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Communication and information-seeking behavior of PhD students in physicists and astronomy

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Abstract

As a part of a wider doctoral research, this paper deals with the communication and information-seeking behavior of research (PhD) students in physics and astronomy. Based on a qualitative case study of PhD students in the Department of Physics and Astronomy at University College London, this study seeks to derive behavioral patterns in information-seeking activities of PhD students. The study aims to investigate the intradisciplinary differences in information-seeking activities of physicists and astronomers. The findings show the high reliance of PhD students in physics and astronomy on electronic journals and their low use of libraries. The findings reveal differences in the information-seeking patterns of students who conduct theoretical research and those of whom are involved in experimental research. The research highlights the need for the study of small subject communities within academic disciplines instead of studying users in a broad subject area such as physics as one single domain.

Introduction

Physics and astronomy, two closely associated fields, are among those that embraced the use of digital technology in their information systems and services. Physicists are renowned for having one of the, apparently, most efficient information systems (Nicholas et al, 2005). They are known as innovators in methods of scholarly communication. In fact these two fields were among the leaders in the experimental publishing models and scholarly

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communications such as pre-print and e-print archives and open access. For example, the Institute of Physics Publication, as one of the pioneers in electronic scientific publishing, started making its journal available online as early as September 1994 by launching *Classical and Quantum Gravity* on three types of servers including List, Gopher and World Wide Web (Singleton, 1997) and it was the first major publisher that made all its thirty three journals available online in January 1996 (Dixon, 1999). For years physicists and astronomers have communicated current research with their colleagues through a process known as pre-print. This was the distribution of articles in advance of the article being submitted for peer review. They have used preprints for over thirty years (Brown, 2001). The World Wide Web was created at CERN physics laboratory in Geneva as a tool to facilitate this scholarly communication. In 1991, the pre-print process evolved into an e-print archive, at Los Alamos national laboratory, and rapidly grew to tens of thousands transactions per day (Valauskas, 1997). Kelly (1997) described this evolution as a paradigm shift of push to pull i.e. the process changed from one where the article was pushed to the reader to one where the reader pulled the article. This was because, for the first time, physicists and astronomers had a place to store their articles so their peers could retrieve them. This move towards electronic communication systems was mostly initiated by physicists themselves (see for instance Langer, 2001; and Boyce and Dalterio, 1996). These attributes make physicists and astronomers a good example of virtual scholars who work in an information environment dominated by electronic information resources.

Normally, the focus of studies that investigate information-seeking activities of subject communities is faculty. The information-seeking behavior of undergraduate students is expected to differ from faculty due to a number of factors. Undergraduate students' information-seeking skills are not as well developed as faculty's. They also have different information needs and seek information in a different context, they normally seek information to address the imposed questions by lecturers rather than self-selected questions. Graduate students, especially PhD students who are mainly involved in research activities, are more integrated in their departmental information environment and their communication and information-seeking behavior is expected to be more similar to faculty's. There have been some studies on both taught graduate (masters) and undergraduate students mainly as users of library services (see Abdoulaye, 2002; Barrett, 2005; Callinan, 2005; Fidzani, 1998; Jankowska, Hertel & Young, 2006; Majid & Tan, 2002; Washington-Hoagland & Clougherty, 2002; Whitmire, 2002;). The studies revealed differences (and sometimes similarities) between students' and faculties' information behaviour and also between undergraduates' and graduates' information behaviour. For example a study on graduate students in humanities showed that although there were substantial areas of overlap, the model of graduate student information-seeking behavior that emerges from the study was not a clear reflection of either faculty or undergraduate models (Barrett, 2005). Study of research (PhD) students' information seeking-behavior could shed some light on the way future scientists develop their information seeking skills. Apart from Brown's study (1999a) on the information literacy of graduate students in physical sciences (chemistry, physics and mathematics), no study has particularly investigated communication and information seeking activities of PhD students in physics and astronomy.

Aim and objectives

This study is a part of a wider doctoral dissertation, exploring the scholarly communication and information-seeking behavior of physicists and astronomers. The full project entails use of different data collection techniques including semi-structured interview, questionnaire survey, critical-incident information, and electronic journals' usage data analysis. The total sample of the study includes PhD students and academic staff (researchers, lecturers and professors) in the Department of Physics and Astronomy at University College London.

