Extending the Role of a Healthcare Digital Library Environment to Support Orthopaedic Research

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Abstract

A digital archive, together with its users and its contents, does not exist in isolation - there is a cycle of activities which provides the context for the archive's existence. In arguing for the broadening of the traditional view of digital libraries as merely collections towards the processes of collecting and deploying, we have developed an extended digital library environment for orthopaedic surgeons which bridges the gap between the undertaking of experimental work and the dissemination of its results through electronic publication.

Keywords

Electronic Publication, Orthopaedics, Research Cycle, Virtual Universities

1 Introduction

A digital library, together with its users and its contents, does not exist in isolated splendour. There is a cycle of activities, which provides the context for the library's existence, which the library supports through its various roles of information access, discovery, storage, dissemination and preservation. In the e-learning context the digital library has an important role in the undertaking of science, and with the recent developments of the Grid for computer-supported scientific collaboration [1] and Virtual Universities for computer-supported education [2], its role has increased.

Marchionini and Maurer assert that 'digital libraries will allow learners of all types to share resources, time and energy and experience to their mutual benefit' [3]. 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 scientists are to go beyond the present position it is essential that they have access to the raw data in their research and training. Marchionini and Maurer also suggest that digital libraries should offer greater opportunities for users to deposit information. 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 [4], 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 [5].

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 them [6]. Weatherley et al. have proposed a model that will aid reviewers in reviewing complex material or a digital collection [7]. The peer review of collections and peer comment is a significant part of the dissemination 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 [8]. While this is only a proposed scenario, Lyon recognises the need for researchers to undertake experiments, deposit raw data, and produce pre-prints using Web services.

We have developed a Web-based environment which we call the Dynamic Review Journal to support such activities in the context of a healthcare digital library: the Virtual Orthopaedic European University. Within the DRJ environment, orthopaedic trainees and surgeons not only collaboratively develop and disseminate the documents which are subsequently managed by the archive, but are also supported in the cycle of activities leading up to the production of these documents - the management of surgical trials, collation and analysis of experimental results, and organisation of internal project discussions.

2 VOEU and the Dynamic Review Journal

The Virtual Orthopaedic European University (VOEU) project aims to build a Virtual University dedicated to the training of higher surgical trainees and the ongoing professional education of orthopaedic surgeons across the European Community. 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 DRJ 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 a surgeon's continuing professional development - research must be undertaken and papers published to achieve goals under the learning contracts with their professional colleges.

We have extended the UK arm of the VOEU Web site[1] to support this process. Within this context, the 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 surgeons before being disseminated to the wider orthopaedic community. The DRJ also allows surgical trainees to gain experience in the research process by immersing themselves directly in this environment - trainees can, under supervision from a tutor or team leader, analyse data from existing trials, investigate hypotheses, discuss archived articles, and even prepare and submit their own reports for assessment. This practical (procedural) experience thereby reinforces the declarative (factual) content learnt in the VOEU managed learning environment.

Figure 1 illustrates the major activity spaces in the DRJ and the work-flow supported within these spaces.

