Extending the Role of the Digital Library: Computer Support for Creating Articles

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ABSTRACT

A digital library, together with its users and its contents, does not exist in isolated splendour; nor in hypertext terms is it merely the intertextual relationships between its texts. There is a cycle of activities which provides the context for the library's existence, and which the library supports through its various roles of information access, discovery, storage, dissemination and preservation. This paper describes the role of digital library systems in the undertaking of science, and in particular in the context of the recent developments of the Grid for computer-supported scientific collaboration and Virtual Universities for computer-supported education. This paper focuses on a specific framework, the Dynamic Review Journal, which supports the development and dissemination of documents by assisting authors in collating and analysing experimental results, organising internal project discussions, and producing papers. By bridging the gap between the undertaking of experimental work and the dissemination of its results through electronic publication, this work addresses the cycle of activity in which a digital library rests.

Categories and Subject Descriptors

H.3.7 [**INFORMATION STORAGE AND RETRIEVAL**]: Digital Libraries; H.5.4 [**INFORMATION INTERFACES AND PRESENTATION**]: Hypertext/Hypermedia; I.7.4 [**DOCUMENT AND TEXT PROCESSING**]: Electronic Publishing; J.3 [**Computer Applications**]: LIFE AND MEDICAL SCIENCES—*Medical information systems*

General Terms

Human Factors

Keywords

EPrints, E-Science, Grid, Orthopaedics, Virtual Universities

1. INTRODUCTION

1.1 Science, Publishing, Hypertext

The accepted role of scientific and scholarly publication is to record research activity in a timely fashion, keeping others in the research community up-to-date with current developments. Until very recently, it has been the case that printed journals were the most efficient method for the dissemination and archival of research results. Technical advances in the past decade have allowed the process of scholarly communication to take other forms, particularly in the dissemination and storage of articles via the World Wide Web.

As well as giving publishers a new medium for making their journal archives available [10], it also gave authors the means to break the so-called "Faustian bargain" and directly distribute their articles in pre- or post-publication form from their own Web pages [8] or in organised "eprint archives" [7].

However, other factors beyond the development of the printing press in the late 15th century led to the production of the first Scientific Journal in 1665 [21]. The emergence of a reliable postal system and the development of the experimental method in the 16th century also had a significant role.

Similarly, it may not be simply the technical support for reproducing and distributing articles electronically (electronic publishing, e-print archiving and digital libraries), but also the emergence of technical support for improving human communication in the form of highly collaborative, large-scale activities and analyses (the Grid, Virtual Universities) that is likely to precipitate significant change in the field of scientific communication and significant changes in the way its communications are produced, curated and disseminated [14]. For example, the old medium allowed a paper to be published as the summarisation of a scientific activity - the discarded raw observations that led to the article's conclusions are replaced by a description of the method for recreating the experiment. However, researchers are becoming more interested in the potential of the new medium for preserving experimental data as well as experimental conclusion: the ability to provide hypertext links between the article and the data to create an audit trail for reviewers and thus facilitate further analyses and meta-analyses.

1.2 The Grid

The Grid is a computing infrastructure for undertaking 'big science' [5]. Beginning as a mechanism for applying scientific computation to large-scale experimental procedures, it has developed to encompass large-scale human collaboration [6], the kind of distributed collaboration which now characterises many areas of scientific endeavour (from particle accelerators to genomic experiments). This kind of support might be in the form of video-conferencing, meeting facilitation or even decision rationale and group memory capture rather than simply large-scale computation and peta-scale data access.

In the UK, the accepted term for scientific activities augmented by the Grid is 'e-science'. This paper will adopt that term when we wish to discuss the scientific activity without unduly focusing on the enabling computational technology.

1.3 Virtual Universities

A Virtual University is a distance education programme that is delivered across the Internet: education in which students and teacher are not in the same place or the same time [2]. Virtual universities are also about large scale short-to-medium term collaborations, composing groups of people with shared educational objectives. The particular role of education in the scientific process is discussed in the next section.

1.4 Open Archiving and Sky Writing

A third string to the e-scientists' slowly evolving bow is becoming increasingly familiar within the digital libraries community. Open Archiving [12] started with the aim of increasing the dissemination of scientific information by promoting the development of inter-operable archives of scientific literature. The most prominent example is the High Energy Physics (HEP) archive which currently has over 220,000 articles and sees 12,000 users per day.

Running in parallel to the (sometimes lengthy) publication process and avoiding the toll-based access of journal subscription, the HEP archive allows physicists to increase the tempo of their literature by reducing the delay between the appearance of an article and the appearance of a citation to it to less than a month [1]. This phenomenon is fancifully described as *sky writing* [9], the potential of returning the speed of scientific communication from the year-on-year turnover of journal articles to a tempo more closely related to human conversation.

2. DIACHRONIC SCIENCE

These technological aids, wonderful as they are, suffer from being disjoint. The current vision for the Grid focuses only on the immediate aspects of E-Science — the experiments, analyses and meetings which occur over the duration of a project. As well as these synchronic aspects, any scientific effort (and E-Scientific efforts in particular) will have diachronic features, those collaborative activities which extend through time, enabling the influence of the project to carry on beyond its funded timescale and disseminating its knowledge beyond the boundaries of the original collaboration.