This article is based on the result of the first phase of the study, which is limited to the qualitative study of PhD students. The study takes a micro-approach, which would allow for more in-depth data collection that is more suitable for exploring complex behavioral activities (Ellis and Haugan, 1997). The aim of the study presented here is to help better understand the general research process of the participants and the patterns of their information-seeking activities. The study seeks to find out the position of different information resources in their information-seeking activities, and to recognize the role that digital information services and sources play in their information-seeking activities. Moreover, the study tries to find out any intradisciplinary differences in the communication and information-seeking activities of PhD students with regard to the kinds of research they conduct.

Background

So far there have been a few studies that have focused mainly on physicists and astronomers. A few of those that carried systematic research on information behavior of these scientists are out-of-date. It is not clear whether their findings would match the information behavior of today's scholars who work in a digital information environment. These studies include the one by Ellis, Cox and Hall, 1993; Barry's study of information-seeking and effect of IT on information activities (Barry, 1995); and the Institute of Physics Publication's (IoPP) survey in the first half of the 1990s (Singleton, 1997). Ellis, Cox and Hall (1993) tried to investigate physicists' information behavior systematically. They adopted a qualitative approach in their research and tested a model of information-seeking patterns that had been developed by studying social scientists. But the information environment has changed enormously since their study was carried out (before the considerable growth of the Internet and different kinds of digital information resources). Barry (1995) also used physicists as the case for studying the impact of information technologies available at the time (such as CD-ROM and OPAC) on information activities of academic scientists. The unpublished survey of IoPP mainly focused on some particular scholarly communication activities of physicists such as their role as author, editor or referees of scientific articles and did not include their information-seeking behavior. Tenopir and King (2002) did a series of surveys during the period 1970-2002 on a wide range of academics and researchers including physicists and astronomers. However the main theme of their surveys was the use of journal articles and readership patterns. They tracked the main changes that have happened in the use of scholarly journals and readership patterns of the scholar. The subject of their most recent survey was use of journals by astronomers (Tenopir et al., 2005). The use of other kinds of information resources and the way scientists seek the information they need were not included in their studies.

There have been a few more surveys conducted on physicists and astronomers. Brown (1999b) used a questionnaire survey and studied approaches and preferences for finding information, use of library systems, and use of some specific indexing/abstracting tools available at University of Oklahoma by astronomers, chemists, mathematicians, and physicists. The study provided some statistics on the extent of physicists and astronomers' reliance on different information resources, such as *Physics Abstracts*. It also gave some information about how popular and important some particular physics journals and resources were. Brown also conducted a questionnaire survey (Brown, 1999a) on the information literacy of Graduate students in the physical sciences at the University of Oklahoma. The results of the survey, which included mainly open-ended questions, showed a high degree of information literacy among graduate students. The study demonstrated that the students were able to find, effectively use, and evaluate information to meet their specific needs with minimal anxiety. However, it was not clear how they became information literate from the study. Another survey by Tenopir et al (2005) carried out in 2002 investigated mainly

readership patterns and journal use just by astronomers. Their study focused on a particular type of information resource i.e. journals. It provided valuable information on how astronomers found and located journal articles and it revealed that they were considerably reliant on electronic journals. However, it did not cover astronomers' information-seeking behavior as a whole irrespective of the type of resources used. CIBER also conducted an unpublished survey (Nicholas et al, 2005) for IoPP. Though the study included some inferences on information-seeking behavior of physicists, the main goal of the survey was to investigate their interaction with scholarly journal systems, especially IoPP journals.

These studies raised some issues about the information-seeking behavior of physicists in the current information environment which is dominated by electronic information resources. For example CIBER's survey (Nicholas et al, 2005) showed that physicists tended to use Google to search for research articles. The researchers interpreted that "this suggests their information-seeking traits are not that different from the rest of the population, who are Google mad". The other finding of CIBER's study was the fact that individual journal websites were an important and frequent source of data for physicists. The researchers suggested that this might be because physics authors prefer a rifle-shot approach to finding information, rather than face the full force of the information explosion. Maybe, too, they have a much better idea of what they want than most users. So why physicists prefer to use journal websites and Google and why they do not show as much interest in bibliographic or full-text databases as they are expected to do is yet to be investigated. On the other hand the survey of astronomers by Tenopir et al (2005) revealed that they relied much more than other scientists on online searching of bibliographic databases. This indicated, according to the researchers, that astronomers shifted away from traditional browsing.

Methodology

The data for the study was gathered through semi-structured interviews of 26 PhD students in the Department of Physics and Astronomy at University College London. The list of the interviewees is presented in Appendix A.