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

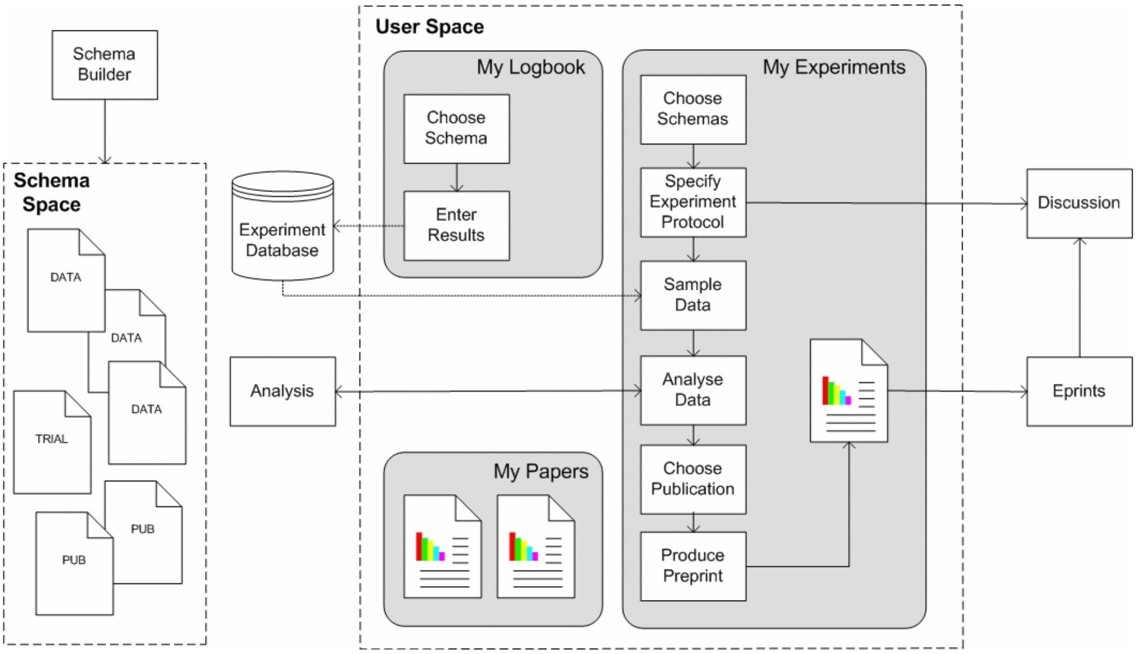

Figure 1: DRJ activity spaces and workflow

2.1 Schema Space

In general terms, beyond the specific application of the VOEU, the Schema Space is the mechanism by which the Dynamic Review Journal can be configured to the evolving needs of a particular scientific/learning community, through the formal specification of experimentation procedures relevant to that community. This configuration is currently achieved using three different types of schema:

- Data schemas describe the exact nature of the experimental data (for example, specification of variable names, types, and possible values). In the VOEU context, there are a number of data schemas for collecting orthopaedic clinical trial data, including shoulder and hip operation data and post-operative mobility test scores.
- Experiment schemas describe experimental procedures or protocols. For example,

in VOEU a protocol could specify that a surgeon conducting a trial of type X needs to record an experiment description, statement of purpose and an outcome hypothesis. Human-readable guidelines are also included, to help users meet the requirements of the protocol and to help reviewers to ensure that the requirements have been met.

- Publication schemas describe the required format for submitting experimental results to relevant journals or conferences (for example, Abstract, Introduction, Background, Experimental Methods, Results, and Conclusions). As with experiment schemas, human-readable guidelines are also included. In the VOEU context, there are currently two publication schemas describing the submission formats for the Journal of Bone & Joint Surgery (JBJS) and the British Medical Journal (BMJ).

All three types of schema are created using a Template Generation Toolkit, introduced in Section 3.

2.2 User Space

The User Space is where users use the schema space to orchestrate practical data entry and collation, experimentation, and dissemination. The User Space is further subdivided into three personalised areas: My Logbook, My Experiments, and My Papers (Figure 2).

