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The potential use of online tools for scientific collaboration by biology researchers

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Abstract:

Purpose – This study aims to discover the research practices of biology researchers and to assess the suitability of the OJAX++ Virtual Research Environment (VRE) for these researchers.

Design/methodology/approach – Usability testing was used to evaluate the usability of OJAX++ in relation to biology researchers. Interviews with biology researchers in a large Irish university were conducted to investigate their research information behaviour, to establish user requirements in their discipline and to evaluate the feasibility of using OJAX++ in their research.

Findings – The results show that biology researchers used online tools extensively in their research but do not use social networking tools. Email and phone conversations are the preferred methods of collaborating with colleagues. The biology researchers found that OJAX++ was easy to use, intuitive and professionally presented but in its present format, OJAX++ does not fit in with current research practices as they do not use Web 2.0 tools that facilitate tagging. A list of requirements of a VRE for biology researchers is presented.

Originality/value – The findings of the study will assist developers of VREs and other web tools to better understand how researchers, in particular biologists, collaborate during the research process and what they require from online research tools. This study gives an important insight into the information behaviour of life science researchers.

Keywords: Online research, Scientific collaboration, Virtual Research Environment, Web 2.0, Usability testing, Information behaviour

Article Classification: Research paper

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1. Introduction

Collaboration in science is of great importance and has been addressed by many authors including Olson and Olson (2000), Olson *et al.* (2002), Hara *et al.* (2003) and Birnholtz (2007). Scientific collaboration is defined by Sonnenwald (2007) as "human behavior among two or more scientists that facilitates the sharing of meaning and completion of tasks with respect to a mutually-shared superordinate goal and which takes place in a social context."

As science and scientific collaboration has developed over the decades so has information and communication technology. E-Research is collaborative and multi-disciplinary in nature, it processes and generates increasingly large volumes of data, and therefore requires new tools and technologies to support it (Jeffery and Wusteman, 2012). Virtual Research Environments (VREs) have been developed in order to fit these requirements (Sarwar *et al.*, 2013). The definition of a VRE is still evolving (Jeffery and Wusteman, 2012) but the UK Joint Information Systems Committee (JISC) describes it as a:

"shorthand for the tools and technologies needed by researchers to do their research, interact with other researchers (who may come from different disciplines, institutions or even countries) and to make use of resources and technical infrastructures available both locally and nationally" (JISC, 2010). Other terms that correspond to this definition of a VRE include: collaboratories, collaborative virtual environments, gateways, science gateways, portals, virtual organisations and cyberenvironments (Carusi and Reimer, 2010, Voss and Procter, 2009).

Web 2.0 and social media have changed the nature of how society communicates and interacts with each other. Aragon, Poon, and Silva (2009) point to a new generation of physicists, biologists, and other scientists who have grown up using technology such as Facebook and Twitter, and are developing and applying new methods of collaborating to the their work. However, barriers to the adoption of new collaboration technologies still exist.

This study aimed to investigate the current research practices and requirements of biology researchers in a large Irish university and to assess the overall suitability of a prototype VRE, called OJAX++, for these researchers.

2. Background

2.1 Scientific Collaboration and the Adoption of New Technologies

Since science has always been a form of what we now call "distributed knowledge work", scientists were among the first to recognise the potential of emerging information and communication technologies for enhancing and extending their work (Olson *et al.*, 2002, p. 44).

Hara *et al.* (2003) developed a framework that identifies types of collaboration among scientists, and identifies factors that influence collaboration. Hara *et al.* (2003) found that collaboration can often be viewed as a rite of passage for students and postdoctoral researchers. On all levels, the factors impacting successful collaboration relate to compatibility, work connections, incentives and socio-technical infrastructure (Hara *et al.*, 2003).

Birnholtz (2007) offers an alternative explanation for "collaboration propensity" - the likelihood of an individual researcher engaging in collaboration at a particular point in time and with regard to current research interests. Birnholtz (2007) examined how the nature of the scientific work impacts on collaboration propensity by studying three different scientific disciplines: earthquake engineering, high energy physics and neuroscience. All three disciplines have differing cultures of individual versus collaborative research (Birnholtz, 2007). This study suggested that the nature of the work may, in fact, be more important than social factors in explaining collaboration propensity, despite certain complexities (Birnholtz, 2007).

Many factors impact on the design, adoption, and use of a collaboratory and these broadly relate to career, personal motives, participation costs, scientific advancement, community, and development or sustainability costs (Lassi and Sonnenwald, 2010). Researchers often have concerns about collaboration and barriers to collaboratory adoption, for example, researchers are often afraid that credit will not be given where it is due, this is despite the fact that co-authorship can lead to increased citations over a longer period of time (Lassi and Sonnenwald, 2010).

The Research Information Network (RIN) and the British Library (2009) studied the patterns of information use, in seven research teams, in a wide range of life science disciplines. Information sharing and collaboration is a key part of, though not central to, the research activities of the life science researchers studied (RIN and British Library, 2009). Several important findings emerge from the data collected:

- There are several barriers to data sharing *e.g.* data collection can take years and can contribute to a researcher's individual "intellectual capital".
- Many researchers are concerned about posting data on the web.
- Although some researchers are aware of the potential of Web 2.0 and social networking tools, they do not use them intensively. This is because of the time needed to become familiar with these technologies, the sheer numbers of tools and services available, and the lack of a critical mass of people using them.
- Many researchers are "grappling" with emerging tools and services that are not necessarily fit for their purposes and they often rely on recommendations from colleagues when choosing them (RIN and British Library, 2009).

A key finding of the 2010 RIN report is that while the majority of researchers use at least one Web 2.0 tool for purposes related to their research, frequent or intensive use is rare (RIN, 2010). Moreover, researchers do not view Web 2.0 tools and services as comparable to, or substitutes for, other channels and means of communication (RIN, 2010). It was also found that the adoption of Web 2.0 services by researchers depends on: their intuitiveness, their ease of use, how they build on the researcher's existing practices and above all, whether they offer users both obvious advantages and practicably zero costs to adopt (RIN, 2010).

The RIN reports (RIN and British Library, 2009, RIN, 2010) support previous findings about concerns over data sharing, present the current challenges facing policy-makers regarding the adoption of Web 2.0 tools, and highlight the importance of user-centered design. The concept of "collaboration technology readiness" (Olson and Olson, 2000) is as relevant today as it was ten years ago, even if the technological climate has changed completely.

2.2 Usability Studies

In order to build VREs that are easy to use and that bring clear benefits to the user, the user must be involved in the design process. This is the principle behind user-centered design, or interaction design (Long *et al.*, 2005, Olson *et al.*, 2002, Wusteman, 2009a). Although various user-centered design methods exist, usability testing has become common in recent years (Bevan and Macleod, 1994, Jeng, 2005), and is arguably the most successful user-centered design method (Wusteman, 2009a).

There is no one universally agreed definition of usability with several authors proposing definitions (van Welie *et al.*, 1999). Nielsen (1993) defines usability as having five attributes: efficiency, learnability, memorability, error recovery, and satisfaction. Similarly, Shneiderman and Plaisant (2010) attributes five analogous factors to usability: speed of performance, time to learn, retention over time, rate of errors by users, and subjective satisfaction. The ISO's definition of usability is the "extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use" (International Organization for Standardization, 1998, p. 2).

Frøkjær *et al.* (2000) also define usability as comprising of the aspects of effectiveness, efficiency, and satisfaction. Effectiveness is the accuracy and completeness with which users can complete certain tasks (Frøkjær *et al.*, 2000). Efficiency is the relationship between accuracy and completion of tasks and the time taken to complete and learn the tasks (Frøkjær *et al.*, 2000). Satisfaction is a measure of the user's attitude to and comfort with the system (Frøkjær *et al.*, 2000). Usability evaluation methods, and in particular usability testing, are used to assess these main aspects of usability along with factors such as learnability (Augustine and Greene, 2002, Clark, 2004, Dickstein and Mills, 2000, Hammill, 2003, Jeng, 2005). Frøkjær *et al.* (2000) conducted a usability testing experiment with 87 users and found that the correlation between efficiency and effectiveness was negligible. Therefore all three factors should be considered independent of each other and all three should be measured during usability testing (Frøkjær *et al.*, 2000). It is essential to measure satisfaction in usability testing as many users prefer systems or tools that they do not use fully efficiently or effectively (Dillon, 2002, Frøkjær *et al.*, 2000).