The Department of Physics and Astronomy at UCL is one of the largest and oldest departments in its field in the UK. Its history can be traced back to early 19th century (Fox, 200?). It was rated at 5 –the second highest rank- in the last Research Assessment Exercise (RAE) in 2001. It is a research oriented department with about 150 academic and research staff and more than 100 PhD students. It consists of four main research areas and contributes to six research centers that each has their own researchers. The four main research areas, and the number of students interviewed in each group are :

- Group A: Astronomy, Astrophysics and Atmospheric Physics; 5 students
- Group B: Elementary Particle Physics; 6 students
- Group C: Atomic, Molecular, Optical and Positron Physics; 8 students
- Group D: Condensed Matter and Materials Physics; 5 students

Participants were interviewed during November 2005 – January 2006. Personalized friendly emails were sent to the students addressing them in their forename and asking them to participate voluntarily in the study. The subject and aim of the study, confidentiality of the data, and the permission from the head of the Physics Department for undertaking the study were mentioned in the emails. The interviews were carried out in mutually agreed time and place at the convenience of the interviewees, in most of cases, in the common rooms in the department of Physics and Astronomy. The interviews were conducted by the senior author

and recorded using a digital voice recorder. The interviews had variable length from 20 to 50 minutes with an average of 30 minutes.

Prior to the start of the interview, students were given a brief description of the study and the interviewer answered any questions the participants might have had about the study. A protocol was used to conduct the interviews and is provided in Appendix B.

The data analysis began with transcribing the interviews. The transcribed interviews were sent to the interviewees for their confirmation. The finalized interview transcriptions were analysed and the themes were coded and the data were extracted.

The researchers chose a qualitative research approach as the main approach because of the possibility of contextualization, and also due to the exploratory nature of the study. As Gorman and Clayton (2004, p. 125) wrote “interview and open-ended questions may lead to unexpected insights and they enable a researcher to explore causation, for example to understand why individuals or organisation behave in the way that they do, something that most quantitative research cannot really answer”. However, it has to be mentioned here that the data presented here is a part of a wider project and the full project will benefit from other data collection techniques –as complimentary to interview data- such as a follow-up questionnaire survey, critical-incident information and electronic journal usage data.

The interview included questions about the participant’s research topic, their educational background, the nature of their research (experimental or theoretical), the techniques they use for keeping up-to-date, their use of different information resources such as journals and e-print archives, their problems, and their communication activities (relation with colleagues, attending conferences etc.).

Findings

Unlike PhD students in arts and humanities that start their PhD studies with their own research plans and proposals, PhD students in physics and astronomy (and probably some other scientific disciplines) join a running research project and work on a particular aspect of it. It is worth mentioning that the doctoral programs in the U.K. are not run the same way as they are in some other countries such as U.S.A.. The doctoral programs in the U.K. are different in that usually do not involve coursework and the students are immediately heavily involved in research. This difference probably makes a difference in how the doctoral students seek/use information. The common way in which they go through the initial familiarization process is to get introduced to a few key resources, usually papers and sometimes books or conference proceedings, by their supervisors as a start point. In theoretical physics these are likely to be classical review papers on the subject while in collaborative experimental physics they might be collaborative papers produced by group members just for internal use, as well as journal papers. The next step they normally take is to look up the references of those papers for finding more relevant materials and get familiar with the research area. Doing a comprehensive literature search in the beginning of PhD by using bibliographic databases seems not to be the norm. This is partly due to the vague idea that students have about the focus of their research in the beginning. This makes it hard to do literature searches and therefore students normally start by chaining and tracking references.

As they move further in their studies, students improve their information seeking skills and, as a few of them mentioned, become capable of finding literature and information faster. They also become more efficient in filtering through information resources and find what is best for them.

> I can't say I have noted a large change in my info-gathering habits from about halfway through my first year to now. Obviously at first I was less sure about how to find results and relied heavily on colleagues and my supervisor for advice. Even now we flag up papers that may be useful to one another we come across in general searching. After a few months my information gathering experience was sufficient that I could perform searches fairly successfully on my own but even now I occasionally find I have missed a useful paper… this experience has been constant. And maybe at first the types of information I was seeking related to general studies of the subject or reviews rather than specific studies, but if I found anything that looked useful, however specific, I would save it and read it. I would say based on my experience that once you have a system that works okay, you do not make any major changes to it – perhaps minor ones as more sources of info occur to you or you learn more about database searching. [DE1]

Keeping up-to-date

In astronomy and astrophysics, PhD students are very reliant on use of e-print archives (particularly arXiv.org) for keeping up-to-date. They normally set email alerts or check the e-print server regularly. There are other alerting services such as MyADS by NASA Astrophysics Data System, which are used by students in astronomy.