These activities are a well-known part of the scientist's profession (publishing papers, publishing data, giving seminars, rerunning experiments and checking others' results, comparing approaches from different projects, generalising or specialising the work of others, and, of course, teaching).

Publishing activities (the writing of reports, workshop papers, and refereed conference and journal articles) have a significant effect through time. The individual publications may be the result of the immediate collaboration, with working drafts exchanged between each of the project partners; the collected (linked) publications of a project show signs of the extended collaboration, as more results, analyses and conclusions emerge building successively on each previous publication. The details (ordering and preferences) of how these processes result in a combination of reports, presentations, conference papers, journal articles and a publicly accessible record of preprints and reprints change with the discipline in which the project is being carried out, but the general pattern remains the same.

This immediate collaboration generates 'the literature' which is subsequently read by other scientists in other projects, and whose work it informs and inspires. These scientists may be minded to rerun the original experiments, perhaps adapting the process in some way, to check results, or to specialise or generalise a reported principle. They, in turn, write articles which link to the original work, thus demonstrating its impact, a quality prized by tenure committees and funding organisations alike. This loose-coupled, diachronic collaboration afforded by publishing affords is a principal foundation of the scientific process, whereby we "stand on the shoulders of giants".

This is where digital libraries stand, mediating hypertext access both to publishers' postprint certified collections and the communities' preprint archives. However, focused as they are on acquiring, maintaining and preserving collections (within a strict budget) and then providing information discovery services to their clients, the researchers and academics, they are blind to (or neutral about) the processes by which this information is created, crafted, evaluated[1], gathered, distilled, expressed, reviewed[2] and then exploited[3].

Publication provides a mechanism to extend research collaboration beyond the confines of the original activities, in-

[1]researched

[2]written and published

[3]fed back into a new research or learning activity

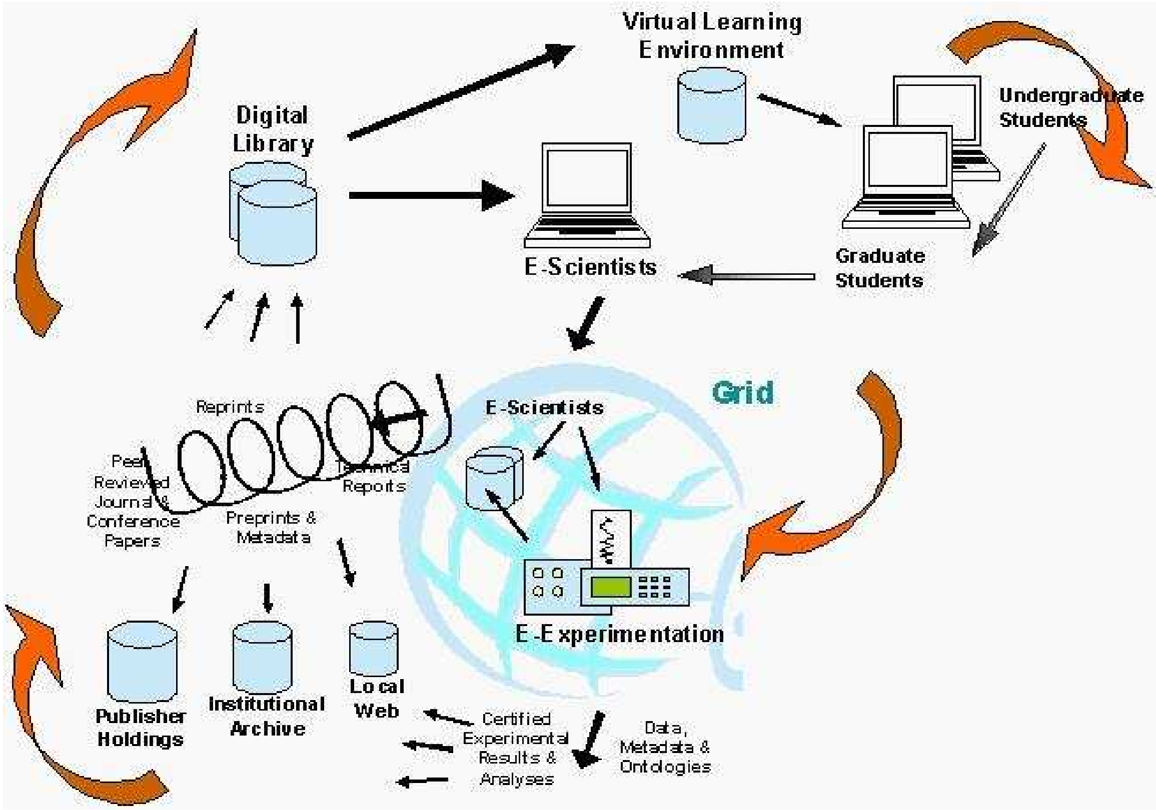

Figure 1: The E-Science Cycle

crementally advancing the scope of scientific knowledge. The current deployment of web technologies increases the effectiveness of this loose-coupled collaboration; the role of the digital library is to focus the various channels (archives, publishers' websites and aggregation agents) into a single portal which mediates these strands of diachronic collaboration.