Various authors (Blažič *et al.*, 2007, Ju and Gluck, 2005, Long *et al.*, 2005) document their experiences of employing usability testing in software development projects including an e-learning system, a software interface menu and a digital photographs library. Interestingly, Ju and Gluck's (2005) study required their testers to have prior knowledge of the system before usability testing began, and Blažič *et al.* (2007) found that effective use of the system required some form of training. Regarding VREs, however, both the RIN (RIN and British Library, 2009, RIN, 2010) and JISC (Carusi and Reimer, 2010) reports indicate that researchers are reluctant to take up new technologies if they are difficult to use or require training. Therefore, a bottom-up approach to VRE development should ideally involve usability testing with "users" who have no prior knowledge of the system, at some point, in order to correctly assess how learnable or intuitive the system is for novice users.

2.3 OJAX++ Virtual Research Environment

OJAX++ is a VRE currently in development in University College Dublin (UCD) by the School of Information and Library Studies (SILS). OJAX++ allows users to use Web 2.0 applications and then gathers or aggregates the data from the applications into a single portal, so that the users can organise their online activities and collaborate on their research in one place (Jeffery and Wusteman, 2012). Recent literature on VREs (Carusi and Reimer, 2010, SURFnet, 2009, van der Vaart, 2010) has championed user-centered VRE design and customisable, lightweight frameworks. OJAX++ reflects this approach; it adopts a lightweight, modular framework, with emphasis on interoperability and integration of third party applications. This trend in VRE design is challenging the "one-size-fits-all" approach because researchers' needs vary according to each academic discipline. Thus, VRE frameworks need to be sufficiently flexible to respond to alternating research needs (Carusi and Reimer, 2010).

Two usability studies of OJAX++ were conducted in 2010 using information studies researchers from UCD (Coffey, 2010, Jeffery, 2011). Based on the results of these studies, several recommendations were made to improve the VRE and a number of these were implemented in subsequent versions of OJAX++ (Coffey, 2010, Jeffery, 2011). This study aimed to assess the usability of OJAX++ Version 0.3 with researchers from an alternative discipline, namely biology researchers from UCD, as it is believed that life science researchers use online research tools differently to human science researchers.

OJAX++ uses activity streams as an organisational tool, as they are time-ordered (Freeman, 1997) and transparently store information. The fact that this information is stored at the time it is created facilitates information retrieval (Jeffery, 2011). Tagging is used to classify the data and add the content to the relevant project activity stream (Jeffery and Wusteman, 2012). The tags are created by the user when they set up the project. These "project tags" are then applied in third party applications and the related content is imported into the project activity stream. Figure 1 shows a screenshot of the profile page where a user can choose their preferred third party tools such as Twitter, Delicious, myExperiment and Connotea.

3. Research Questions

The aim of this study was to investigate the current research practices and requirements of biology researchers in UCD and to assess the overall suitability of the OJAX++ Virtual Research Environment for these researchers. The research was divided into four sub research questions.

1. What are the information uses, practices and user requirements of biology researchers?
2. How could OJAX++ be used with biology research groups?
3. How does OJAX++ fit in with current research practices among biology researchers in UCD and how might it change these practices?
4. How usable would OJAX++ be for biology researchers?

4. Methodology

4.1 Research Methods

The user-centered design technique of usability testing (Long *et al.*, 2005, Wusteman, 2009a) was the main methodology chosen to evaluate the usability of OJAX++ in general and also in relation to biology researchers. Experts in the field advocate that in the latter stages of the development of user interfaces, usability testing is crucial (Krug, 2000, Nielsen, 2003), and this has been a method of choice for various VRE studies (Allan *et al.*, 2007, Stanley *et al.*, 2007). The present test phase built upon previous usability testing which was part of the Agile design cycle of OJAX++ (Coffey, 2010, Jeffery, 2011). Thus, the results from these previous tests, which involved information and library studies researchers, could be compared to the results of this study involving biology researchers.

Interviews with biology researchers were then conducted to investigate their research information behaviour, to establish user requirements in their discipline (Carusi and Reimer, 2010, Wusteman, 2009a) and to evaluate the feasibility of using OJAX++ in their research.

4.2 Semi-Structured Interviews

In order to investigate the current research practices and requirements of biology researchers in UCD, it was necessary to uncover their research methods and information needs through semi-structured interviews. Lee (2003) notes that researchers in information behaviour increasingly recognise that, in information seeking, the overall goal significantly influences the process. Thus, it is advantageous to study one group at a time and use the resulting understanding of that group's information-seeking behaviour as the foundation for developing information systems to better serve them.

Interviews with three biology researchers were conducted with the durations averaging approximately 50 minutes. The data produced from these interviews were analysed using grounded theory and involved three stages: finding conceptual categories in the data; finding relationships between these categories; and, conceptualizing and accounting for these relationships through finding core categories (Robson, 2011). Seven main codes were decided upon after three rounds of coding.

4.3 Information Flow Maps

Information flow analysis and the creation of information flow maps have been used in universities and industries to illustrate how information flows within organisations (Ahlstrom, 2005, Davis *et al.*, 2001, Humphreys, 2006, Loughman *et al.*, 2000, Pereira and Soares, 2007, Plasters *et al.*, 2003; RIN and British Library, 2009, Stapel *et al.*, 2008). Data are collected in the form of interviews from researchers or workers in the study organisation and are used to create information flow maps, which are then presented to the study participants for verification (Davis *et al.*, 2001, RIN and British Library, 2009).

Draft information flow maps were introduced during the interviews with the biology researchers. They were used as a visual aid for interviewees when faced with questions about how they conduct their research, and more specifically, about how information is created and used in the course of their research. A different flow map had been created for each researcher's area of interest based on the authors' expertise, as well as the information flow maps outlined in the RIN and British Library report (RIN and British Library, 2009). These draft information flow charts were then modified based on the interviewees' comments.

4.4 Heuristic Evaluation and Navigation Stress Test

A heuristic evaluation involves a small set of evaluators examining the interface and judging its compliance with recognised usability principles *i.e.* the "heuristics" (Nielsen, 1995b, Nielsen and Molich, 1990). Long *et al.* (2005) showed that a heuristic evaluation was a useful way of uncovering usability problems that may not have been identified by other means. The heuristic evaluation was undertaken by one of the authors using an adapted form of Nielsen's Ten Usability Heuristics (Nielsen, 1995a).

A stress test, based on Instone's Web Site Navigation Stress Test (2005), was conducted on a random OJAX++ project page with notes taken on possible improvements for the navigation system. This test was used to address the following three basic user concerns: 1. Where am I?, 2. What's here?, and 3. Where can I go? (Instone, 2005). These concerns are important for users of OJAX++ and for VREs in general as users are not necessarily familiar with VREs (Carusi and Jirotka, 2006, Rock, 2008).

4.5 Usability Testing

Usability testing methodology was based on that used by the two previous usability studies of OJAX++ (Coffey, 2010, Jeffery, 2011). Due to the Agile development methods being employed, a level of standardisation between the three usability tests was advantageous so that results could be compared.

4.6 Usability Test Design

The test itself followed the design of Krug (2000). It included a:

1. Spoken introduction by facilitator.
2. Pre-test questionnaire.
3. Usability Test.
4. Post-test questionnaire.

Seven biology researchers participated in the usability testing with each test lasting less than one hour. The tests were conducted using an HP laptop and were recorded using Screencast-o-Matic software (http://www.screencast-o-matic.com/) to capture the visual, audio and screen movements of the participants. The facilitator introduced the user to the test. The introduction followed guidelines by Krug (2000): it explained to the participants that it was the software being tested, not them, and as such there could be no "wrong" answers. Each participant then read and signed a disclaimer form to allow the test to be recorded.

The pre-test questionnaire was then administered to participants. This questionnaire was based on one created by Coffey (2010) for the previous usability test. The aim of the questionnaire was to provide information on the participants' use of Web technologies, applications and services to communicate and collaborate during their research, as well as their knowledge of OpenID.

