally new concept in the domain of materials science.

Similarly, the IBVRE project has demonstrated that the VRE concept is highly applicable to the integrative systems biology domain, while it can also have relevance for any discipline characterised by the need to run computationally intensive simulation experiments. Significantly, according to the project's report, "the VRE technology developed is already starting to have a major impact on the efficiency of biomedical research at three leading heart modelling groups around the world. By removing the need to develop complex scripts and manage compute resources, simulation experiments are more reproducible and easier to carry out by those lacking a high degree of technical expertise. In some cases, technical training time has been cut from up to a year to a matter of days, opening up this area of science to a wider community, including the teaching and learning communities."

In addition to introducing a new way of conducting experiments, VREs also **provide a different way of handling data**, whilst improving awareness of data management issues. As a consequence, this can lead to more effective project management and documentation.

The SAKAI VRE for Educational Research was successful both in researching the nature of academic collaboration and developing production-quality software tools which in turn demonstrate that such research and development projects are viable. At the same time, the team acquired a much better understanding of the nature of academic research collaboration in terms of processes, procedures and concerns of social science research projects which, in turn, informed the development of their VRE tool, e.g. cross-tool, cross-site search tool (SAKAI Search tool and collaborative writing tool (SAKAI Wiki Tool). Crucially, as the final report points out, the experience of VREs by the TLRP community has resulted in "a cultural shift in this community, where VRE use is now seen as an aspect of project design, user engagement strategies and dissemination and impact plans".

The Political Discourse project introduced VRE tools in the research community by forming an Early Modern VRE Research Group which attends regular Access Grid-enabled meetings recorded by MEMETIC. For the participants this is a totally new way of liaising and interacting. In enabling historians to work in a VRE environment, the project has met one of its main objectives, i.e. "engaging a community that previously had no such platform in a VRE and highlighting its potential for the Humanities". In line with the previous project which explored the VRE potential in the field of Humanities, the BVREH team also found that VREs can help analysts of ancient documents perceive a totally new way of conducting academic research.

In the field of Humanities, the OGHAM project involved on-site data gathering with the help of a wireless network with full internet access and the use of mobile PCs and PDAs. As was reported by the project, this was of great value for both teaching, (and it proved particularly stimulating for Arts and Humanities students) and research, since it facilitated information acquisition and flow.

Similarly, ISME's ability for remote experiment steering allows supervisors to oversee experiments conducted by students and suggest corrections if necessary, so that the 'beamtime slot' is not wasted.

3.5. An evolving user base

VRE1 projects encompassed a wide variety of target user groups:

- Researchers and academic staff, e.g. IBVRE, GROWL, MEMETIC, OGHAM, Political Discourse, ELVI, EVIE, BVREH, SAKAI for Educational Research;
- Students, e.g. ISME, IBVRE, Political Discourse, CORE, OGHAM;
- Developers, e.g. GROWL, ISME, CSAGE;
- Administrators/School managers, e.g. ELVI, EVIE.

It is also notable that the notion of user was more comprehensive than the above list suggests. For example, for CHESIRE 3 the main target was institutions and other organisations (as opposed to academics/researchers *per se*). Similarly, GROWL aimed at different classes of users, e.g. application and tool developers. Moreover, as will be discussed in the following section, projects discovered that new types of users emerged as they developed their respective VREs.

Projects' views of users varied from seeing them as co-participants in the design of technology (CORE), to on-going collaborator (ELVI) to a source of data informing the technological development process. However, they all invested considerable resources in terms of time and effort in both identifying and analysing their respective users' requirements and engaging them not only in the VRE project itself but also in longer-term relationships. These efforts, involving in most cases the early identification and engagement of users in an iterative and participatory process, resulted in adequately capturing their needs, and provided a basis for the modification of the technology. As a result, the users were more likely to develop an interest in and use VREs, since the latter assisted them in their respective tasks.

For example, the CORE project involved end-users from the very beginning, adopting a participatory design in developing their demonstrator. Indeed, a representative of the user community was involved in the inception of the project, and even helped write the bid which addressed a specific user requirement, i.e. the need to carry out multi-site medical trials. As a result, there was a pull from users, and not a push from technology developers. According to the project's final report, participatory design ensured that its main stakeholder group was involved and stayed engaged throughout the development lifecycle. Similarly, the SAKAI education team's close ties with their target user community, (i.e. TLRP directors and researchers), resulted in the latter's enhanced understanding of and increased confidence in the VRE vision. This has, in turn, resulted in both greater levels of use and numbers of users.

The IBVRE project also supported a close relationship between developers and target users, with a view to ensuring that the latter's requirements were adequately captured and addressed in the technical solution.

A general finding from the VRE1 projects is that co-participatory and co-constructive approaches to technology development are more likely to enhance user engagement and increase take-up. Moreover, adoption, where appropriate, of a rapid research-development cycle, i.e. rapid user requirements data collection and analysis, prototyping, testing and validation, feedback and piloting in an iterative manner can also help to maintain user engagement and even recruit new participants, e.g. SAKAI for Educational research, BVREH, IBVRE.

3.5.1. An expanding user base

Projects' involvement with users went beyond the data elicitation phase aimed at user requirement analysis. In most cases, a concerted effort was made to maintain user engagement and promote take-up. The latter was made easier by the close attention that project teams had paid to discovering actual user needs (as opposed to pursuing a "high tech" vision for its own sake) and in addressing these needs as comprehensively and quickly as possible.

For a number of projects involving and engaging users is seen as one of the main outcomes of their work. For example, one key outcome of CSAGE has been the involvement of their target community, i.e. Arts and Humanities, as manifested by increased interest and take-up. Specifically, at present, four research groups are using the CSAGE technology. Two groups are using the CSAGE software, one in the field of robotics to send transmissions, while another, the Manchester linguistics group, has set up a virtual environment for learning Japanese. In addition, artists, (e.g. dancers) are already developing the CSAGE technology and use it for presentation purposes.

Since the CORE tools were developed in close co-operation with the end users, thus responding to their actual needs, it is not surprising that the CORE project outcomes are already being used by its target community. At present the CORE demonstrator is being used in three hospitals and the Wessex training region. In the latter, all Higher Surgical Trainees (HSTs) in the Wessex region and many consultants have become more aware of the benefits of collaborative research environments.

Similarly, the researchers in the Integrated Biology project are just beginning to use the VRE which is likely to improve collaboration. Interest in the IBVRE technology by its end user community has been demonstrated by the latter's willingness to invest considerable effort into ensuring that the VRE worked correctly with their local IT resources as well as developing the tool further to suit their individual needs. As was reported, simply raising the awareness of IBVRE among its target user community has resulted in a high level of uptake by this community. On the other hand, the OGHAM's research and project team are the main users of both the PDAs/Tablet technology and the IADB database available through the wireless link to portakabins on site. According to the ISME completion report, at this stage of the project, the major stakeholder group benefiting is the PhD students who receive VRE support with the help of instrument scientists.