There is also a looser coupling that exists between researchers as educators and their students, particularly in the context of higher education. Here the output of research activities is used to form and inform the next generation of scientists and E-Scientists. The deployment and adaptation of scientific materials into study packs, modules or learning objects is a crucial part of the educational process, and a *raison d'etre* of University education. It may be that the "distance" between cutting-edge research and the classroom may be different for postdoctoral education (as demonstrated in a later section) and undergraduate education, but the goal of passing new information on is a kind of collaboration (in the extreme, an extended diachronic collaboration with a subsequent generation).

It seems reasonable that the accepted picture of e-science could be enlarged (see figure 1) from its current focus on experimentation and analysis to feature these processes of wider significance, since without these aspects of diachronic collaboration there would be no ongoing science and, indeed, no scientists.

3. RELATED WORK

Dalgaard expands the notion of scholarly hypertext away from hypertext being merely intertextual relationships between articles to the relationship between text and archive [4]. He points out that from its very inception, hypertext was thought of both at the level of the text and at the level of the network, arguing that in the context of the Web, hypertext has become the paradigmatic rhetorical structure of a global and distributed archive. Accordingly a scholarly archive is the collection of scholarly texts, and the catalogues and reference works giving access to them. Dalgaard observes that most navigational options are presented as texts (lists of works, authors names, references, etc) — this is the hypertextualization of the scholarly archive.

The historical image many people have of the scientific process is that of a lone scientist or small team working in a basement laboratory. A similar picture appears for the use of libraries, where researchers ferret away in dusty books for vital missing bits of information. Levy and Marshal have examined the early underlying assumptions and how they affected digital library development [13]. In their article they challenge these images, especially the assumption that digital libraries are used by individuals working alone. They point out that the work carried out by both research staff (in doing research) and library staff (in providing the service), is one of collaboration, and that digital libraries should support formal and informal collaboration and communications.

Similarly Marchionini and Maurer point out that that "digital libraries will allow learners of all types to share, resources, time and energy and experience to their mutual benefit" [16]. In their proposed future of digital libraries, sharing resources becomes an important factor in supporting teaching; this includes the ability to share raw scientific data and other datasets. Many e-science projects have collected a vast amount of data: if the next generation of e-scientists are to go beyond the present position it is essential that they have access to the raw data in their research and training. These early visions are slowly being realised, for example McGrath *et al.* have developed a system that will locate, browse and retrieve astronomy data across several databases [18], but there is still a need for those that have the technology skills, librarians, and users, to work together to provide appropriate tools for handling, manipulating and analysing these large datasets [20].

Marchionini and Maurer also suggested that digital libraries should offer greater opportunities for users to deposit information. There are projects beginning to do this, for example the Digital Library for Earth Science Education (DLESE) project allows students to explore geospatial materials and Earth data sets; groups of students can then manually create reports using this data, and discuss the reports [17]. Weatherley *et al.* have proposed a model that will aid reviewers in reviewing complex material or a digital collection [22]. The peer review of collections and peer comment is a significant part of the disseminating process, which adds value to any collection. Lyon sees the digital library in the context of an information grid as consisting of a collection of resources for learning and teaching, data repositories for research purposes, or as archives of diverse cultural heritage materials [15]. While this is only a proposed scenario, Lyon recognises the need for researchers to undertake experiments, deposit raw data, and produce preprints using web services.

4. THE DYNAMIC REVIEW JOURNAL

Recent advances in Web technologies allow such concepts to be realised. The Dynamic Review Journal (DRJ) has been implemented as a Web-based environment for supporting a critical subset of the e-science cycle (figure 1): the collation and analysis of experimental results, the organisation of internal project discussions, and the production of appropriate outline documents depending on the requirements of conferences and journals selected for dissemination. DRJ-Framework is the software which has been implemented to embody these process.

Figure 2 illustrates the DRJ-Framework concept, in the context of an e-science community Web site and existing (integrated) Web-based services. Implemented as a toolkit of generic Microsoft.NET[4] components, DRJ-Framework can be integrated with existing Web sites. Although the DRJ-Framework itself provides data storage and management capabilities, facilities have also been provided to help communities integrate DRJ-Framework with existing data repositories. Distributed eprint, discussion, and analysis services provide integrated support for document (e-print/reprint) management, communication, and e-experimentation respectively.

Figure 3 elaborates this picture in order to illustrate the major activity spaces in DRJ-Framework and the work-flow supported within these spaces.

4.1 Schema Space

The schema space is the mechanism by which the generic DRJ-Framework is specialised to a particular e-science community, through the formal specification of e-experimentation procedures relevant to that community. This specification is currently achieved using three different types of schema:

[4] `http://www.microsoft.com/net/`

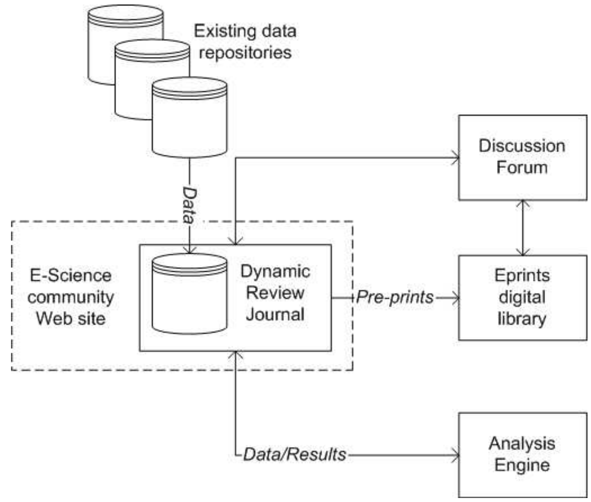

Figure 2: Conceptual overview of DRJ-Framework.