The next phase was the usability test. Each participant was asked to complete a set list of tasks and to explain their reasoning and thoughts behind their actions during the process. The tasks were designed to evaluate the usability of the most important features of OJAX++ (Table I).

The final phase of the usability test was the post-test questionnaire. Each participant answered a mixture of closed and open-ended questions in relation to OJAX++ and the tasks they had performed. The purpose of these questions was to obtain feedback on the various functions and features of OJAX++ and its ease of use (Krug, 2000).

The three main aspects of usability were assessed by this methodology. Effectiveness was measured by the percentage of the testers that completed each task without any prompting by the facilitator. Efficiency was assessed by the average time taken to complete each task. The post-test questionnaire examined satisfaction by measuring the testers' attitudes to the ease of use, presentation and intuitiveness of OJAX++ using a Likert scale.

4.7 Participants

The testing and interviews took place in June 2011 with the participants drawn from the School of Biology and Environmental Science in University College Dublin, the largest university in Ireland with approximately 25,000 students and 7,000 postgraduate students. In 2011, there were 82 postgraduate research students, 24 postdoctoral researchers and 27 academics in the School. This was to provide a contrast to the results obtained from the two previous usability studies which were conducted with information studies researchers from UCD.

A priori criteria sampling was used to establish a sample framework before sampling began with four different categories of researchers selected – professor, lecturer, postdoctoral researcher and PhD candidate (Pickard, 2007). Convenience and snowball sampling (Pickard, 2007) were used to select participants from UCD School of Biology and Environmental Science with the aim of obtaining researchers in each of the different categories present. Convenience sampling is a common method in usability testing (Jeng, 2005). Seven researchers were selected to participate in the usability testing: one professor, one lecturer, two postdoctoral researchers and three PhD candidates, and consents were obtained from each. Interviews were conducted with three of the usability test participants, one from each of the three categories of researchers.

The usability testing in this study was one cycle in an Agile development (Coffey, 2010, Jeffery, 2011) and was not a summative evaluation which justified using seven testers. In addition, both Nielsen (2000 and 2012) and Virzi (1992) recommend using a small number of subjects in usability tests with five testers uncovering 80% or more of usability problems.

4.8 Data Analysis

The responses from the pre- and post-test questionnaires were tabulated using Microsoft Excel. The screencasts of the usability tests were examined in detail and the data produced were then analysed for commonalities and trends.

The interviews were recorded with a digital MP3 recorder and transcribed using Microsoft Word and Windows Media Player or SoundScriber software. The resulting transcripts were coded using Word's commenting function. A provisional coding template was established and, after three stages of coding, the resulting quotations were analysed to determine key information in the context of this study.

5. Results

5.1 Heuristic Evaluation and Navigation Stress Test

The results of the heuristic evaluation revealed positive findings in terms of the site's aesthetics and clear labelling. The interface was seen to be clean and not overloaded with information. The labels were clear and written in language appropriate for researchers from all disciplines. The logged-in status, with the username shown at the top of the screen above the log out option, was always visible, and the name of the active project was clearly shown.

The negative findings of the heuristic evaluation concerned user control and freedom, and the lack of help and documentation. Certain actions, such as "delete project" or "remove user" were not possible for the regular user. Another important usability concern was the lack of information about how the site works, which is particularly important for new users. Apart from the "Learn More" option for OpenID on the login page, there was no help option or guide.

The navigation stress test similarly highlighted the clear labelling and easy navigation of the site in general. However, the fact that links in the activity stream did not open in a new window was deemed a problem as it meant that the user was constantly navigating away from the active project page. Other navigation issues highlighted were the absence of the VRE name "OJAX++" on all pages, the "Projects" and "Dashboard" links being directed to the same page, and the main heading and logo link not directing the user to a home page.

5.2 Usability Testing - Pre-Test Questionnaire

Test participants expressed a familiarity with, and use of, online research tools during their daily research activities (Figure 2). Testers used between two and eight online research tools with an average of 5.1 tools per tester (Figure 3). This compared to between three and twelve online research tools (average 6.6) used by the five information and library studies researchers surveyed by Coffey (2010). Only eight online research tools out of the thirty listed in the pre-test questionnaire were used by the biology researchers but another tool, the Web of Science, was used by four of the participants and was included in the results (Figure 4). In contrast, the information and library studies researchers tested by Coffey (2010) used thirteen different online research tools. None of the seven test participants had heard of, or used, OpenID before.

5.3 Summary of Usability Test Issues

There were several issues with six of the seven usability test tasks and these are summarised in Table I.

Table I. Usability test tasks and issues

Task No.	Task Description	Summary of Usability Test Issues
1	Use OpenID to log in to OJAX++.	This task proved to be one of the most time-consuming as none of the participants were familiar with OpenID. Much of the time was taken up in creating a compatible OpenID account for those without them. Testers 3, 4 and 5 had interoperable accounts and completed the task in the quickest times, but only Testers 4 and 5 did so without further prompting.
2	Create a new personal profile, and add the third-party application, Delicious. (N.B. You will need to set up a Delicious account if you haven't got one already.)	Delicious accounts had to be set up for each participant. This contributed to this task taking the most time to complete. Only Tester 2 required a prompt when adding a username which suggested that the third-party application interface was largely intuitive. There was a delay in completing the task for four testers due to the positioning of the "Save Profile" button.
3	Create a new project and add two tags to it; "ecology" and "research".	No problems were encountered.
4	Use Delicious to bookmark a webpage on the subject of "ecology" (you will need to open a separate Google tab to fulfil this part of the task), and associate it with the tags "ecology", "research" and others if you wish. Then switch back to OJAX++ and check your new project for any new activities in the activity stream.	All testers had to be prompted to refresh the OJAX++ screen after the bookmarking had occurred. Four testers did not see the "New Activity" bar at first, whereas for the remaining three it stood out immediately.
5	Switch to the project "VREcapstone" and filter the activity stream (i.e. the list of activities or list of items) to find content from the user "FintanBracken" which are bookmarks and have the tag "research".	All testers successfully navigated through the project selection and used the tag filter. Four testers were prompted to use the bookmark filter. Despite prompting, Tester 6 was unable to distinguish bookmarks from other items in the activity stream.

Task No.	Task Description	Summary of Usability Test Issues
6	Search the activity stream in the project "VREcapstone", for the most recent comment on it.	Only Tester 2 successfully completed this task without prompting or further explanation. The central difficulty in this task was differentiating between the "Newest Activity" filter and the "Recently Active" filter, comprehension time varied between the participants. Tester 7 did not understand the filtering process in relation to the comment feature.
7	Add a comment to the activity stream in the project "VREcapstone".	All testers successfully completed the task. Tester 4 asked how to close the comment box as it was not obvious how to do so.

In terms of efficiency, Task 7 on average took the least time to complete at 32 seconds while Task 2 required the most time with 5 minutes 17 seconds taken on average by the testers (Table II). The average time take to complete a task was 2 minutes 44 seconds (Table II). The testers were most effective at completing Task 3 and Task 7 with 100% and 86% respectively of participants not requiring any assistance from the facilitator to complete the tasks (Table II). All testers required a prompt to complete Task 5 and on average only 47% of testers completed a task unaided (Table II). Each tester only effectively completed three or four out of the seven tasks without a prompt (Table II).

Table II. Percentage of testers completing each usability task unaided and time taken to complete each task

Participant	Time taken to complete task (in minutes and seconds)							Average (All tasks)	% of tasks completed without prompt
	Task 1	Task 2	Task 3	Task 4	Task 5	Task 6	Task 7		
Tester 1	6:43*	6:33*	1:05	4:50*	2:16	3:21*	0:15	3:34	43%
Tester 2	4:44*	6:38*	0:43	5:09*	0:55	0:58	0:37	2:49	57%
Tester 3	1:53*	2:40	1:05	5:10*	0:35*	1:03*	0:35	1:51	43%
Tester 4	4:30	3:49	1:20	3:00*	0:47*	2:26*	1:00*	2:24	43%
Tester 5	1:33	4:02	0:37	3:27*	2:00*	1:27*	0:30	1:56	57%
Tester 6	7:53*	7:25	0:40	4:15*	1:32*	1:40*	0:30	3:25	43%
Tester 7	7:50*	5:53	1:15	2:17*	1:12*	3:38*	0:20	3:12	43%
Average time taken (Efficiency)	5:01	5:17	0:58	4:01	1:20	2:05	0:32	2:44	
% of testers completing task without prompt (Effectiveness)	29%	71%	100%	0%	29%	14%	86%	47%	

* indicates participants who required a prompt by the facilitator to successfully complete the task

5.4 Usability Testing - Post-Test Questionnaire

All of the testers agreed that OJAX++ was easy to use and professionally presented. Five testers agreed that it was intuitive; the remaining two testers neither agreed nor disagreed (Figure 5).