The above discussion presented project examples where the initial target user groups have begun to use the VRE tools available to them. However, some projects went well beyond their initial user base and engaged a number of other actors, not least institutions and even industry.

For example, the fact that the CORE project managed to build a demonstrator which orthopaedic surgeons are currently using since it (i) meets their requirements and (ii) focuses on quantifying how to do double blind trials (the most reliable method of medical trials) has generated strong interest among the pharmaceutical industry. Moreover, the team feels that they proved the need for such VREs for other communities, e.g. other medicinal disciplines.

The Political Discourse project has successfully engaged a multidisciplinary group of humanities scholars from HEIs across the country in its Virtual Research Group to jointly work on the theme of "Different constructions of the polity and commonwealth". The group uses the Access Grid for monthly meetings (and has had a core group of 11-12 participants in each of the nine or so sessions held so far) and SAKAI platform for ongoing collaboration such as sharing papers, quotations, posting work and potentially the joint writing of a research paper. The project has therefore succeeded in expanding its initial user base of MA students in the field of History of Political discourse to established humanities scholars. In doing so, the project has shown how a VRE can be applied to other research groups and to inter-institutional research and taught research programmes, e.g. by deploying VRE tools for the MA programme in the History of Political Discourse 1500-1800. Crucially, it demonstrates that VREs can be universally valuable as long as they are 'fit for purpose', ie address a need and possess the functionality which corresponds to this need.

The SAKAI portal demonstrator project's Blogger and AGORA tools (downloaded by approximately 180 institutions) have attracted strong interest by SAKAI project itself, which would like to include them into their core tools. Moreover, the project has written two sets of code (JSR 168 and WSRP) which will go into the SAKAI core code. The tools developed by the SAKAI for Educational Research project have been released as part of the SAKAI distribution and are in use across a wide range of research groups at Cambridge, within the TLRP and other Education Research communities. According to the final report, research groups in other disciplines, at other institutions and in inter-institutional and inter-disciplinary projects are also using these tools, (e.g. the Wikis have been directly incorporated into institutional systems.)

At an institutional level, ELVI's VRE is the research portal on Nottingham University's portal. Although this VRE is still not fully embedded, by now almost 100% of researchers have used it in the last two years to put their publications on the system. Academics have used the research activity channel for RAE, i.e. to make sure that their funding totals and publications lists are on the database. So far, the VRE is mainly used for preparation of the University's RAE submission, but it is hoped that it could also become a powerful tool for encouraging collaboration by enabling academics to explore the research interests of colleagues throughout the University. Moreover, its research activity channel is now available to school managers and senior administrators, while two Schools (Computer Sciences and Biomedical

Schools) have recently asked to make the research activity channel available to all the academics, thus expanding the current user base.

As regards the BVREH project, thanks to their VRE1 work and related demonstrators, they have been able to expand this work with VRE2 funding. Significantly, BVREH is now an "umbrella" under which a number of other projects (all other Humanities projects), including VRE2, are included. The plan from the Humanities Division is that BVREH is now part of its IT infrastructure vision.[9]

3.5.2. VREs and Teaching

Some of the VRE1 projects have also proved how VREs can be used to enhance the quality of teaching and training of students. For example, the OGHAM project involved on-site data gathering with the help of a wireless network with full Internet access and the use of handheld PCs and PDAs. This was of great value for both teaching (and it proved particularly stimulating for Arts and Humanities students) and research, since it facilitated information acquisition and flow. Similarly, the ability for remote experiment steering provided by ISME allows supervisors to oversee experiments conducted by students and suggest corrections if necessary, so that the 'beamtime slot' is not wasted. The biggest initial beneficiaries of IBVRE have been students as there are shorter training times for undergraduates. Students can start with the experiments right away, without having to be trained in computer programming. The shorter training time means quick productivity and ability to complete the experiment.

Moreover, the Political Discourse project ran modules[10] for the MA programme[11] using VRE technology, comprising both Access Grid (for seminars) and SAKAI platform (for online collaboration). This is a departure from the way this MA has been usually taught. Consequently, the project acquired considerable knowledge in the use of the SAKAI portal in the context of post-graduate research-led learning and the pedagogical implications of joint Access Grid seminars. To this end, the pedagogy of the MA has been revised and involved twinning the pedagogy with the technology as well as re-designing the modules. Overall, the pedagogy was simplified to encourage the use of the discussion board and Wiki by the students. The latter favoured the discussion board and used this for substantial exchanges. As one student user commented, the SAKAI discussion forum "is good because it encouraged us to get ready" for the seminars as the students had to post their ideas there before class. Moreover, according to the student user, using the Access Grid for seminars was "at first disconcerting, but now it's no longer a problem. You become more focused". In general, students found the exercise useful, while the feedback on the seminar structure made the teaching more efficient. Finally, it also enabled them to make connections and work with other institutions. As one student user stressed "[The VRE] allowed us to communicate with other institutions. We are

[9] However, this does not necessarily mean that this particular VRE will be the way forward; rather it is the most likely way forward.

[10] 2 core modules (at 20 credits each) and a historiography module (10 credits)

[11] The full MA in the History of Political Discourse 1500-1800 programme has been run for students at both UEA and Hull.

working with twice the number of the academics (and therefore get access to) wider expertise." There are also discussions about using CSAGE/Access Grid in teaching and learning in Arts and Humanities with particular reference to choreography at the University of Bedfordshire.

3.5.3. Novel use of the technologies

An particularly interesting finding from our investigations has been the manner in which the **technology has been taken up by users or institutions in a number of novel and/or unexpected ways**. For example, in the SAKAI VRE for Educational Research, SAKAI was used not only as a tool for collaboration but also as a research instrument: to safely collect research data from school-age subjects. Specifically, a project in Scotland which used the SAKAI VRE to involve children in an e-consultation aimed at exploring models of how to involve them in consultation processes. On the other hand, the Botanists at Cambridge are using the Wiki tool in SAKAI to generate web pages quickly. This use of SAKAI as a research tool was entirely unexpected and there is considerable interest in the potential of the SAKAI platform to support innovative research techniques. Similarly, CSAGE has promoted innovation in dance choreography, using stereoscopic viewing. As has been stressed, VREs have the potential for creating new metaphors for research. For example, as artists were using the technology, they were developing research methodologies, e.g. recording performances differently and developing a new ontology for choreography. As was mentioned by one user, "it [Access Grid] was a novel usage, a creative tool, compositional environment in part in the AG environment. So the AG was used not only as a method of communication but to create artwork…The CSAGE stereoscopic viewer has definitely expanded the boundaries of methods of dance, composition, representation of the body". Moreover, since the RAE is interested in the ways in which practice is documented, "the archiving and annotating of choreography (using MEMETIC) is really important: it gives access to knowledge (which is an important step forward) and further evidence".