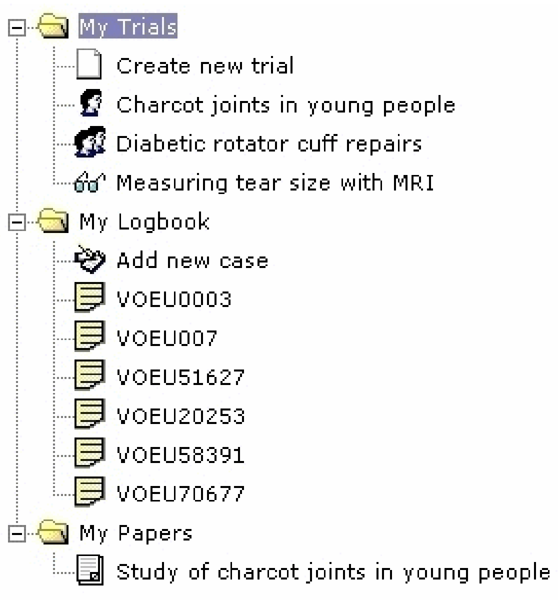

Figure 2 Personalised User Space Navigation Menu

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 community database, making data available (anonymously and with the patients consent) to other community members. My Experiments is a workspace for the experiments which the user works on. A user may be involved an experiment in the capacity of lead investigator (initiates experiment and acts as coordinator and contact for duration of experiment), associate investigator (assistant), or reviewer (monitors the progress of the experiment and reviews its outcomes according to agreed guidelines). When a new experiment is initiated, a discussion facility is automatically set up to facilitate and record communication between the users involved (this is also the means by which reviewers can give feed back the practitioners). Figure 1 outlines the work process facilitated by My Experiments:

1.**Define/Choose experiment and data schemas.** 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. If no suitable schemas are available, the lead investigator can create a new schema specifically tailored to the requirements of the experiment. In the case of trainees, a tutor or group leader takes the role of lead investigator.

2. **Specify experiment protocol.** The lead investigator enters the specifics of the experiment protocol (in accordance with the chosen schema), including assigning associate investigators and reviewers to the study. In the case of trainees, the tutor assigns the roles of associate investigators and reviewers to students.
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. **Define/Choose publication schema.** To initiate the publication cycle, an investigator first chooses the publication schema corresponding to the target conference or journal. Again, if no existing schema meets the requirements of the desired dissemination route, a new schema can be created. In both cases, this produces a 'skeleton' paper. In the case of trainees, the chosen publication schema will usually correspond to an 'assignment report' format.
6. **Produce outline paper.** The investigators proceed to 'flesh out' the paper to produce the beginnings of what will form a pre-print[2]. Results from the dataset analyses can be selectively included in the paper.
7. **Submit to Eprints.** The completed paper can be previewed before being automatically

submitted to the Eprints digital library component. Subsequent versions of the paper leading to submission, peer review and reprint are managed by the Eprints [9] server. Investigators continue to discuss the development of the paper in the discussion forum.

It should be noted that the 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, inviting a new student to join the exercise), return to the dataset at any point to add/remove experimental results or perform more analyses, and produce many different pre-prints describing different aspects of the experiment.

Finally, My Papers provides a simple shortcut allowing the user to quickly access all the papers and reports produced by the various experiments and exercises worked on.

Figure 2 shows the User Space of a surgeon who is currently working on three trials, undertaking a different role in each (roles are depicted using icons next to each trial): lead investigator in the charcot joints trial, associate investigator in the rotator cuff trial, and reviewer in the tear size trial. The surgeon 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.

3 Evolving to Changing Needs of Users

In order for an approach such as the DRJ to succeed, the digital library environment needs

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[2]An article submitted for peer review but not yet accepted.

to be able to evolve to meet the changing needs of its user community - it is unreasonable to expect the developers of such a system to predict and encode every possible experimental procedure, every type of data that can be collated and analysed, and every possible dissemination route that users will follow to publish their results to the wider community. The Schema Space is therefore the fundamental aspect of the design of the DRJ, providing the mechanism by which the DRJ can be configured to the requirements of a community (in the case of the VOEU, the community of orthopaedic surgeons and trainees within the EU), a particular group of users, or even an individual. The schemas in the Schema Space provide an interface between the data stored by the system and the users' view of that data – for example, in the case of the data schema, the type and format of sets of data variables are specified and subsequently used to dynamically generate user interfaces for entering, viewing, and performing statistical analyses.