Data schemas describe the exact nature of the experimental data (for example, specification of variable names, types, and possible values).

Experiment schemas describe experimental procedures or *protocols*. For example, a protocol could specify that any e-scientist conducting an experiment of type X needs to record an *experiment description*, *statement of purpose* and an *outcome hypothesis*. Human-readable guidelines are also included, to help scientists meet the requirements of the protocol and to help reviewers to ensure that the requirements have been met. As a simple example, the e-scientist guidelines for the *experiment description* may state "summarise the content of the experiment", whereas the reviewer guidelines ask "does the experiment description adequately summarise the content of the experiment?".

Publication schemas describe the required format for submitting experimental results to relevant journals or conferences (for example, *Abstract*, *Introduction*, *Background*, *Experimental Methods*, *Results*, *Conclusion*). As with experiment schemas, human-readable guidelines are also included in publication schemas. Where possible, the publication schema also describes mappings with the experiment protocol (for example, specifying that the experiment *hypothesis* should appear in the *Experimental Methods* section of the article preprint — this allows outline preprint 'previews' to be generated semi-automatically without requiring the e-scientist to copy and paste information between protocol and preprint).

Schemas are created using the *Schema Builder* interface of DRJ-Framework. In our experience of applying DRJ-Framework to the VOEU project (discussed in the next section), an elected subset of the community "bootstrap" the schema space with a representative set of data, experiment, and publication schemas, which are then augmented by individual e-scientists as needs arise.

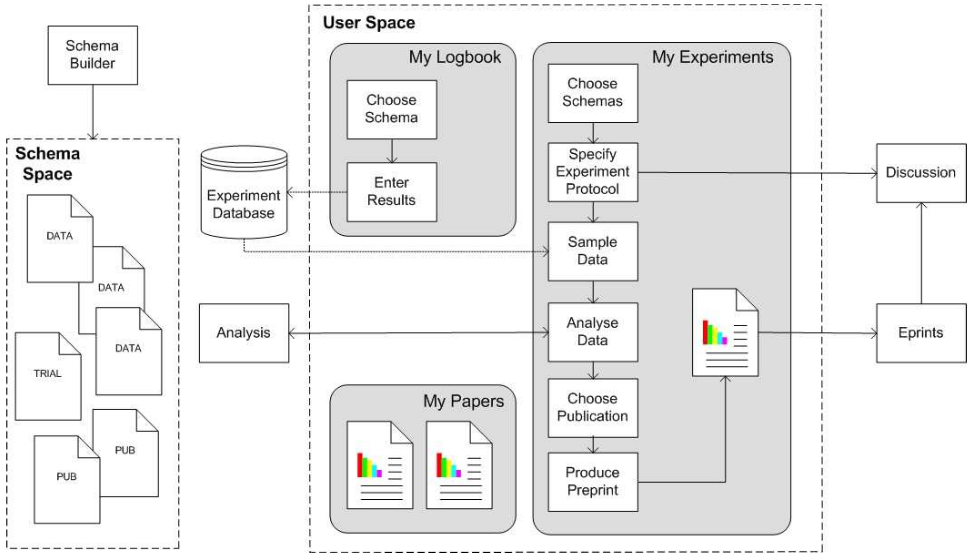

Figure 3: DRJ-Framework activity spaces and work-flow.

4.2 User Space

The user space is where e-scientists use the schema space to orchestrate practical data entry and collation, e-experimentation, and dissemination. The user space is further subdivided into three personalised areas — *My Logbook*, *My Experiments*, and *My Papers*.

My Logbook is an experiment logbook, in which experimental results can be entered (in accordance with a selected data schema). Logbook entries are subsequently added to the DRJ-Framework community database, making data available (anonymously) to other community members.

My Experiments is a workspace for e-experiments which the e-scientist works on. An e-scientist may be involved in an experiment in the capacity of *lead investigator* (initiates experiment and acts as coordinator and first point of contact for duration of experiment), *associate investigator* (assistant), or *reviewer* (monitor the progress of the experiment and review its outcomes according to guidelines). Reviewers have read-only access to the experiment protocol and set-up. When a new experiment is initiated, a discussion facility is automatically set up to facilitate and record communication between the e-scientists involved (this is also the means by which reviewers can give feed back to the practitioners).

Figure 3 outlines the work process facilitated by *My Experiments*:

1. **Choose experiment and data schemas** — When an experiment is initiated, the lead investigator chooses from the schema space the experiment and data schemas which best describe the procedure to be carried out and the data to be collated (these may be existing schemas, or new schemas generated by the lead investigator specifically for the experiment).

2. **Specify experiment protocol** — The lead investigator then enters the specifics of the experiment protocol (in accordance with the chosen schema), including specifying which other community members will assist in the experiment in the roles of associate investigators and reviewers. The experiment protocol may subsequently be updated by any of the investigators, perhaps as a result of critical comment from the reviewer.