> I receive daily emails from astro-ph, which I scan daily for related research. The emails contain both the title, authors, an abstract and a link to the main text, so I scan for keywords in the title and authors I know, then peruse the abstract to see how relevant the work is…. I also receive emails roughly every month from The Astrophysical Journal notifying the contents of the journals with titles, authors and links to individual papers. I am also registered with a service the NASA ADS database provides; called MyADS, it allows you to personalise information you wish to see from the database, i.e. you can select authors, keywords etc., which it will monitor and update you with new entries on, via fortnightly (I think!) emails. [AT2]

In some sub-domains of theoretical physics, which are very well covered by e-print servers, students heavily use e-print servers for keeping up-to-date. For example students who are doing theoretical research on quantum computing check Quant-ph section of arXiv.org on a daily basis.

> I look at it [arXiv.org] everyday. In fact it's my homepage so when I start my web browser I get it because otherwise I forget to look everyday. So it comes up and I look everyday. [CE2]

In collaborative experimental physics, students rely more on the emails they receive by group members. Normally one person in the collaboration sends an email to the other members on a weekly or monthly basis, listing the most important recent articles, which are of interest to the group. The research groups in the Department of Physics and Astronomy at UCL regularly run several seminars, in which speakers from the department or other institutions give a talk about current research projects. The students find some of these seminars useful for keeping up-to-date. However, they also believe some of them are very broad and not related to their research areas. The other mechanism used for keeping up-to-date at UCL is journal clubs. Some of the research groups hold regular meetings in which a volunteer

member reads one or two recent pertinent articles and try to dissect them for the others in a short meeting.

> We have a weekly journal club in our group where two people take two papers that have published in the last week and present them to the rest of the dozen people in our close area and they review the paper and say what's been researched and what their conclusions were and also it's an opportunity for the rest of us to know what's going on so we get to hear about two more papers every week. [AT4]

There is close communication between students and supervisors and they inform each other of new interesting papers.

Use of electronic journals

All of the participants preferred using electronic journals and rarely use the library. Their first choice for obtaining journal articles is to get them online. They all mentioned going to the library as their second step for obtaining an article if they fail to get it online. The main reason mentioned by the interviewees for going to the library was to get a copy of an older paper that is not available in electronic format, or to borrow a book. Journal articles turned out to be the most important resource for research activities in physics and astronomy. This was not surprising as the past studies also showed that scientists place high value on scholarly journal articles (Tenopir et al, 2005; Tenopir & King, 2002). Books are mainly used by students for background studies mostly in the beginning of the PhD, or for learning technical skills such as computer programming.

Several log analyses of electronic journals and survey studies of users in the past (Nicholas, Huntington and Watkinson, 2003, 2005; Institute for the Future, 2002; Tenopir, 2003) revealed higher usage of and preference for PDF over HTML format of articles among different subject communities. PDF is believed to be print-friendly while HTML is more suitable for reading on screen. The common pattern among all the interviewed students was to print out the papers that they want to read thoroughly. Reading on screen was limited up to the phase when they decide whether an article interest them or not. They normally check the titles and if the title sounds interesting and relevant, then they would check the abstract. If the abstract confirms that the article is of interest for them, they then print the article out. The main reasons for not reading on screen seem to be saving their eyes and also the convenience of reading on paper as they can underline and highlight, as well as read them on bus and train while commuting.

> Although LCDs are much more comfortable these days but having a paper in your hand, something you can scribble on directly, it's much more comfortable. [DE1]

However, they are conscious about high consumption of paper and try to save paper by printing double-sided or not printing those articles that they just need for a specific piece of information.

Evaluation of resources

Most of the interviewed students were aware of the issues concerning validity and credibility of information resources, particularly journal articles and preprints. While published journal articles are normally trusted due to the fact that they are peer reviewed, preprints are treated with caution. Those who read preprints, read them mainly for keeping up-to-date. If the study presented in a preprint is to have some effects on their research, students tend to discuss it

in detail with their supervisors and colleagues and if possible check the results. They normally try to obtain the published version of preprints if they sound interesting to them. According to one student '*in physics, things are typically right or wrong, there isn't much scope for interpretation or 'opinion'* [BE3]". In collaborative experimental physics, particularly high energy physics, students trust papers because they are produced by large numbers of authors (sometimes by hundreds) and they go through strict screening processes before a collaboration releases them to the public. In these areas of physics, the names of authors do not have much significance in the students' judgement on papers' credibility simply because there are too many authors on the papers. Meanwhile, in theoretical physics, students are more likely to consider authors and their reputation as a factor in their judgement. In order to see whether they can rely on a paper, they '*don not read just one paper but look at the spectrum of papers [DT5]*'. In high competitive sub-domain of physics, there is a sense of trust on collective knowledge because they believe if some faulty results get published, they would get found very quickly by the subject community.