Until recently, this mechanism was only available to those users with the appropriate technical nous to formalise their data requirements using the schema grammar – some of our most recent work has therefore focused on building a toolkit to enable the wider (non-expert) VOEU community to configure the DRJ to the particular requirements of their experimental activities. The first barrier to achieving this goal was the use of the term 'schema' - for surgeons, this is an alien term within their day-to-day work experience, so the more familiar term 'template' was chosen in its place. This change of name from schema to template also emphasised the evolutionary nature of most schemas. Rather than start with a blank schema and add new items, the majority of new schemas would be modifications of existing ones. Therefore an existing schema could form a template around which new ones could be created. The DRJ's schema-building component thus became known as the Template Generation Toolkit.

3.1 The Template Generation Toolkit

The Template Generation Toolkit (TGT) enables non-expert users to quickly and easily add new schema specifications, or 'templates' to the DRJ Schema Space, in accordance with their specific requirements. The TGT has been developed in the form of a pedagogical toolkit - such toolkits guide users through the process of articulating their information needs to produce an information plan for a particular task [10]. Pedagogical toolkits lie between restrictive wizards which force a user through a particular route (for example, a printer installation wizard) and more open frameworks which provide unrestricted access to a different parts of a creation process. The TGT therefore, is designed to provide a structured way of creating new schemas.

For example, in the case of data schemas, variables can be grouped together into sets based on the type of data they record. For example, a patient data set could include age, weight, height, and ethnic origin, while a data set for recording elbow movement could include range and degree of motion in various directions, pain experienced, and muscle response. New data schemas can then be built using sets defined by existing schemas and 'fine-tuned' by adding, deleting, or modifying individual variables (Figure 3).

Once a data schema has been created using the Template Generation Toolkit, it is immediately available to members of the VOEU community to use to input new case data.

When a suitable number of cases based on the new schema have subsequently been entered into the VOEU database, the dataset can be searched and analysed.