The testers were unsure of OpenID with some commenting that they were initially confused, and one did not understand the concept. Tester 4 commented that they would like to see a register button. All testers found it an easy process to add third-party applications. Six of the testers said they found using tags to bring third-party content into OJAX++ useful. However, Tester 3 asked if there was a need to use tags rather than just emailing the link. They appreciated that it allowed a controlled discussion regarding the link but were concerned about who could see comments. All of the testers found it an easy process to search for items in the activity stream.

5.5 Assessment of User Requirements - Semi-Structured Interviews

The interview protocol focused on six main areas: background information of the interviewees; their information practices; the tools they used in their research; their opinions on collaboration and sharing; VREs; and, future uses of technology in research. Three rounds of coding indicated that there were seven main codes emerging from the data which were:

1. Perceived utility of social network.
2. Attitudes towards collaboration or sharing with fellow researchers.
3. Data storage, trust and intellectual copyright.
4. Impact of web tools on research.
5. State of research in the life sciences.
6. The research process.
7. Advantages of VREs.

The three codes that occurred most frequently during the coding process are discussed in Table III.

Table III. Primary interview codes and discussion

Code Label	Discussion
Perceived utility of social network	This code was used to describe the attitudes of researchers towards the use of social networks for research purposes. While two of the seven testers indicated in the pre-test questionnaires that they had used Facebook before for their research, all of the interviewees concluded that they would not be inclined to use it to communicate with one another about their research. Tester 6 stressed that you can never be certain of an "immediate reaction" if you post something on Facebook. All tend to use email or phone calls as their preferred method of communication.
Attitudes towards collaboration or sharing with fellow researchers	This was used whenever interviewees commented on collaboration and sharing of information. Tester 1 highlighted the difficulty of getting all of the collaborators to "sing [the] same words" when generating research questions. All of the interviewees emphasised the importance of frequent discussion and interaction to ensure the success of the collaboration either through meetings, conferences or email.
Data storage, trust and intellectual copyright	One of the main themes which arose from the coding of interview data was the concern about data storage, copyright, and, in particular, the issue of trust amongst researchers. All of the testers frequently stressed the importance of protecting their work. They all showed a certain level of reluctance about sharing their datasets even when required to do so by the bodies which publicly funded the research. Tester 1 mentioned that there is "always an issue about who has access to [the data]". Tester 3 spoke about how a member of a funding body had to be invited to a meeting with the researchers because "none of [them]… would give up information" and that he had to spend an hour convincing them that it would be "safe" to give him the datasets and that "no one else would have access to it".

5.6 Assessment of User Requirements - Information Flow Maps

Information flow maps were produced for a PhD student researching freshwater biology, a postdoctoral researcher of population genetics and a senior lecturer of terrestrial ecology (Figures 6 to 8).

Information flows into the main stages of the research process included article searches on Web of Science, and discussion with colleagues. The main types of information flows from the research process were journal articles, funding body reports, and conference presentations. The information flow maps helped identify parts in the research process where a VRE, such as OJAX++, could potentially assist the researchers, such as in searches for journal articles, communicating with collaborators, and co-authoring papers.

The research process is very similar for all stages of research but, as the researcher moves up the hierarchy, they become less reliant on information from their supervisors (Figure 6). Once they become a senior lecturer they are more involved in hypothesis development for large-scale projects and in discussions with collaborators and potential collaborators (Figure 8).

6. Discussion

This section discusses the results in relation to the four research questions of the study.

6.1 What are the information uses, practices and user requirements of biology researchers?

The results of the pre-test questionnaires showed that biology researchers used online tools extensively in their research but used fewer than researchers in library and information studies (Coffey, 2010). The researchers do not use social networking tools in their scientific research and the most popular web research tools are Google Scholar, Skype and Web of Science (Figure 4).

The user requirement interviews revealed that email and phone conversations are the preferred methods of collaborating with colleagues. The information flow maps proved a useful aid in prompting the researchers to address all of their information uses (Figures 6 to 8). The researchers did not use librarians to find information and instead consulted colleagues. In addition, the library's search interface was by-passed by two of the three interviewees in favour of Web of Science, or Google Scholar, when searching for journal articles.

These results support the findings of the RIN and British Library study which found that life science researchers use informal and trusted sources of advice from colleagues, rather than institutional service teams, to help identify information sources and resources, and that the use of social networking tools for scientific research purposes is far more limited than might be expected (RIN and British Library, 2009).

None of the interviewees had used a VRE before, but it became apparent that there were a number of requirements that a VRE would need to fulfil in order to be useful to them and these are detailed in Table IV.

Table IV. Requirements of a VRE for biology researchers

Requirement	Description
Discussion	The provision of a forum for hypothesis development, data analysis and group formation.
Access to collaborator and colleagues	The ability to find people easily and not rely on long distribution lists.
Repository	The availability to all members of the team to have current versions of document.
Article sharing	The facilitation of journal article sharing and collaboration on literature.
Critical mass of users	The participation of a considerable number of users would be required, before researchers would invest in VRE.
Customisation	The capacity to customise the VRE to suit the individual researcher.
Originality	The ability to offer something new and not just rehashing existing tools.
Filtering and searching	The implementation of filtering and/or searching mechanism to find precise information.

The researchers had a number of concerns in relation to VREs including:

- Data deluge: the fear that too much information available via the VRE could become a distraction.
- Intellectual Property rights.
- Security of the data stored in the "cloud".

6.2 How could OJAX++ be used with biology research groups?

From the user requirement interviews and the post-test questionnaires, it appears that OJAX++ could be used by research groups to bring information and documents from a variety of sources together in one place. OJAX++ would be useful for biology research groups:

- To organise projects.
- To communicate with research group members.
- To share links to websites with other members of a research group and comment on them.
- To collaborate on reports/papers with several colleagues.
- To sort and organise large amounts of information and also their thoughts on various articles, links, etc.

However, the successful use of OJAX++ within a research group requires "buy-in" from all team members, particularly the supervisor/project manager. Researchers need assurance that everyone is required to and will use OJAX++, before they can be confident that it will be beneficial to their research projects.

6.3 How does OJAX++ fit in with current research practices among biology researchers in UCD and how might it change these practices?

In its present format, OJAX++ does not fit in with current research practices among biology researchers in UCD. Biology researchers do not use many Web 2.0 tools for research and particularly not tools that facilitate tagging. In order to use OJAX++ they would be required to use Web 2.0 tagging tools. The major change for biology research practices, if OJAX++ was introduced, would be the increased use of these Web 2.0 tools. There might also be improved collaboration between colleagues and better organisation of the information needed for their projects.

6.4 How usable would OJAX++ be for biology researchers?

The results of the heuristic evaluation and the navigation stress test showed that, in general, OJAX++ had clear labelling and a clean user interface and Carusi and Riemer(2010) state that “a simple interface and user-friendly tools are high on the list of researchers’ desirables” (p. 39). The usability in relation to the creation of new user profiles and new projects was good and the comments feature was also easy to use. Negative aspects included lack of adequate user control and freedom, and that links in the activity stream did not open in a new window. These usability issues were not uncovered in the usability tests in this study or in the previous tests by Coffey (2010) and Jeffery (2011).

Overall from the usability testing, the biology researchers found that OJAX++ was easy to use, intuitive and professionally presented. In general, they found it relatively easy to add third-party applications, to use the tagging feature and to search the activity stream using the filters.