> I mean there is a lot of rubbish on the preprint server. One way of evaluating is that I look whether I know the authors, because of these many conferences I know a lot of people basically. So in many cases I can tell whether it's going to be a good paper or bad paper just by looking at the authors. Also but good people write bad articles, so I would never really rely on an article without checking its results myself. I read the beginning of the article and see if it makes any sense to me. Okay for adding a citation to my own publication I don't have to check the whole article. If I wan to cite what has been done in the field yet then I can add my citations without having checked all the results; though I prefer to cite published papers of course. If I want to rely on the results by using them and building something new based upon those results then I would check it. [CT3]

Searching for information

The survey by CIBER (Nicholas et al, 2005) revealed that the most frequent method of locating research articles by physicists was 'visiting a journal's web site' followed by 'searching Google'. In terms of dependency, CIBER's survey showed that respondents were most dependent on visiting a journal's web site for finding articles followed by visit to library, then Web of Science and searching Google. The results of current research did not confirm the statement by CIBER's researchers that physicists tend to use Google to search for research articles. Students mentioned that they would not use Google to look for papers and they would prefer to search specialized databases such as Web of Knowledge or journal publishers' websites to find journal articles. Google is rarely used for finding journal articles, although it is heavily used on a daily basis by students. They use it for finding general information and conducting general searches on the Internet, whenever they have an information problem for which they do not know where to look. One student mentioned that he uses Google Print to meet his information needs whenever he has an information problem.

> My first source is usually Google and I use print.google.com and I use Amazon search within the books function because Amazon has scanned a lot of books within physics so if you search for a specific theory you search in Amazon and you actually get the very page of the book. [CT3]

Several reasons were mentioned by student why they like Google and use it heavily: It has a very handy conversion tools and is good for equations [DE1, AT1]; it indexes presentation files that include lecture materials [CT1], it has a simple interface [BE2]; because it is 'cool', 'efficient' and they like its brand [CT2]. While a few students had not heard of Google Scholar, some others used it every now and again to search for papers.

> I like Google Scholar because it searches several journals at the same time. It searches all the main journals and also some journals that you might not have

> thought about using. You can see the citation of the papers and that's very useful. [CT2]

Problems

One of the main problems for the participants was not having access to older articles. Many journals still do not have their entire backfile digitized. Students were generally very impressed with the high availability of digital information services and resources but the digitization of journals' backfiles were among their top requests. A few also mentioned the problem of obtaining articles from obscure journals that institutions do not usually subscribe to, for example Japanese journals. Meanwhile, students in astronomy seem to have fewer problems with accessing the papers. One of their main problems is the amount of effort required for filtering though available information and finding what is best or what they really need.

> It can be very time consuming to do a thorough literature search, especially when lots of similar data is published and you really have to root around for what is the 'best' of this. [AT2]

Conclusions

The results of this study show that PhD students in physics and astronomy rely highly on digital information resources and services. The type of research they carry out –experimental or theoretical- has significance in their information-seeking activities, including the way they start their research process and the techniques they rely on for keeping their knowledge up-to-date. These intradisciplinary differences merit more investigation and elaboration, something which will be pursued in the next phases of this research project.

The study also confirms Hagstrom's (1970) statement that large and high prestige departments might be expected to be centers of communications and all members of these departments, including those with little personal prestige, might benefit from this position. This is because, according to him, most university scientists communicate more with their departmental colleagues than with the others, and they are often introduced to the work of scientists in other institutions by their departmental colleagues. The Department of Physics and Astronomy at UCL seemed to be rich in terms of communication activities due to research collaborations between research groups and the wide range of seminars and journal clubs.

This study has both theoretical and practical implications. One of its theoretical implications is that it contributes to our knowledge about the scholarly communication and information-seeking behavior of physicists and astronomers. This research also demonstrates that a qualitative approach is appropriate to study information-seeking behavior. Moreover, the results of this study have practical implications for those responsible for designing information systems who need to better understand the behavior of their users. Since this study is a case study, the results would be helpful for the Department of Physics and Astronomy at UCL to improve its internal information and communication environment, as well as the information literacy of its PhD students.