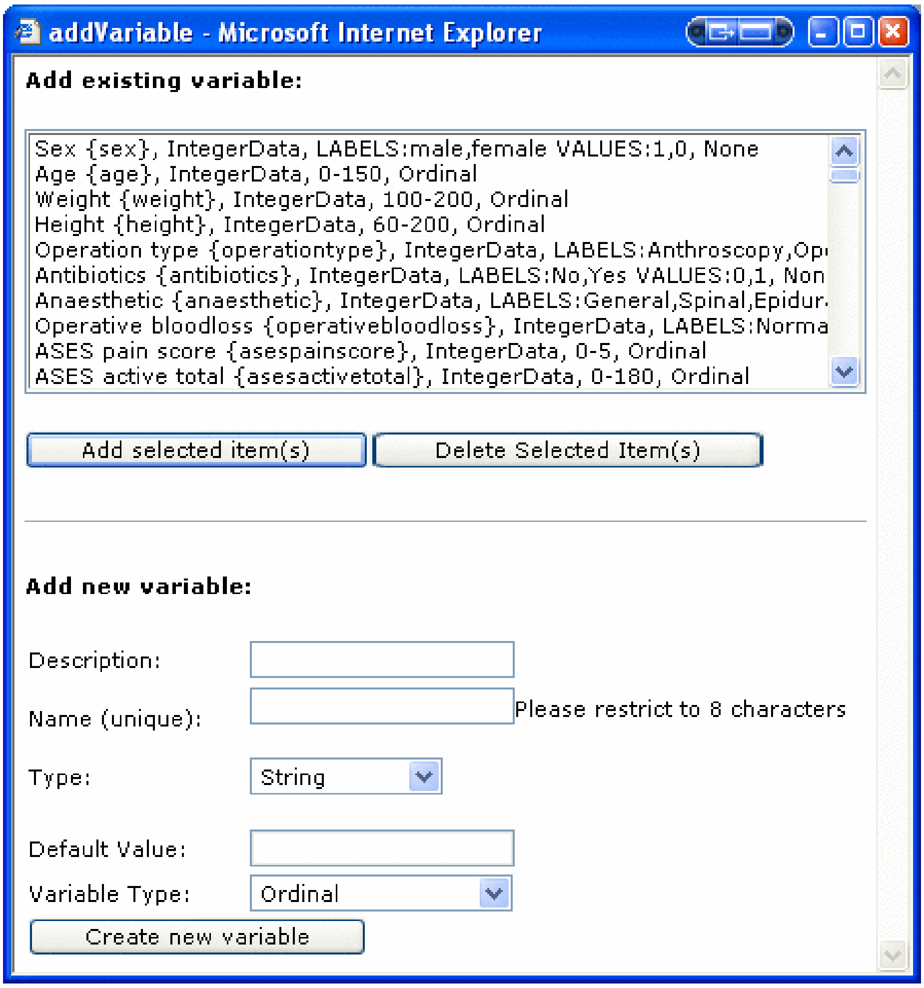

Figure 3 Adding a new variable to a schema in the Template Generation Toolkit

3.2 Issues Raised

The development work on the Template Generation Toolkit has raised some issues within the context of the VOEU community, which have wider implications that must be borne in mind as we move towards our goal of more widespread adoption of a Dynamic Review Journal-based infrastructure supporting the experimental work of other on-line scientific communities (see Section 4).

One issue that was faced concerned the lack of presentation information defined within the data schema. Without this information, the user interfaces generated from the data schema (including data entry forms, data viewing tables, search forms, and data analysis forms) are simplistic and simply list each variable in the order that they are defined in the schema. While this was sufficient in most cases, in specific cases we were asked by surgeons to adjust the appearance of the forms so that they mirrored their paper-based counterparts. This issue potentially hints at a much larger one - that in large-scale trials involving participants from multiple institutes throughout the EU there is a much greater need for customised presentation of information then would be required in the case of a smaller trial whose participants are all part of the same institute. Issues such as cultural, linguistic and political differences all need to be properly addressed. VOEU currently hold a 'user profile' information for each registered user of the system, which has provided a useful starting point for our work in this area to provide personalised interfaces in different languages or presentation styles.

Another issue facing multi-national trials is the potential difference in local policies between participating institutions; a VOEU-specific example is that of different policies used in different regions for assessing a patient's pre- and post-operative motor facilities - surgeons in the US use the AIPES system, whereas in the EU the CONS system is used. The former measures shoulder movement by degrees, the latter measures the same movement on a scale of one to five. A mechanism to enable the DRJ to map between the different types of assessment could be defined in this instance, allowing scores from both types of system to be compared and analysed side by side; however, there may be some cases in which a measurement in one system has no equivalent in the system to which it is being compared.