The software developed for MEMETIC was also used in unexpected ways, such as the evaluation of performance art in the Locating Grid workshops. On a different note, although MEMETIC was developed as a meeting support tool, it can also be used for ethnographic use since the MEMETIC toolkit allows use of Access Grid nodes for ethnography. Indeed, the latter application of MEMETIC proved to be quite popular, i.e. the second most popular application. As was outlined in their final report, MEMETIC can have a variety of uses beyond video-conferencing scenarios, thus having the potential to enhance the value of Access Grid hardware by increasing its application and functionality into new areas of usage. CHESHIRE 3 also discovered that people were willing to use their technology in new and unforeseen ways. To this end they are currently talking to the JSTOR archive of scholarly journals which wish to use CHESHIRE 3 technology in their "sandbox" and make use of the tool as part of the quality control process of their services. In particular, they wish to use FAB4 to 'spot check' the translations that are done of scholarly articles in the JSTOR. In relation to GROWL, an unexpected outcome was the perceived convergence of several sets of “Lightweight Grid Middleware” towards an equivalent architecture to GROWL.

Indeed, this discussion highlights how socio-technical systems can dynamically evolve; through the interaction between the technological artefacts and users, with the latter re-claiming and adapting technology for their own needs and in novel ways.

3.6. Expanding the knowledge of VREs

Finally, the Programme has also generated learning around VREs, in particular the relationship between the user and the VRE technology. Several projects have gained a better insight into what users want from a VRE and, especially in the case of the SAKAI Education Research project, how they use it. The IBVRE project, for instance, has found that all users really wanted are tools to support the research process. “It did not matter how this was done”. Elsewhere it was considered that academic researchers still have to learn how to use a VRE, especially as this technology is not (yet) as ‘natural’ or intuitive to use as other types of routine work technologies.

The project work has also helped to improve the understanding of how VREs can be defined. What is interesting about these definitions, compared to where the VRE Programme began, is that now understandings about VREs appears to revolve much more around a socio-technical view of what these technologies are used, and usable for, rather than purely focusing on technical architectures. The definition put forward by the SAKAI Education Research project exemplifies this observation:

> We would (…) now define [a VRE] much more in terms of realised affordances rather than in purely structural or functional terms. Basically it would be possible to put together a VRE from lots of different components and as long as they play well together that could act as a VRE for many people. You only have to look at what you can put together in a personalised Google environment (e.g. gmail, gdocuments, spreadsheets, widgets, chat) to see what I mean. The advantage with SAKAI, though, is that the tools are designed to mesh together and allow workflows to run across tools.
>
> *SAKAI Education Research*

The view of the History of Political Discourse project is a further example, as is the understanding of VREs proposed by the CSAGE project below.

> A VRE must be intimately associated with a VRC [Virtual Research Community] or a VRO [Virtual Research Organisation]. Collaboration is key, otherwise it's a glorified work station. How you collaborate is determined by the community involved and needs to be decided by what the community needs. (…) It does not matter if it [the VRE and its tools] is not integrated.
>
> *History of Political Discourse*

> "An aim of a future VRE we believe should have the property of helping to redefine the research methodology. A good VRE should not just be used to aid the research process; administration, report/data gathering, computational /process operations and dissemination; but be able to shape the research. A VRE can be used to understand **new forms of research methodology** as well as **aid the current forms.**"
>
> *CSAGE draft final report*

It will remain the task of the VRE2 Programme to further enrich our understanding of what VREs really are and the multitude of ways in which they may be used in an academic environment.

3.7. The sustainability challenge

3.7.1. Maintenance and development needs of the VRE technologies

Most VRE1 projects require further funds in order to sustain current activities or continue to develop the technologies created in order to enhance their functionality or tailor them more to user needs or explore 'softer' issues related to use.

In most cases, 'simply' continuing the current level of use of the technology requires further funding: for instance, staff are required to debug and develop or, where the Access Grid is employed, provide technical and other coordination support to users. Members of project teams are mainly on temporary contracts funded through third stream money, so that their ability to facilitate continued access to VRE technologies for their existing user communities is highly dependent on the availability of further financing.

Beyond the sole maintenance of the technology, however, project teams have a range of ideas of how their VRE technologies can be improved further, these include:

- Enhancing existing tools. CORE, for instance, is looking at improving the collaborative authoring tool and is looking to continue to build web services. The MEMETIC toolkit could be developed to make recordings viewable in common media formats (e.g. Windows Media Player or Real Player). OGHAM "would like to improve the technology to work on 3-D models."
- Widening the user base and tailoring tools further to researchers' needs. In the case of the SAKAI portal demonstrator project, for instance, more funding

would be needed to allow the team to provide SAKAI environments to those researchers approaching the team about providing SAKAI environments. In the case of the MEMETIC project, the potential of the toolkit for use in ethnographic research is an additional usage scenario and one which the team is looking to explore.

- Exploring the 'softer' issues around the use of technologies which warrants further research. In some instances, the research and development work carried out under the VRE1 programme has raised questions relating to non-technical issues of the use of the technologies, in particular questions of data protection, ethical issues around displaying information online and issues of security and authentication.

Sustainability therefore also becomes a question of the ongoing and expanding use of the research outputs from VRE1 to the UK academic community. Below we will explore in more detail the options that are currently available to the projects.

3.7.2. Sustainability options

The sustainability of the VRE technologies developed under the VRE1 Programme appears largely to be a function of three particular factors:

- Access to sufficient resources to continue to support and develop the VRE technology;
- Support in principle from the HEI and ideally a strategic objective to implement VREs across the institution;
- The absence of 'path dependency' issues, especially in relation to HEIs' existing VLEs, MLEs or other distributed IT systems.

It is also fair to say that the VRE1 projects' dependency on third stream funding has not reduced. Technologies need to be further developed, or access to them ensured. This requires both access to finances and personnel. Some projects are able to keep the tools developed accessible for some time: GROWL, for instance, continues to make available various components online "for the foreseeable future"[12]; CSAGE has continued to provide the stereoscopic viewing system for loan since the project ended and will continue to do so until the end of 2007. Nevertheless, with few exceptions, project teams' institutions are not in a position where they can offer financial backing. The sustainability of the projects' work is therefore highly dependent on being able to access alternative sources of financing.