The main roadblock for the uptake of OJAX++ by biology researchers is user expectations. Despite the testers agreeing that it was easy to use and professionally presented, a number of testers did not immediately see the potential benefits of OJAX++ or how it could help them in their research. Krug (2000) discusses how usability testing can uncover deeper problems with a website, such as users not understanding the purpose of the site, or realising, after testing, that users will not necessarily want to use the site because they are satisfied with their current practices. Post-test questionnaire comments included:

- “Initially I didn’t fully understand what the full application of this software is.”

- “The value of the software is full user participation which I'm not sure would happen.”
- “Don't really understand the concept of bookmarks and how it could be useful.”

It is possible that the concept of OJAX++ as a research tool might have been better conveyed to the biology researchers had the third party applications and usability key tasks been tailored more to their research activities and needs. Carusi and Reimer (2010) assert that a lack of technical support for the back-end operations of the VRE and direct support for researchers using it are significant barriers to the use of VREs. Recent literature suggests that librarians may be ideally situated to assist with support in VREs due to their knowledge of information management and the interests of specific research communities (Wusteman, 2008, Wusteman, 2009b).

The usability testing uncovered three other significant roadblocks for biology researchers to use OJAX++. One of these issues involved the process of logging onto the system using OpenID, which caused difficulties and was time-consuming for many of the testers. A major roadblock to the biology researchers using OJAX++was the lack of use they made of web tools that facilitate tagging. Concerns around the security of data and privacy settings in OJAX++ were raised by the biology researchers which is another important issue that needs to be overcome before uptake of OJAX++ occurs in significant numbers.

7. Conclusions and Further Research

The aim of this paper was to examine the current research practices and requirements of biology researchers in UCD and to evaluate the overall suitability of the OJAX++ Virtual Research Environment for these researchers.

The findings from this study indicate that biology researchers do not use many Web 2.0 tools for research. Furthermore, they do not use social bookmarking sites such as Delicious or social networking sites such as Twitter when conducting their research. The study shows that OJAX++, in its current phase of development, is not feasible as a VRE for biology researchers. While biology researchers found OJAX++ to be generally easy to use as well as professionally presented, it does not fit in with their current practices. Currently, the only way for content to be added to OJAX++ is by assigning tags to bookmarks, citations, tweets, workflows or other content in Web 2.0 applications that can then be imported into an OJAX++ project that uses the same tags. Therefore biology researchers would have to start using these Web 2.0 tagging tools in order to be able to use OJAX++. Future iterations of OJAX++ could address this roadblock by including a system of bookmarking and sharing links directly within the VRE itself. Similarly messages with tags could also be posted directly in OJAX++. These new systems would allow users that don't already use tagging web tools to fully participate in OJAX++ whilst simultaneously enabling tags from other third party applications to be imported.

The study also indicated that researchers had a number of concerns about the security and privacy of the information kept on OJAX++. These tie in with a more general apprehension about sharing datasets and intellectual property/copyright issues which arose during the interviews. The degree of control a user has over their data is a factor that can influence the uptake of services such as VREs (RIN, 2010; Smith *et al.*, 2010). Future development of OJAX++ should address these concerns and include documentation on the security of the VRE, the legal position regarding intellectual property of research activity and data aggregated on OJAX++, and the use of cloud data storage particularly the potential loss of data if a web tool discontinues service. Privacy controls at item and project level should also be implemented in OJAX++ so that potential users know that their research activity is private and their data secure.

The usability issue with OpenID should be dealt with in future versions of OJAX++ by providing a traditional signup method in addition to very explicit instructions to users on how to log in using OpenID, and giving prominence to the icons of the most popular OpenID providers such as Google and Yahoo.

The user requirement analysis revealed that biology researchers recognised the potential of VREs for organising projects, communicating and collaborating. However, some of the biology researchers stated that they did not initially understand the benefits of OJAX++ and this could be improved by including a user guide and an introductory video on the homepage to showcase key features. Another barrier to successful uptake of a VRE is that users are reluctant to invest time and effort learning to use the system unless they know that all of their research team members or peers will fully engage with the VRE. Therefore, marketing of OJAX++ and encouraging specific research teams to fully use the VRE will be crucial to its long-term sustainability.

The potential solutions to the major usability issues of OJAX++ could also be useful for other developers desgning web tools for current and new biologists. In addition, an important outcome of this research is the provision of a checklist for VRE developers of the requirements of these systems for biology researchers (Table IV). A further implication of this checklist is that it may be useful for developing other web tools for scientists such as reference management software and scientific bookmarking services. Designers of interfaces for biology researchers, such as academic search engines or collaboration tools, could also use the information flow maps (Figures 6 to 8) to identify stages in the research process of biologists where a web application could assist the researchers.

This study contains some limitations as only a small sample of researchers from one discipline and one university were studied. Future research should involve investigating the research practices and requirements of researchers in other disciplines and universities. Usability testing of a larger number of participants with OJAX++ or other VREs such as ourSpaces (Edwards *et al.*, 2012a, Edwards *et al.*, 2012b) should be conducted to establish if the results of this study are applicable to other disciplines, universities or even other VREs. As part of a programme of further VRE usability research, Barry *et al.* (2012) examined the usability of myExperiment (Goble *et al.*, 2010) in 2012. Finally, a longer term evaluation with a small group of researchers working together on one or many projects for a minimum of one week with OJAX++ should be conducted, as this would allow the researchers, the potential end users, to gain a better understanding of the concept of OJAX++ and how it could benefit them in their research.

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9. Figures

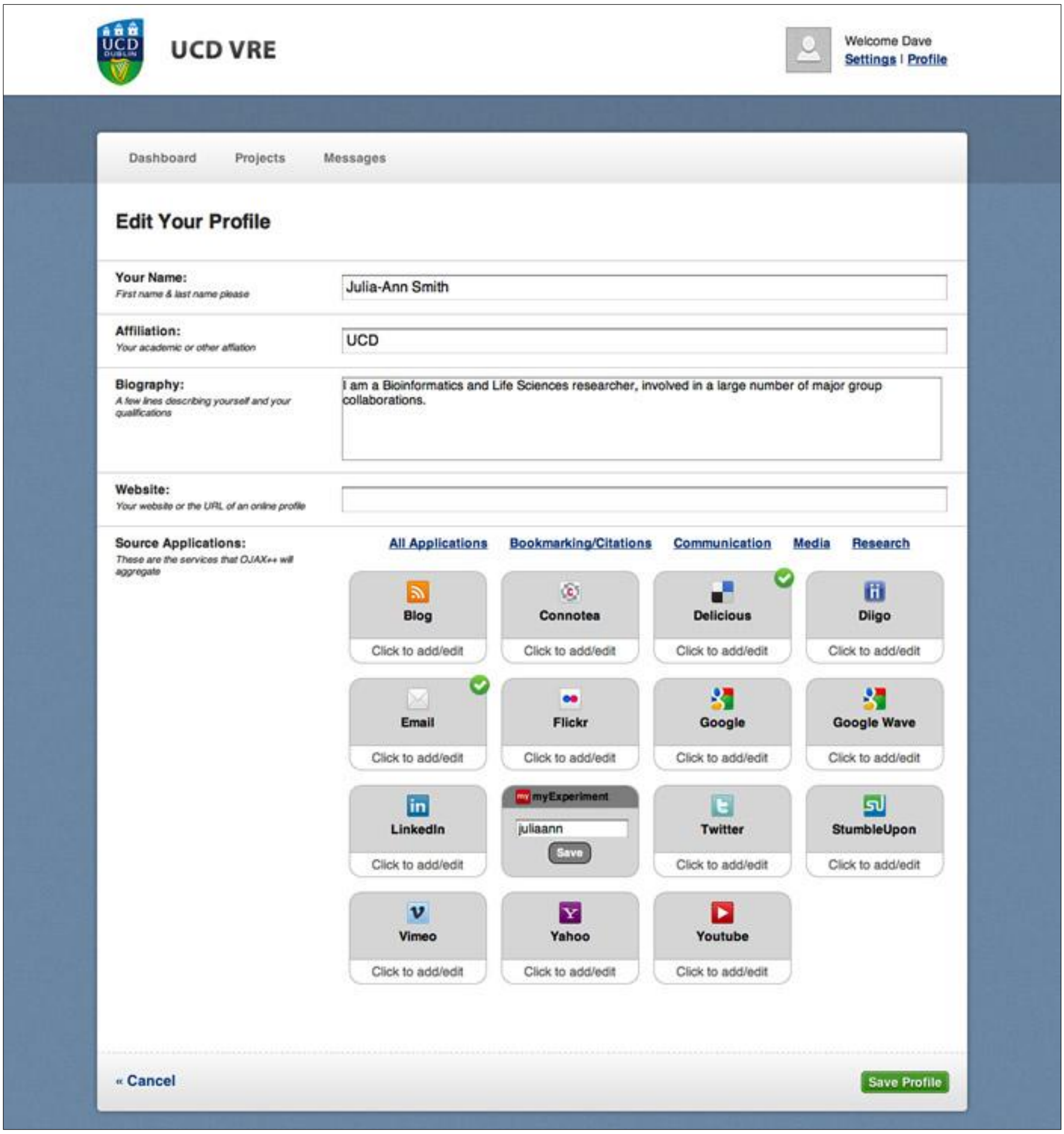

Figure 1. Screenshot of OJAX++ profile page (Source: Jeffery & Wusteman, 2012)