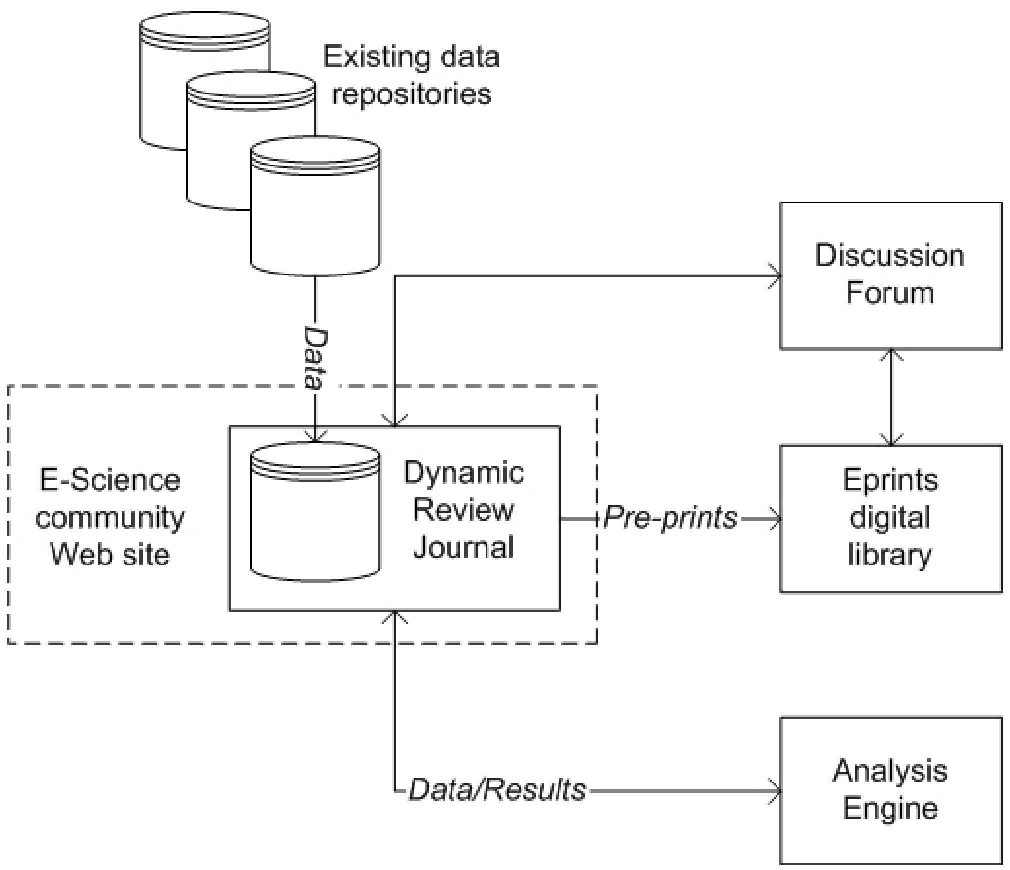

Figure 4 Conceptual overview of the DRJ

4 Deploying the DRJ in other Online Communities

Although originally conceived as part of the VOEU, the Dynamic Review Journal has been developed as a generic framework with the aim of being adopted as an infrastructure to support the experimental work of other online scientific communities. Figure 4 illustrates the framework concept, in the context of an e-science community Web site/archive. Implemented as a toolkit of Microsoft.NET components, the DRJ can be integrated with existing sites. Although the framework itself provides data storage and management capabilities, facilities have also been provided to help communities integrate the DRJ with existing data repositories. Distributed Eprint, discussion, and analysis services provide integrated support for document management, communication, and experimentation respectively.

However, although the current workflow structure supported by the DRJ fits well into the current working practice of orthopaedic surgeons, we acknowledge that this may prove too restrictive for other communities in which research practices are more explorative. For example, within the field of orthopaedics there are very restrictive requirements and formats for publishing papers which fit very well with the current template-driven model, but in other fields publishers' requirements may more open-ended. We are therefore looking at ways in which a less rigid workflow processes could be supported. BSCW (Basic Support for Cooperative Work) [11], for example, provides Web-based shared workspaces allowing collaborating users to collect and structure any kind of information (including, but not limited to, documents, images, spreadsheets, software, and URL links to other Web pages or FTP sites) in order to achieve their goals of collaboration. Users primarily access workspaces through a normal browser (no additional software required), although a separate BSCW events server feeds a downloadable monitor applet with events about the presence and activities of other users in the workspace, allowing users to better coordinate their work.

In line with the framework illustrated in Figure 4, a distributed BSCW server component could manage shared workspaces for each experiment, enabling the investigators to collaborate in an unstructured (explorative) manner at each stage of the experiment whilst still being driven by the underlying DRJ workflow process. As an example, at the publication stage the experiment metadata and selected results could be "exported" to the shared workspace where the investigators mould it into a preprint outside of the rigid DRJ template model, before making it available to the community via the Eprints server.

5 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 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. Each participant then completed a questionnaire designed to capture their responses to a number of different aspects of their VOEU 'experience', based on the Software Usability Measurement Inventory (SUMI) [12], including extensions proposed by [13] for evaluating hypermedia systems. SUMI enabled us to measure several different aspect of the VOEU 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.