Several projects have, of course, been successful in winning VRE2 funds. This includes the MEMETIC, OGHAM, BVREH and IUGO teams. In addition, the CSAGE project has a minor role in the VRE2 CREW project.

For those project teams that were unsuccessful with their VRE2 bids (and indeed to those who were successful), however, it would seem that a wider range of funding sources is now available. Whilst projects explained that at the time of the first VRE call it was only JISC funding which matched project ideas, it would seem the existence of demonstrators and prototypes, and an emergent user base, facilitates the tapping into a more diversified range of funding streams. For instance, project teams have submitted funding bids involving their technologies to:

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[12] GROWL Final Report, p 13

- AHRC (MEMETIC, Political Discourse, CSAGE);
- The British Academy (funding won by the Political Discourse project during the lifetime of its VRE1 work);
- ESRC (GROWL);
- JISC – other than the VRE Programme (SAKAI Education Research and CSAGE)
- The EU (Cheshire3).

At the same time, other, non-research council, sources of financial support seem to have opened up to some projects. These include, for instance:

- The North West Development Agency NWDA which partly funds "work to sustain and extend work done in the GROWL project (…) with the deployment of the NW-GRID a priority."[13]
- Private companies: the CORE project, for instance, is in negotiation with businesses as regards the expansion of the system to a larger user group. The Cheshire3 project reported that "we have had interest from commercial organisations such as Rank Xerox and Globit – a German company which specializes in conferences and peer review."
- The Access Grid support centre: an avenue envisaged by the MEMETIC team to roll out the toolkit to the UK Access Grid community. An application to allow Manchester University to continue to host the Access Grid Support Centre has been submitted.
- The SAKAI community. Some of the code developed by the SAKAI Portal Demonstrator project will be integrated into the SAKAI source code and will therefore live on as integral part of SAKAI. Equally, tools developed by the SAKAI for Educational Research project (e.g. the wiki tool) have been released as part of the SAKAI distribution.

Nevertheless, there can also be no doubt that despite the apparent widening of funding sources that can be potentially tapped, the dependency on third stream funding remains an ongoing threat to the potential sustainability of the VRE technologies. While some projects are confident about their prospects, others feel that the lack of funding is holding back the development of otherwise popular tools.

This dependency on third stream funding is a particular issue especially because few HEIs are at the present moment in time able to contribute substantial resources to the development or maintenance of VRE technologies, even if they have been developed by their own project teams. There are exceptions, of course, but they are few. Manchester University has, reportedly, provided small amounts of 'bridge funding' to the CSAGE project and hired two new staff whose computing skills project teams can draw on. Where HEIs are offering support to VRE project teams, this often tends to be 'in kind' rather than cash. The University of Reading, for instance, has taken over from departmental IT services in backing up data produced from the OGHAM VRE. IUGO, too, reported having received support from central IT services at Bristol University. EVIE received strong support from the library and input from University staff. The University of Southampton made the person in charge of supercomputing available to the CORE project team.

[13] GROWL final / completion report, p.

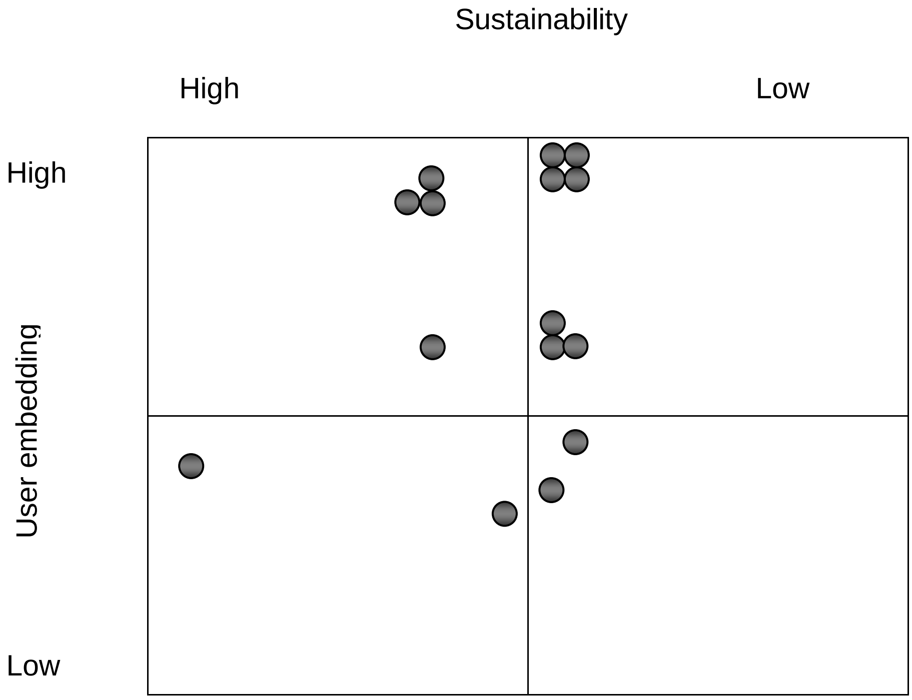
However, the fact that HEIs are not giving significant financial backing to VREs does not mean that the idea does not resonate with them. In fact, support for VREs has found its way into the ICT strategies of several HEIs supplying VRE1 project teams. And the work of the VRE1 project teams has in several cases had a significant impact on this development. For instance, a requirements analysis produced by the IBVRE project fed into work on scenarios for a VRE in Oxford University's ICT strategy. At departmental level, the Humanities Division at Oxford University has made a strong commitment to maintaining VRE activities as a key element in the development of its own research and ICT strategies in part due to the findings of the BVREH project. Other outputs from Oxford based VRE projects also fed into strategy documents. At other HEIs, representatives of VRE project teams engaged in dialogues with their HEIs to inform ICT departments or the University or departmental administrations of their activities and increase the probability of sustainability in this way. One project has suggested that their technology become part of the University's research portal to support virtual research teams in storing and retrieving audio-visual data from meetings or videoconferencing. However, whilst the University is interested in the project and the VRE technology, the project considers that there maybe somewhat lesser interest in prototype technologies which may not deliver a fully fledged production grade product. The Political Discourse project presented the project's work at several institutional events, such as the University of Hull's VLE review and the HEI's eServices Integration group.

Overall, many projects have faced challenges of institutional embedding and have tended not to have been well supported by their HEI. As a result this has, on occasion, produced a dislocation from both the institution itself and related bodies such as IT services. At departmental level, too, projects can be quite isolated. Against this background, a number of projects have been tactical in securing funding early on, bringing in external organisations or private companies, connecting up and social networking. In a number of cases this strategy has already produced tangible payoffs.