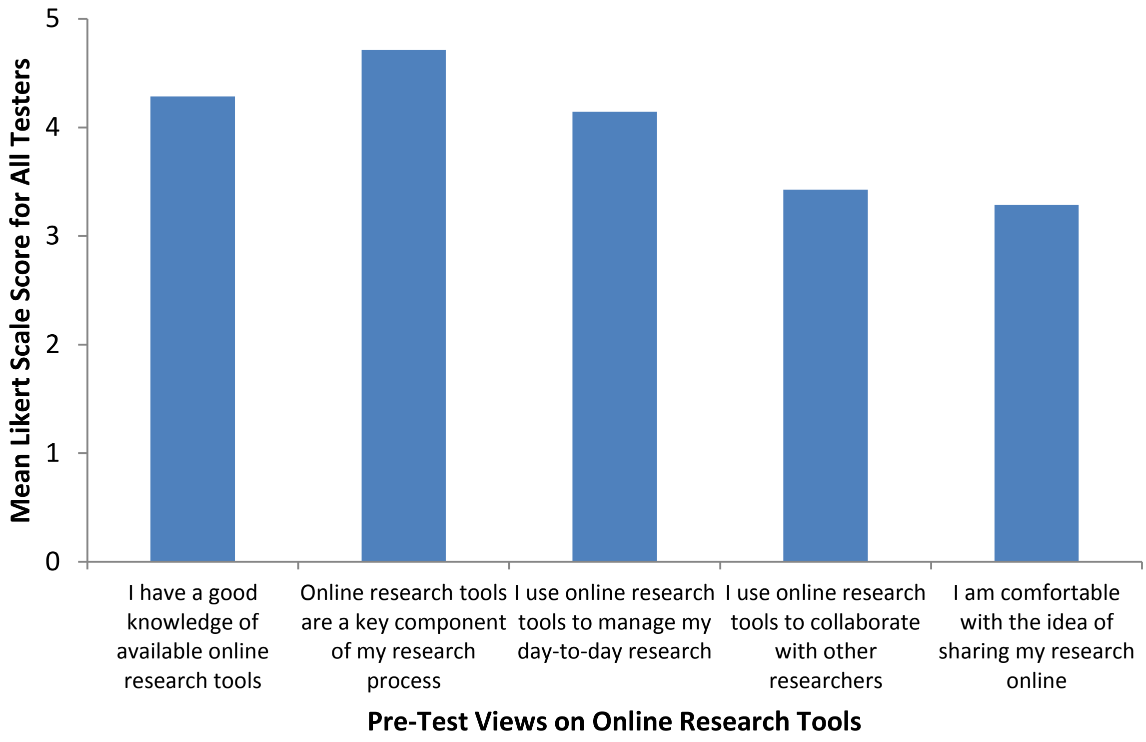

Figure 2. Mean Likert scale score of the opinions of biology researchers on their use of online research tools. (Likert scale: 1 = Definitely Not / Never; 2; 3 = Neutral / Sometimes; 4; 5 = Definitely / Frequently)

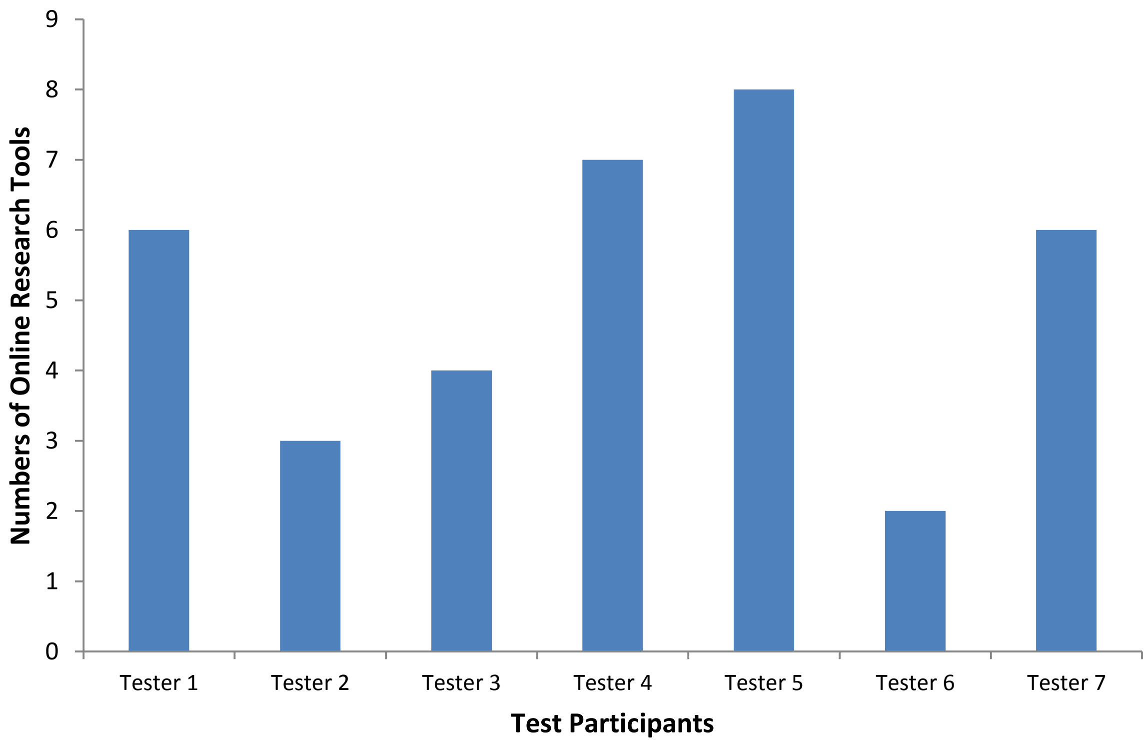

Figure 3. Number of online research tools used by biology researchers during their research activities