3. **Sample data** — Investigators create a dataset for the experiment, either by importing their own records from the *My Logbook* area, or by searching the community database.

4. **Analyse data** — Investigators perform a series of analyses on the dataset, using a distributed analysis service, to test the experiment hypothesis.

5. **Choose publication schema** — To initiate the publication cycle, an investigator first chooses the publication schema corresponding to the target conference/journal. This produces a 'template' pre-print based on the conference/journal submission guidelines, which may be partially filled with data from the experiment protocol (according to mappings with the experiment schema described in the publication schema).

6. **Produce outline paper** — The investigator proceeds to 'flesh-out' this publication template to produce a basic pre-print, a process which includes selecting which analysis results to include.

7. **Submit to Eprints** — The completed pre-print can be previewed before being automatically submitted to the Eprints digital library server. Subsequent versions of the pre-print leading to submission, peer review, and reprint are managed by the Eprints server. Investigators continue to discuss the development of the paper in the discussion forum.

It should be noted that this work-flow is not enforced as a linear progression from experiment protocol to pre-print; investigators can make changes to the experiment protocol as the experiment progresses (for example, bringing a new associate investigator on board), return to the dataset at any point to add/remove experimental results or perform more

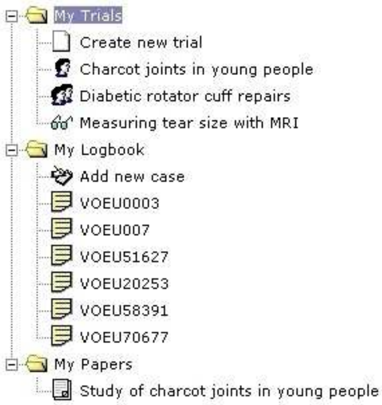

Figure 4: DRJ user space.

analyses, and produce many different pre-prints describing different aspects of the experiment.

Finally, *My Papers* provides a simple shortcut allowing an e-scientist to quickly access all the papers produced by the various experiments worked on.

5. APPLYING DRJ TO THE VOEU PROJECT

The Virtual Orthopaedic European University (VOEU) is a Virtual University dedicated to the ongoing professional education of orthopaedic surgeons across the European Community. VOEU is developed by a consortium of orthopaedic surgeons drawn from six European countries with the aim of producing a system in which 'e-surgeons' can learn about and disseminate material on surgical techniques in Orthopaedics, especially Image Guided Orthopaedic Surgery. The VOEU-managed learning environment for training surgeons consists of hypermedia educational material (including problem cases and assessment), interactive simulators, and communication tools (moderated and asynchronous message boards) together with the Dynamic Review Journal.

The objective of the project is to provide integrated computer support across the research and educational cycles because these activities are intrinsically coupled as a part of the requirements of the surgeon's Continuing Professional Development (research must be undertaken and papers published to achieve goals under the learning contracts with their Professional Colleges).

Within VOEU, a Dynamic Review Journal has two main functions; to aid surgeons in preparing findings for publication, and to support the educational process. Orthopaedic surgical trials typically run for extended periods (up to 2 years), with postoperative assessment results being collected regularly. The collated results are then analysed and discussed by a team of e-surgeons before being disseminated to the wider orthopaedic community. We have extended the UK arm of the VOEU Web site[5] to incorporate the DRJ-Framework components and support this process. The following procedures were necessary to achieve this integration:

- DRJ-Framework components combined with existing VOEU "look and feel" and VOEU community vocabulary (for example, the *My Experiments* work area became *My Trials*).

[5]`http://voeu.ecs.soton.ac.uk/`

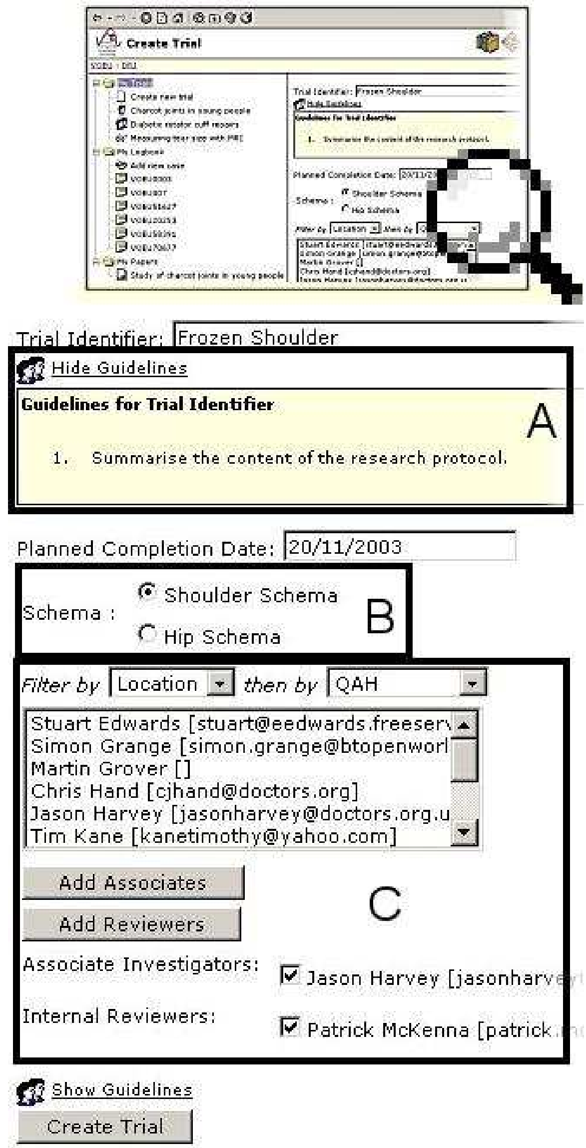

Figure 5: Entering trial protocol information.