3.7.3. A relationship between sustainability and user embedding?

It is clear from the discussion above that all projects – to a greater or lesser extent – struggle with sustaining their outputs in the short to medium term. The question is therefore, whether sustainability is easier for some projects than it is for others. We might, for instance, speculate that the sustainability of a VRE technology will also depend on how strongly it is embedded in a particular user community: the more a technology addresses the particular needs of a defined user group, the more likely it is that this group will sustain and continue to adapt that technology as it is seen as valuable. Likewise, sustainability might be positively correlated to organisational embedding: the more supportive an organisation is of a technology, and the greater its capacity to support the technology, the greater the probability of a sustainable technology. Below we test these hypotheses by exploring, with the help of the VRE project data, whether they can be either verified or falsified.

Matrix 1: Sustainability and User Embedding

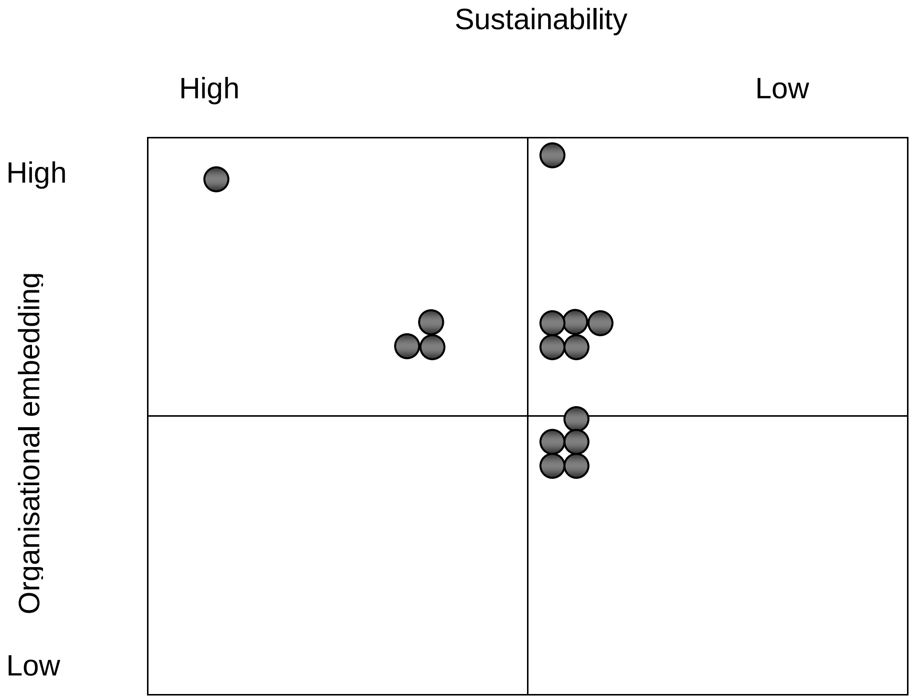


The two-by-two matrix above shows for the VRE1 Programme, the relationship between user embedding and sustainability. ‘High sustainability’ means the VRE technology is maintained and / or developed by the HEI directly, or that this is done by organisations other than Universities (e.g. project teams or user groups). ‘Low sustainability’ means that VRE technologies are exclusively dependent on third stream funding. Equally, ‘high user embedding’ means that the technology has been developed with and for a specified user community, or has subsequently been adopted by users, whereas ‘low user embedding’ means that the technology has not been taken up by users or that users are divided over its benefits.

This matrix also indicates that, given these parameters, VRE1 projects are clustered in a middle field where a significant number have achieved high or relatively high embedding, but where dependency on third stream funding is also high, leading to issues for the sustainability of projects and technologies due to the inherent risks associated with this kind of funding (i.e. staff and funding gaps). Nevertheless, it is noteworthy that a few projects can be characterised as having high user embedding and high sustainability, because either project teams or user groups are sustaining the technology themselves. However, it does seem to be the case that high user embedding *per se* is, at this stage, no guarantee for high sustainability, although it may increase the chances slightly.

What about the relationship between organisational embedding and sustainability? In Matrix 2 below, high organisational embedding means a VRE technology is permanently adopted by a HEI or a project team as a ‘virtual organisation’. ‘Low organisational embedding’ means there is no adoption of the VRE technology by project teams, and the HEI does not have a commitment to VREs (as expressed, for instance, in the institution’s ICT strategy).

Matrix 2: Sustainability and Organisational Embedding



Examining at the relationship between sustainability and organisational embedding in the VRE1 programme, we observe a positive relationship between the organisational embedding and the sustainability of a VRE technology: the table indicates that where a VRE technology is highly embedded in an organisation, be this HEI or a project, the sustainability of the technology seems to be higher than where a technology does not have a firm institutional base.

4. LESSONS LEARNT

This chapter explores some of the main lessons that have been learnt from the research and development work of the VRE1 Programme. Focusing in particular on the issues around user engagement and technology development it explores what went well, what did not go as well as expected and key challenges in projects' work.

4.1. Identifying and working with users

4.1.1. What worked well?

One important characteristic of all projects has been their conscious effort to, and success in, clearly identifying and engaging their respective user communities at the various stages of their project lifecycle. As expected, projects varied in their approach to user requirement analysis. For example, the ELVI project team held 44 Focus Groups that span the whole breadth of academic schools and faculties, the University administration/management, and the student population. On the other hand, the BVREH project produced a scoping survey aimed at finding out what Humanities researchers needed for a VRE, adopting a bottom-up approach in the way it undertook an extensive user requirements survey. Significantly, it was pointed out that "one key factor for the enthusiastic response they had [among Humanities scholars] was that the project had researched extensively and, as a result, met specific research user requirements".

Projects identified two methods of identifying and contacting users to include in the research work which they reported as effective:

- *Going through intermediaries*. These might be people at other HEIs the project teams knows, or people in a co-ordinating role in a school or department. Using such intermediaries to make introductions or pre-select people who can then be contacted by the project team has proven a successful method of finding potential end-users.
- *Disseminating information about the project through a variety of channels and in different formats early on*. The SAKAI education research project, for instance, found that this had a number of benefits, including building interest in the project and helping to recruit new participants.

The VRE1 Programme also generated rich findings on how to engage successfully with users, in particular relating to the following five areas:

- *Getting end-users involved in the project* - early on. A number of projects reported that working closely with end-users – from the beginning of the project and throughout the research and development work – had worked well. One respondent summed up the benefits of working in this manner: "people don't tend to buy into stuff unless they've been heavily involved in developing it." This was confirmed by one user who said "researchers need to make sure a system serves what we need." Another project reported that the iterative development cycle they had adopted: user requirements elicitation, prototyping, user evaluation, refinement, user evaluation – worked effectively to ensure users were happy with the system and "feel comfortable using it in their work."