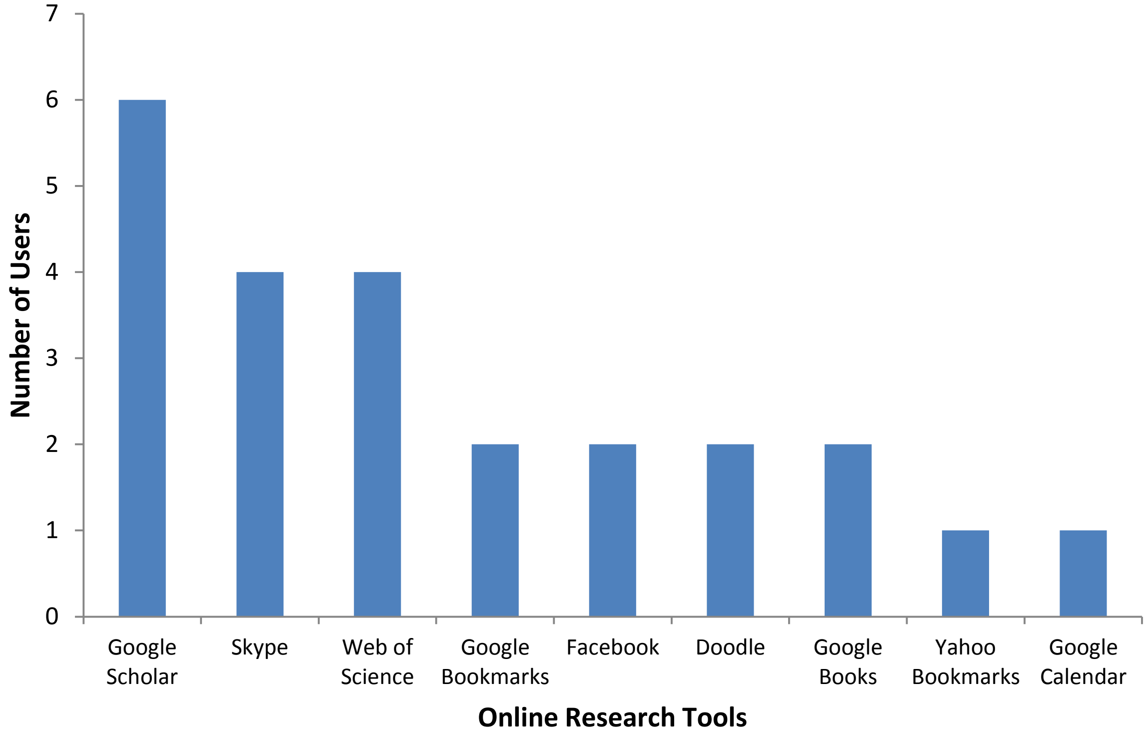

Figure 4. Numbers of online research tools used by biology researchers

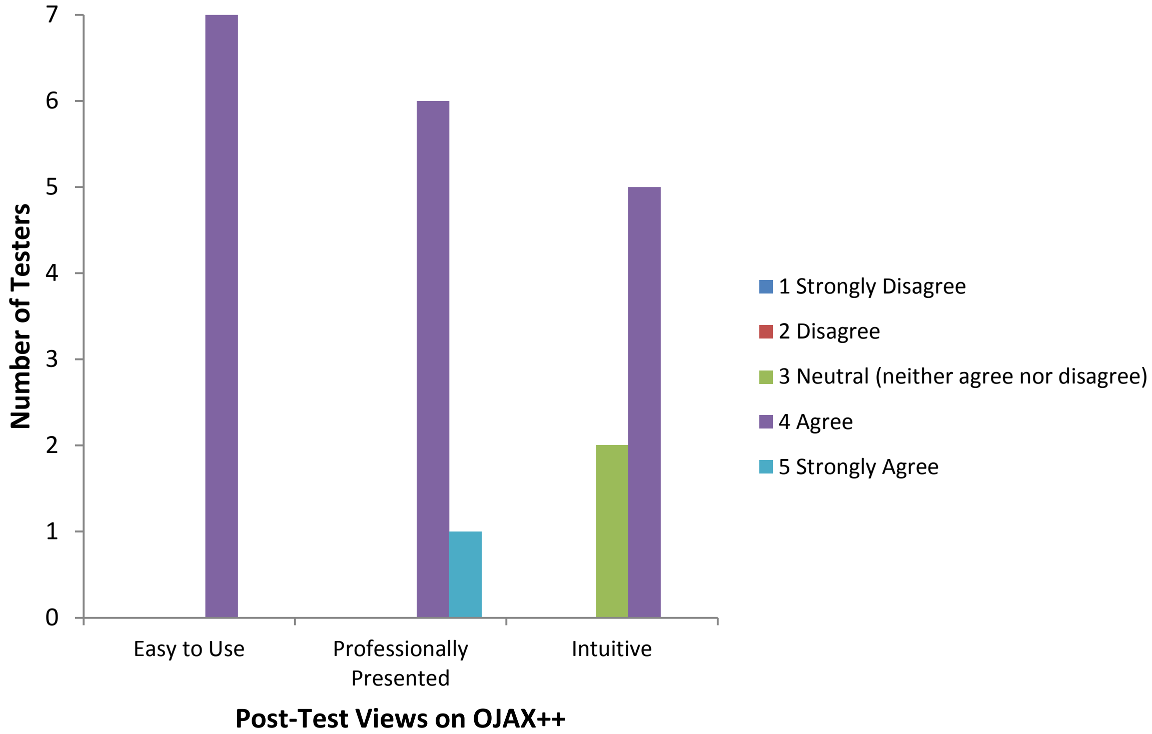

Figure 5. Opinions of biology researchers on the ease of use, presentation and intuitiveness of OJAX++ following completion of the usability test