- Experiment database initialised with a "Virtual Observatory" of orthopaedic cases.
- Schema space bootstrapped by community representatives:

  Data schemas Shoulder and hip operation data, including post-operative mobility test scores.

  Experiment schema Orthopaedic clinical trial protocol.

  Publication schemas Submission formats for the Journal of Bone & Joint Surgery[6] and the British Medical Journal[7].

[6]`http://www.ejbjs.org/`
[7]`http://www.bmj.org/`

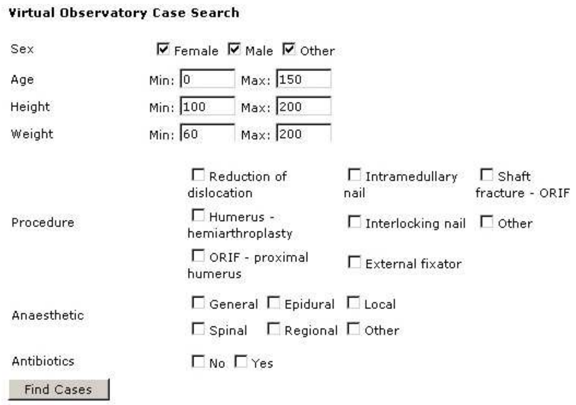

Figure 6: Searching the Virtual Observatory.

5.1 Managing E-Experiments: Example Scenario

To illustrate the DRJ-Framework in the VOEU context, this section outlines the process of managing e-experiments from the perspective of a fictional e-surgeon, Eddie[8].

Figure 4 shows Eddie's view of the DRJ user space (note that this navigation menu is always available, but excluded from some figures for clarity — figure 5). Eddie is currently working on three trials, undertaking a different role in each (note that roles are depicted using icons next to each trial). Eddie is the lead investigator in the "charcot joints" trial, an associate investigator in the "rotator cuff" trial, and reviews the "tear size" trial. Eddie has also entered several experimental records in the personal logbook (patient details, operative procedures, and assessment results), an so far has produced one pre-print.

Formalising Trial Protocol — To initiate a new trial, Eddie first selects the orthopaedic clinical trial protocol from the available experiment schemas. DRJ-Framework then uses this schema to generate a number of data entry forms in which Eddie enters specifics of the trial (figure 5). Guidelines for completing these forms are presented as "stretchtext links" [19] which can be viewed/hidden as required (figure 5A). Eddie also specifies that the shoulder data schema will be used in the trial (figure 5B) and the associative investigators and reviewers who will assist him on the trial (figure 5C). When created, the new trial will appear in Eddie's DRJ user space, and also in the user spaces of the associate investigators and reviewers.

Creating a Dataset — To create a dataset for the new trial, Eddie searches the 'Virtual Observatory' for suitable cases. Since Eddie has already specified the shoulder data schema, only those cases matching this schema will be searched. DRJ-Framework also uses the shoulder schema to generate a search form, so that Eddie can search for specific shoulder cases (figure 6). Eddie and associates subsequently add 42 different shoulder cases to the trial (see trial navigation menu in figure 7), which can be viewed in tabulated form for visual comparison.

Analysing the Dataset — To perform analyses on the dataset, Eddie and associates choose from statistical methods offered by a distributed Analysis Engine. Using the shoulder data schema and metadata from the Analysis Engine, the DRJ-Framework is able to generate an entry form for each statistical method, which Eddie can use to fine tune the analysis (specify test variables, groupings *etc.*). The Analysis Engine queues the requested analysis and notifies the DRJ-Framework when results are available. These results then appear in Eddie's DRJ user space, and can be viewed (Figure 8).

[8] Eddie is a nickname for Edwina or Edward in the UK

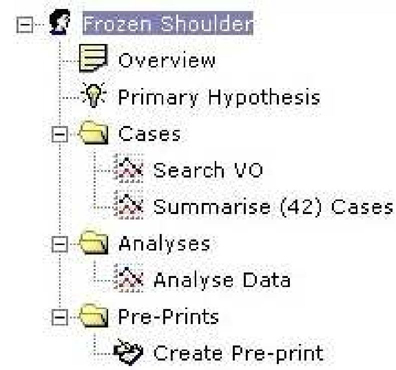

Figure 7: Trial navigation.

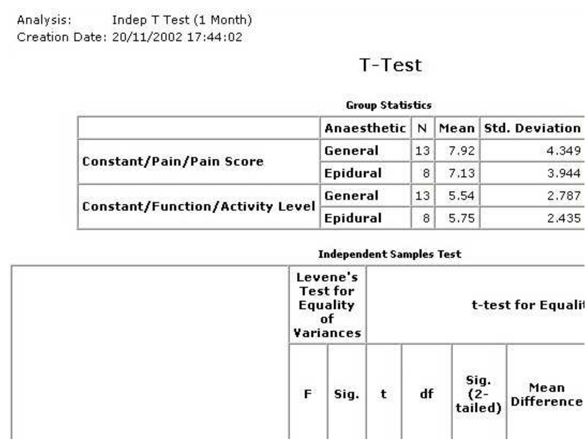

Figure 8: Viewing analysis results.