- *Choosing approaches and methodologies that support user engagement*. Projects reported that participatory design, iterative development cycles, rapid data collection and prototyping had worked for engaging users and finding out what they needed.
- *Keeping users engaged* throughout the project is therefore key if the benefits of the development work are to be reaped. In the experience of VRE1 projects this can be achieved by having users as partners in the project team to ensure they have a stake in what is being developed and therefore an interest in being engaged. Short iterative development cycles of 6-12 months helped one project maintain the interest of users and keep them engaged. The project manager of this project felt that such short cycles seemed "appropriate for most academic research project life cycles". On a more prosaic note, paying users can also help keep them engaged.
- In addition, several of the projects that reported having succeeded in establishing good working relationships with their end-users felt that this had been helped by their ability to *establish trust between developers and end-users*. Indeed, it seemed to have been rarely the case that this trust was there at the beginning of the project work. Rather, it had to be established. The IBVRE project team, for instance, spent significant amounts of time at their end-users' workplaces observing and work-shopping user requirements. The team felt that this effort was rewarded and helped to build a "high level of trust" between developers and end-users which became the basis of a "good working relationship", which further ensured that users' needs could be met. In the case of the Sakai Education Research project, the process of building trust was supported by team members who were able to take up dual roles: they were both technology experts and experts in the subject domain for which the technology was produced. According to the project manager: "I think that even people who in the past have had less than satisfactory relationships with technologists were persuaded in. We were able to provide a brokerage role – between the technologist and the researchers. We had multiple roles for them – one of the team was on the help desk, a trainer and doing education research himself". This highlights that having team members who are able to bridge the boundaries between developers and domain experts could be an important factor for building trust especially in the social sciences and the humanities where scepticism towards new technologies might be more pronounced, and thus more difficult to overcome, than in the natural sciences.
- Finally, some projects provided '*start-up' support to end-users* and found that 'holding users hands', (i.e. taking them through the technology step by step), taking time to do so and even paying users can be important to familiarise users with the technology in a way that is not too rushed or overwhelming. Experience with training sessions was that they allow technology to be introduced to large numbers of (potential) users and that they are generally well received. However, one project found that they could not necessarily guarantee that users did actually adopt the technology once they are back at their workplace.

4.1.2. What was challenging?

Whilst VRE1 projects adopted a number of different strategies for working successfully with end users as part of their research and development work, they also found that doing so was challenging. Working closely with end users introduces an added layer of unpredictability and complexity into the research and development process. The following areas have proven to be challenging:

- *Understanding who the user is and having appropriate strategies for engaging with them*. A number of projects did not initially have a clear view of who their end users were or found that, whilst they were engaging with broad user groups, they were still not talking directly to their real end-users. This meant that they did not always have an accurate picture of what the end user really wants. Linked to this is the considerable time required not only to identify and approach the end users, but also to get them on board and keep them engaged whilst sticking to the project time table. Most projects found they had underestimated the resources in terms of time and effort that should go into this very essential work activity.
- *Balancing user demands with the time and resource demands of the project*. Projects agreed that participatory design methods are very valuable for the development process. However, they also found that, unless managed properly, such methods can cause some tension, for instance by limiting the time available to explore alternative technologies and develop the underlying infrastructure. One project found, for instance, that user demands on modifying the user interface, wanting the system up and running more quickly than is desirable, deflected them from carrying out pure development work as specified in their initial project plan. Tensions can also arise from pursuing an iterative process in the development of technology, where technical development, user testing and stakeholder feedback should go hand in hand. Small-scale projects may experience such tension more acutely, where prototype technologies are involved and there is an intensive development activity over short time scales.
- *Balancing the need to engage with users with the desire to have a stable software that works*. Some projects seemed to be reluctant to expose software to potential users before it was felt to be 'ready' hence potentially missing out on valuable feedback and early marketing opportunities.
- Finally, *sustaining the relationship with the user community* and fitting the project's objectives and timing into that community's plans has proved challenging. Projects found that they had to accommodate users' own needs (for instance in terms of when they could get engaged in the project, fitting the project within their own research lifecycle or testing the proposed VRE in a variety of different and niche ways) made the development work harder. As was mentioned by one project manager, *"Users don't always come on board at the time you would like as a project".* Moreover, some projects had the experience that users who were initially enthusiastic to be involved dropped out later, necessitating a search for new users.

4.1.3. What would projects do differently?

Given these challenges, it is not surprising that the main area projects would address differently is to invest more time and resources in ensuring proper, meaningful and timely user involvement in the future. This means taking time at the very beginning of the project to identify the actual end users of their work as well as to engage and involve them in a sustainable manner. This exercise is expected to enable projects to have a clearer and more accurate view of who their users are. Crucially, it is also expected to enable projects to design the technology in such a way that corresponds to actual user needs and is therefore more likely to be taken up.

Early user engagement will allow teams to collect user feedback while developing the technology solution and adjusting it accordingly as part of an iterative process. Apart from the risk of early "complexification" of the technology, not ensuring proper user involvement at an early stage risks that it may not be used at all. The ISME project, for instance, "*gave the project users the opportunity to have a real 'hands-on' experience with the provided web services, to have a look and feel, so they were able to eliminate the services they did not really need and nominate their 'favourite' services, which they use on a daily basis."*

The corollary of getting users more fully engaged at the start of the project research cycle means that project teams need to spend more time at the start of the project in order to get the users involved. Nevertheless, projects also agreed that they need to be very careful as to the correct timing of user involvement in the co-design of technology by ensuring that users are involved at the right moment and not too early. The CORE project, for instance, found that, *"the use of participatory and co-design approaches are effective in ensuring participation, but require careful management to ensure the hidden technical work is also completed (i.e. the infrastructure). Collaborative authoring may be more easily implemented given the increasing uptake of wikis and especially semantic wikis".*

4.2. Developing and implementing technologies

4.2.1. What worked well?

A number of VRE1 projects considered that what had gone well was their work on the technology and / or its implementation.

Some projects felt that *individual outputs* from their work had gone particularly well. In the case of the SAKAI portal demonstrator project, for instance, it was felt that the development of the Agora and blogger tools had gone particularly well; both are now attracting great interest from the SAKAI and research community. Other projects felt that the *implementation of the systems* they had set out to develop had been successful. The EVIE project, for instance, was pleased with the implementation of 'channels' as part of its VRE (such as the personalised funding opportunities) and felt that the project's success was "showing that a VRE provides a good way of receiving data". In the case of the Political Discourse project, what worked particularly well was the introduction of the MA and the virtual reading group consisting of established scholars in the field of political discourse was a success.