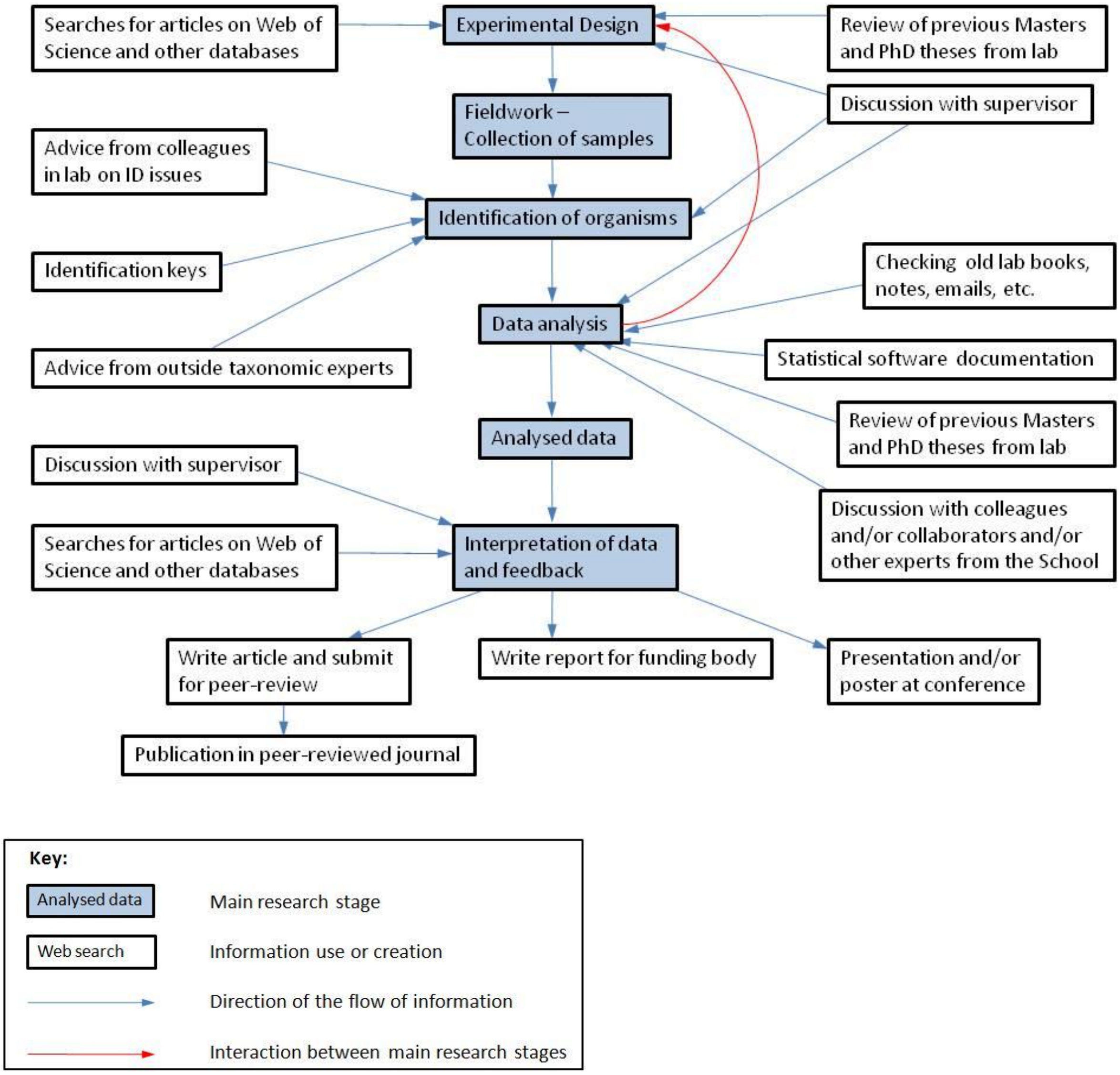

Figure 6. Information flow map for a PhD student of freshwater biology

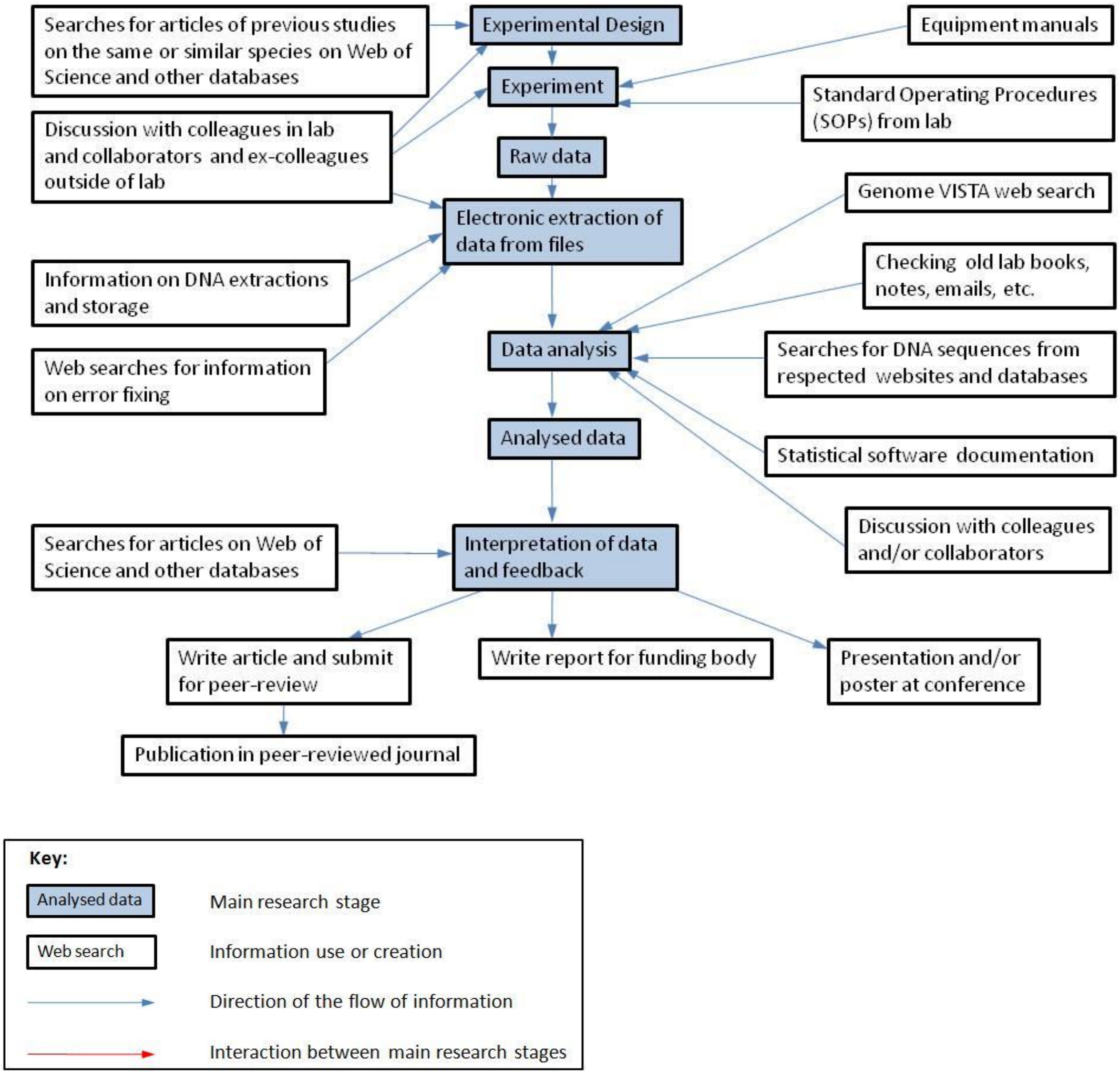

Figure 7. Information flow map for a postdoctoral researcher of population genetics

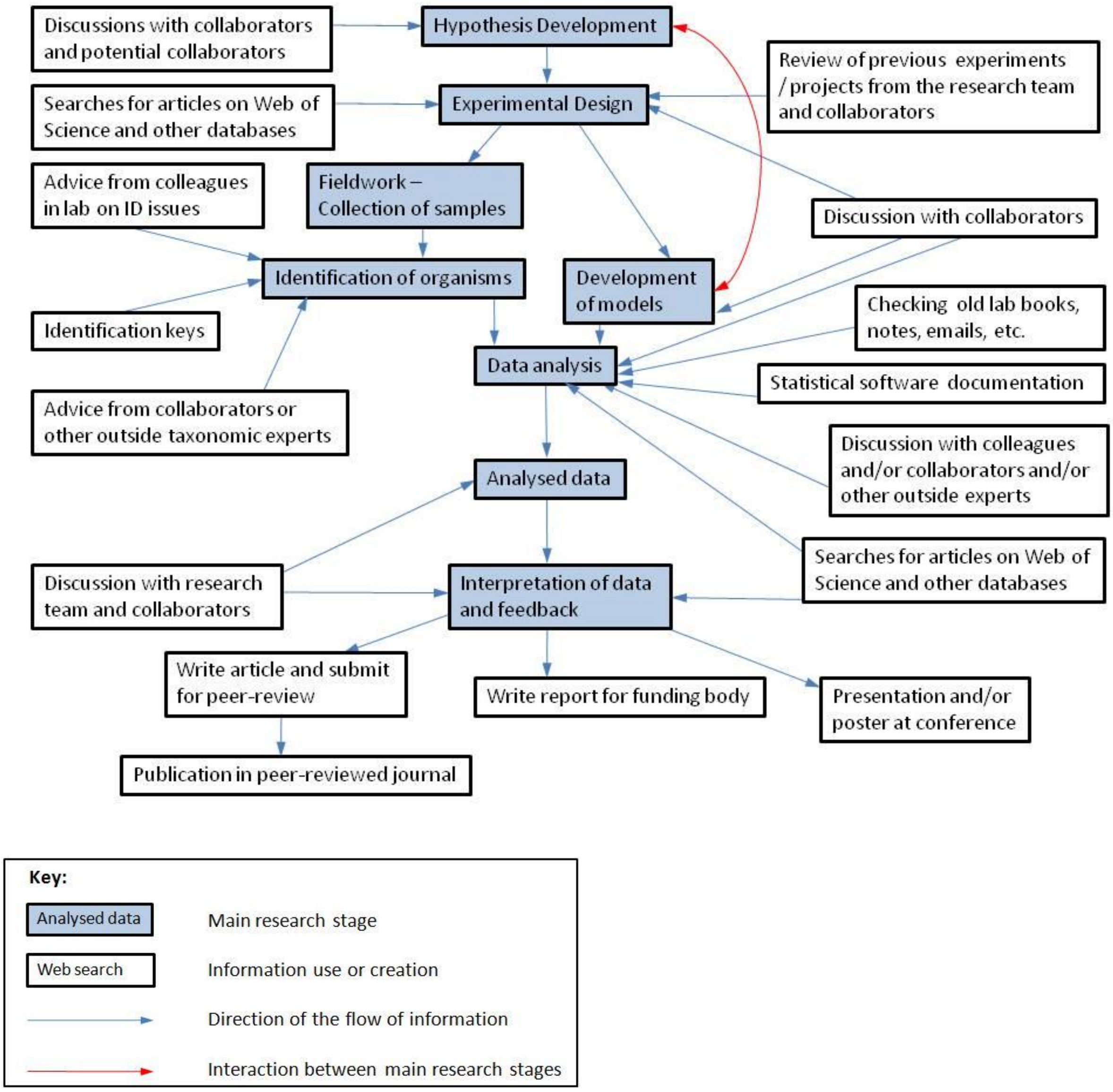

Figure 8. Information flow map for a senior lecturer in terrestrial ecology