Disseminating Results — Having obtained some significant results from the statistical analyses, Eddie then decides to create a pre-print in order to disseminate the results to the wider orthopaedic community. When Eddie selects the JBJS publication schema, the DRJ-Framework generates a pre-print template using the information Eddie entered in the trial protocol. Eddie fleshes out this template, following the JBJS guidelines provided (figure 9), and specifies which analysis results should be included in the preprint. After previewing the pre-print, Eddie submits it: behind the scenes the DRJ-Framework submits the pre-print and its associated metadata to the community Eprints server (where it subsequently becomes available to the VOEU community), and makes the paper available in the user space of Eddie and associates.

6. VOEU EVALUATION

The VOEU project has recently carried out a broad usability evaluation of the range of services offered by the UK Web site. Although this evaluation focused on capturing

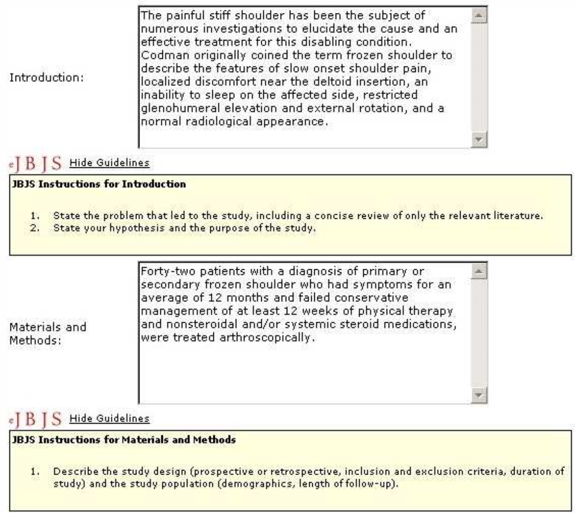

Figure 9: Preparing pre-print.

user's general responses to the overall VOEU 'experience' rather than any specific features of the DRJ, the results nevertheless provide some useful insights into the applicability and utility of the DRJ, as we look ahead to a more in-depth user evaluation of the DRJ's experimentation, analysis, discussion, and publication tools.

The evaluation was carried out by 18 orthopaedic surgeons with a mean age of 30.2 (SD 4.6), and a mean of 5.1 years surgical experience (SD 4.3). The majority of the participants responded to background questions in a way that indicated that they were 'tech-savvy' — they understood the benefits of electronic access to information, used the Web regularly at home and work, and preferred the electronic medium over traditional mediums. Even those who were less tech-savvy acceded the benefits of electronic access — only one participant, a self-confessed 'techno-phobe', maintained that paper-based materials were the easiest and preferred working medium.

Each participant followed a tour through the VOEU Web site, with each area — Digital Library, Education (part of each surgeon's Continuing Professional Development commitment), and DRJ — being demonstrated before allowing the participant to familiarise themselves with its function through 'hands-on' experimentation. Participants were also invited to carry out simple tasks, such as finding information in the VOEU digital library, and taking part in an interactive surgical simulation. In the case of the DRJ, each participant was given the opportunity to run through the entire process of setting up a clinical trial, carrying out data collection and analysis, and producing a targeted pre-print, as described in the e-experimentation scenario in Section 5.1. Each participant then completed a questionnaire designed to capture their responses to a number of different aspects of their VOEU 'experience', enabling us to measure the experience in terms of *impression*, *command*, *effectiveness*, *learnability*, and *aidability*, based on the Software Usability Measurement Inventory (SUMI) [11], as well the *navigation* and *comprehension* extensions to SUMI proposed by [3] for evaluating hypermedia systems. Table 1 shows how each scale corresponds to a different aspect of the VOEU 'experience'.

The results of the evaluation are shown in Figure 10,

Scale	User Experience
Aidability	The degree to which the VOEU site assists the user to resolve a situation.
Command	The extent to which the user feels that they are in control.
Comprehension	The degree to which the user understood the interaction with the VOEU site.
Effectiveness	The degree to which the user feels that they can complete the task within the VOEU site.
Impression	The user's feelings or emotions when using the VOEU site.
Learnability	The degree to which the user feels that the VOEU site is easy to become familiar with.
Navigability	The degree to which the user can move around the VOEU site.

Table 1: Questionnaire scales in relation to the user's 'experience' of using the VOEU site.

Rank		Proposed Extension
1	(1)	Automatic uploading of trial data to other records, such as the BOA logbook JCHST, GMC revalidation.
2	(3)	Pervasive access from handheld devices (e.g. trial data entry from PDA).
3	(4)	Heuristic support for users unfamiliar with statistics management.
4	(5)	Journal submission templates for all leading journals.
5	(7)	Enhanced trial data entry.
6	(9)	Forwarding to national and international trials centres for analysis.