The SAKAI Education Research project found that its approach to a VRE, which involves modular technology where users can choose from about 40 tools, worked well as it had lowered the bar for learning and allows users to match the technologies to their needs.

In terms of project process, the CSAGE project found that following development work with a period of loaning the technology to users works well, as it enables further learning from informal user feedback.

4.2.2. What was challenging?

As well as these ‘successes’, projects also faced some challenges when working on their technologies.

Some found that the technology developed is not as robust as they had expected. Others found that their proposed solutions worked less well in situ even though they had aimed to make them applicable in real research/work situations. This was either due to adverse natural conditions or issues within the organisations using the technology such as work organisation or lacking IT support.

On occasion, the usability of tools could also be a challenge and some projects had concerns about the scalability of their technologies.

For some projects, the time available for the development of the technologies was also a challenge, especially where projects had to start their development work later than expected. For some this meant that their technology outcomes, though usable, require further work to maximise their effectiveness. One project felt, for instance, that they could have spent more time on designing the user interface to make the technology less daunting to potential users. Some projects also found that development activities can take longer than originally envisaged. This, in turn, requires that they change priorities in the course of the project or adjust their ambitions for outcomes to make them more realistic.

4.2.3. What would they do differently?

Interestingly, in view of the nature and scope of the projects, a number of projects reported that with hindsight they would not have spent so much time and energy in developing their technologies. For example, given the recent developments in portal frameworks and the portlet standards (JSR286), some projects stated that they would not have built their own portal.

Projects also stressed the need for shorter iterative cycles in development and for an on-going gathering of stakeholder feedback. As was mentioned by one PM, *“If it is going to be participatory then we needed to speed things up even more. I would have liked to have been more ongoingly co-constructive”.* This, in turn, means more fluid participation rather than discrete participation. In such case, users are regularly involved with technical mock-ups and screen shots etc., ensuring an even more fine grained iteration (co construction / co-configuration).

Finally, projects also reported issues around the interface of technologies that differ in their level of maturity and stability. In such cases, it is inadvisable to interface with immature technologies unless that is allowed for in the project plan.

4.3. Collaboration and management

4.3.1. Team working and project management

Several projects highlighted that they had worked successfully as a team and had established effective means of communicating that suited their work. The GROWL, ISME and MEMETIC projects, for instance, all used a combination of meetings over the Access Grid and face-to-face meetings to stay in touch with project partners. As was reported by the GROWL project, "Access Grid (when it works) is a reasonable substitution for face-to-face meetings, but can't really totally replace them. It is important to have regular meetings in a multi-site project and for the developers to get to know one another and understand each other's way of working."[14] Successful team working was further supported by a feeling of trust between collaborating partners, brought about in one instance by the fact that "everyone was very engaged, very committed to the aims of the project". Frequent email and telephone communication supported team efforts in another project.

Occasionally, technical factors inhibited collaboration. ISME, for instance, encountered difficulties in co-ordinating multi-site based experiments due to the existence of different network regulations, which, in some instances prohibited the use of Access Grid toolkits (either freeware or commercial product). In other projects, however, staff turnover within the team led to delays in carrying out the project work, loss of clarity of project outcomes or less time for user testing cycles. Inter-departmental and wider institutional collaboration also had its difficulties especially where projects relied on the goodwill of IT departments to provide support that is outside their formal role.

Finally, projects learnt three main lessons for project management plans:

- Budget for sufficient time if co-participative approaches are being employed, in order to allow for the exploitation of their benefits and their proper management;
- Where input from other projects is sought this should enter into the project risk strategy since non-project staff may not have the time to contribute due to their own commitments;
- Project time plans and budgets need to be realistic and reflect the work planned. This includes budgeting realistically for items such as development work or travel.

[14] GROWL Completion Report, pp. 8-9

4.3.2. Programme Management

Projects were generally happy with the management of the VRE 1 programme which was described as “supportive”, “a great help” and “unobtrusive”. Whilst the change of programme management towards the end of VRE1 might have meant - on rare occasions - that projects received less support than they may have expected, overall this event did not have a major disruptive impact on the Programme.

Specifically, projects appreciated:

- The Programme meetings as opportunities to meet other project teams, get to know each other and exchange ideas;
- The project visits as valuable opportunities to receive one-to-one support and advice;
- Being kept informed of developments relating to JISC and the VRE Programme.

At the same time, projects offered the following suggestions for the management of the VRE Programme:

- Several projects felt strongly that regular project meetings and reviews were very valuable. These should be held every term or quarter in the form of face-to-face meetings including the project team and the programme manager. Projects felt that such meetings are important to keep projects on track, for projects to get undisrupted time with the Programme management to discuss problems and deliverables in a ‘clearer and calmer atmosphere’ than is possible at Programme meetings.
- A peer review process for design and tools to encourage projects to share their problems and encourage projects to work together.
- Encourage sharing problems and working together.
- Support on the ‘softer’ issues relating to VREs such as ethical issues (both research ethics and the ethics of using specific tools).
- Provision of ‘technical assistance’ to projects, for instance:
    - Drawing up standard collaboration agreements;
    - Appropriate licenses for the release of software;
    - Training on specific technologies relevant for projects’ development work.

When prompted, some projects also expressed the view that a VRE support service could be useful, but that it would need to be based on an interest and need in the community and would need to be properly marketed. “It really needs an ambassador or mediator in the institution who is the link between the project and the VRE advisory service”. One interviewee made the point that a support service would have to be about active support, rather than passive. “It’s also important that people experience it as help rather than a bureaucratic process”

5. CONCLUSIONS AND RECOMMENDATIONS

The VRE1 Programme has clearly demonstrated the potential to have a major impact on changing research practices in the academic community. It has clarified viable routes for conceptualising and implementing VREs. Moreover, the Programme has also helped to clarify what is important and what is less important in the development and deployment of these new technologies: building technologies that are ‘fit for purpose’ of their user communities, rather than follow an abstract idea or concept of what a VRE might or should be. As a result, there is evidence that research practices are already being influenced. At the same time, in HEIs there is considerably more awareness of VREs, with a number beginning to show a real interest in their potential value. Furthermore, across the Programme, a community of practice has begun to emerge – the evolution of which could help to drive VRE2 and any subsequent incarnations of the programme forward.