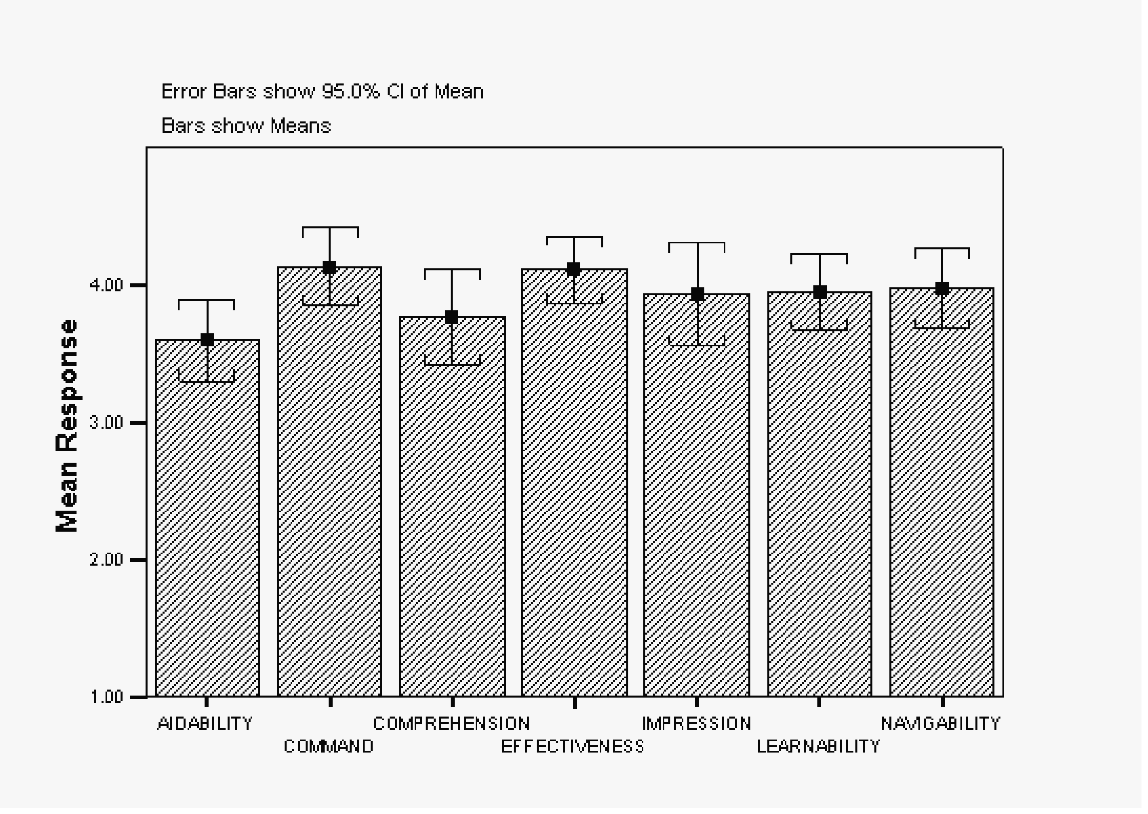

Figure 5 Results of the VOEU usability trial, showing average participant responses for different areas of their VOEU 'experience'

The results of the evaluation are shown in Figure 5, 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'.

6 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'. Our work on the Virtual Orthopaedic European University project argues for a broadening of this view, out from the collections themselves, to the process of collecting and deploying. We have presented our contribution to this ongoing effort, the Dynamic Review Journal (DRJ), 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 embracing such an approach, systems must be able to evolve in accordance with the changing needs of its users, and we have outlined how the DRJ's Schema Space facilitates this and in doing so enables the DRJ to be deployed to support the experimental work of other on-line scientific communities.

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. In providing support for the broader range of scientific activities, it is our hope that scientists can be made more effective in their work.

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