Table 2: Proposals for extensions to the DRJ, ranked by participants in order of relevance.

where a mean response value of 5.0 indicates an entirely positive result, and a mean response of 1.0 indicates an entirely negative result. Initial indications from this trial therefore show a positive response to all aspects of the VOEU usability experience. The greatest positive responses were to the statements "I was able to move around the information in VOEU easily" (navigability), "learning to use the system was easy" (learnability), "I felt at ease trying different ways to get to the information I needed" (learnability), "the system help files provided enough information to use the system" (aidability), "VOEU could be of use to me in my job" (effectiveness), and "using VOEU allows me to accomplish tasks more quickly" (effectiveness). Areas which proved more controversial included "I often become lost/disoriented when using VOEU", "it was difficult to learn more than the basic functions of the VOEU system", and "the system was awkward to use if I wanted to do anything out of the ordinary".

In order to better focus future developments of the DRJ and other VOEU services, participants were also asked in a separate questionnaire to rank a number of proposed VOEU

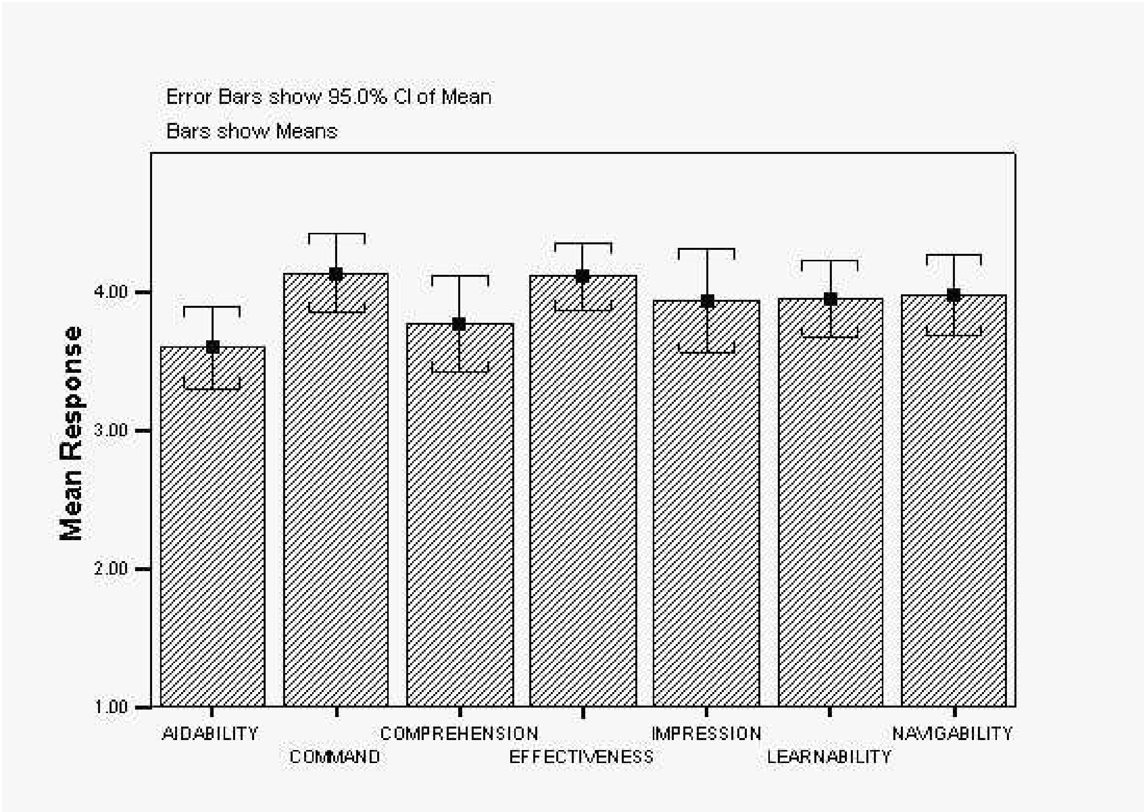

Figure 10: Results of the VOEU usability trial, showing average participant responses for different areas of their VOEU 'experience'.

extensions in order of relative importance to their day-to-day work. Table 2 lists the ranked proposals which are specific to the DRJ (with overall ranking shown in parentheses).

7. CONCLUSIONS

In answer to the question *What is a digital library?* the University of California Digital Library FAQ states 'systems that support the collections of the University'[9].

In this paper we argue for a broadening of this view, out from the collections themselves, to the process of collecting and deploying. We have taken the position proposed by Dalgaard that scholarly hypertext is not merely the intertextual relationships between papers but the relationships between these texts and the wider archive [4]. Parts of the Scientific Community (and the Computing Community) are currently obsessed by the idea of the Grid — in broad brush terms this amounts to the use of computers to make possible or to ease/improve scientific experimentation, analysis, and collaboration. However, we argue that publishing, dissemination, research, and learning are equally important (perhaps more important) parts of the scientific cycle of activities and should not be left to unaided 'mandraulic' effort.

We have presented our contribution to this ongoing effort, the Dynamic Review Journal, and described its integration and use within a Virtual University learning environment as an example of a system which deliberately crosses the barriers between these areas (experimentation, analysis, publishing, dissemination, discussion, and education). In providing support for the broader range of scientific activities, it is our hope that scientists can be made more effective in their work.

[9] `http://www.cdlib.org/about/faq/`

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