However, challenges do remain, and despite the scale of the opportunity that is currently presented by VREs, institutional buy-in and embedding remains an enormous challenge. Significantly, key and critical players in institutions have not tended to have been involved in, or engaged with, these projects consistently and this has been to the detriment of the projects’ institutional success and sustainability. A number of projects have been left in a state of ambivalence and insularity, within the HEI (though in the rare exceptions where institutions have been involved, this has made a huge contribution). At the same time, many projects have simply not had the resources, especially in terms of staff time and money, to engage with the wider environment of their HEIs effectively.

VREs are not only technical innovations *per se*, they are also practice-led innovations which are designed to function in context. In order to encourage the take-up and institutional adoption of VREs the innovation will need to offer clear strategic or research added value to the institution and discipline and will necessarily require an effective communications and social marketing strategy.

In the light of these considerations, we recommend the following actions:

On the basis of the programme outcomes JISC should consider scaling up activities in this area and continue to remain actively involved in steering the VRE development process. We would concur with the view that it may be productive to keep the technology options open at this stage and that it is productive to further explore technology developments, rather than commit to particular technological paradigms.

JISC could assist projects in marketing and disseminating their innovations by helping them make an appropriate business case for VREs, in particular in terms of their potential to enhance RAE profiles, the quality improvement of research and teaching. However, the business case needs to be made at several levels. Firstly, the case for VREs needs to be made more consistently across disciplines to alert broad spectrums of researchers to the added-value of these technologies. Secondly, the case for VREs needs to be made within and across HEIs themselves in order to maximise the potential strategic value of VREs.

JISC can assist projects to both build the business plan and employ social marketing and communication techniques to increase institutional buy-in and user take up. This could, for instance, involve peer consulting: setting up a rolling action learning programme drawing on social marketing and communications to capitalise on the expertise that already exists within the Programme and maximise the knowledge that already exists in this community. Potentially, specialists outside the VRE project teams could work with individual projects in a focused manner to develop plans. The deployment of social marketing techniques as part of an overall strategy for dissemination and awareness raising can also be instrumental in engaging key stakeholders and user communities. Creating the conditions for increased take up and use of VRE technologies is also about building and sustaining dialogues amongst projects, within disciplines and HEIs and within JISC.

Considering that VREs are also practice-led innovations we recommend that more support and resources is allocated to users and user communities. For users to move to new socio-technical solutions, VREs will be required to be robust, intuitive and offer clear added value, as well as being tailored to defined ways of working. Users have high expectations of technological solutions and will tend to use only those systems which will offer a clear instrumental return. To facilitate take-up and adoption users will need to be provided with dedicated technical support; especially in the early start-up and take-up phases as well as longer-term training. We also argue that for the pilots of "VRE2.5" to be successful they will need to be organically embedded in the discipline and have emerged from the bottom up rather than the top down and this will often involve a project or user champion.

Overall, our main recommendation to JISC is to scale up its work on VREs whilst simultaneously providing additional funding for communications and social marketing as well as user support activities.

ANNEX 1: VRE 1 PROJECTS

Strand	Projects
Strand I: Larger scale projects to deploy VRE demonstrators	• Sakai VRE for Educational Research • Sakai VRE Portal Demonstrator • A VRE to Support the Integrative Biology Research Consortium (IBVRE) • EVIE: integration & deployment of existing components within a portal framework • ELVI: Evaluation of a Large-scale VRE Implementation • Meeting Memory Technology Informing Collaboration (Memetic)
Strand II: Projects to identify functionality	• Implementing the Kepler Workflow Interface into the Cheshire Digital Library Framework (Cheshire 3) • Collaborative Stereoscopic Access Grid Environment for Experimentation within the Arts & Humanities (CSAGE)
Strand III: Projects to develop and deploy lightweight, proof-of-concept VRE demonstrators	• CORE: Collaborative Orthopaedic Research Environment • Silchester Roman Town: A Virtual Research Community (OGHAM) • GROWL: VRE Programming Toolkit & Applications • ISME: Integration & Steering of Multi-Site Experiments to Assemble Engineering Body Scans
Cross-strand	• VRE for the History of Political Discourse 1500-1800 • BVREH: Building A VRE for the Humanities • IUGO: Conference Information Integration Project
Strand IV	• The programme formative evaluation
Strand V	• VRE Tools and Resources Interoperability project (eReSS)

Source: http://www.jisc.ac.uk/whatwedo/programmes/programme_vre.aspx

ANNEX 2: JOURNAL ARTICLES PUBLISHED OR SUBMITTED

Charles Severance, Joseph Hardin, Glenn Golden, Robert Crouchley, Adrian Fish, Tom Finholt, Beth Kirschner, Jim Eng and Rob Allan (2007) “Using the Sakai collaborative toolkit in e-Research applications”, in: *Concurrency Practice and Experience on-line*: DOI: 10.1002/cpe.1115 (7 Jun 2007) http://www3.interscience.wiley.com/cgi-bin/jissue/105558633

X. Yang, X.D. Wang and R.J. Allan (2006) “Investigation of WSRP support in selected open-source portal frameworks”, in: *Concurrency and Computation: Practice and Experience*

X. Yang, A. Akram and R.J. Allan (2006) “Developing portal/ portlets using Enterprise Java Beans for Grid users”, in: *Concurrency and Computation: Practice and Experience*

ELVI Submission of article to Journal of Organisational Transformation and Social Change (Jan 2007)

Carmichael, P., Procter, R., Rimpilainen, S. and Laterza, V. (2006) “SAKAI: A Virtual Research Environment for Education”, in: *Research Intelligence* , 96 (August 2006), pp.18-19.

Rimpilainen, S. and Carmichael, P. (2006) “Sakai: An Environment for Virtual Research” *Ennen & Nyt*, 2006(2). Online at: http://www.ennenjanyt.net/2006_2/rimpilainen.html

Carmichael, P. (2007) “New Technologies for Capacity Development and Knowledge Creation in Education Research Technology”, in: *Pedagogy and Education*”, 16(3) (forthcoming).

Carmichael, P., Procter, R. and Laterza, V. (2007) “Collaboration, Processes and Outcomes in Social Science Research Technology”, in: *Pedagogy and Education* 16(3) (forthcoming)

MEMETIC (submission in progress) Paper on participation in Access Grid meetings, *Journal of Pragmatics*

“Integrative Biology - the challenges of developing a collaborative research environment for heart and cancer modelling”, in: *Future Generation Computer Systems*, 23, pp 457–465 (2007) doi:10.1016/j.future. 2006.07.002

Miles-Board, T., Carr, L., Wills, G., Power, G., Bailey, C., Hall, W., Stenning, M. and Grange, S. (2006) “Extending the role of a healthcare digital library environment to support orthopaedic research”, in: *Health Informatics Journal*, 12(2), pp.93-105.

OGHAM: collaborative submission of a major refereed journal article in internet archaeology.