Discussion and future work

In the last few years some studies have adopted the domain-analytic approach to investigate the disciplinary differences in the use of information resources and search strategies. The

domain-analytic approach is a paradigm in information science that was articulated by Hjørland and Albrechtsen (1995). It states that 'the best way to understand information in IS is to study the knowledge-domains as thought or discourse communities, which are parts of society's division of labor.' (p. 400). The popularity of this approach as a conceptual framework for studies in the field of information behavior has been on increase during the last few years and more studies have been conducted using this approach (cf. Brockman et al., 2001; Brown, 1999b; Fry, 2004; Fry, 2006; Fry & Talja, 2004; Guerrero-Bote et al., 2002; Tenopir et al., 2005). However, some researchers such as Palmer (1999), Bates (2002), Hjørland (2002), and Fry & Talja (2004) believe that this approach is still in its infancy.

The past studies clearly showed that there are disciplinary differences in the use of information resources and in information-seeking behaviors. For example studies by Nelson (2001), Rusch-Feja & Siebeky (1999), Smith (2003), Talja & Maula (2003), Tenopir (2002, 2003), Tomney & Burton (1998) revealed differences in use of electronic journals among scholars from different disciplines. But most of these studies have had a broad approach to disciplines and subject areas, and categorised scholars into broad fields such as social scientists or physical scientists, or more specifically chemists and so on. In these kinds of studies the results are normally over generalized and intradisciplinary differences are overlooked. Case (1991) believed that in studies of scholars' information practices, units of analysis should be even narrower than domains and specialties. Fry and Talja (2004) in their study on the use of e-journals showed that not only patterns of e-journal use vary across disciplines, but also within disciplines. These indicate a need for a narrower approach to the study of information-seeking behavior of the scholar.

The next phases of the current research aim to investigate intradisciplinary differences within physics and astronomy in terms of communication and information-seeking activities by using triangulation of data and covering researcher, lecturers and professors in the research sample. The full project will hopefully lead to modelling scholarly communication and information-seeking behavior of physicists and astronomers with regard to the nature of the research they conduct.

Appendices

Appendix A: list of participants

Interviewees	Group	Gender	Type of Research
AE1	A	m	Experimental
AT1	A	m	Theoretical
AT2	A	f	Theoretical
AT3	A	m	Theoretical
AT4	A	m	Theoretical
AT5	A	M	Theoretical
BE1	B	m	Experimental
BE2	B	m	Experimental
BE3	B	m	Experimental
BE4	B	m	Experimental
BE5	B	m	Experimental
BE6	B	m	Experimental
CE1	C	m	Experimental
CT1	C	m	Theoretical
CT2	C	m	Theoretical

CT3	C	m	Theoretical
CT4	C	f	Theoretical
CT5	C	m	Theoretical
CT6	C	m	Theoretical
CT7	C	f	Theoretical
DE1	D	m	Experimental
DE2	D	f	Experimental
DE3	D	f	Experimental
DT4	D	m	Theoretical
DT5	D	m	Theoretical
DT6	D	f	Theoretical

Appendix B: Interview Protocol

Background information: group membership, academic background, research description, type of research (experimental or theoretical), nature of research (group of individual).

Commencing the PhD project: initial familiarization process and the trend in which the research is carried out

Keeping up-to-date: How do you keep up-to-date with developments in your field of research? Use of journals, e-print archives, databases, email alerts and etc.

Searching: How do you generally conduct your searches for literature and information? What kind of services do you use for locating your needed resources?

Obtaining articles: How do you obtain (older) journal articles? How often and why do you use the library?

Distinguishing material: What are the main types of information resources you use for your research? What distinguishes those materials from the others? Do you have some sort of criteria to evaluate the information resources you find?

Conferences: What is the role of conferences in the exchange of information and in finding literature? What are your incentives for attending conferences? Reading conference proceedings?

Department: What is the role of your colleagues and supervisor in finding and searching literature? How do you see the communication and the exchange of information in the department and your research group?

Problems: What causes you the most problems in searching and finding literature?

Trends: Have you noticed a notable difference in your information-seeking activities and methods from the time you started your doctoral studies till now?

References

Abdoulaye, K. (2002). Information-Seeking Behaviour of African Students in Malaysia: a research study. *Information Development*, *18*(3), 191-196.

Barry, C. A. (1995). Critical Issues in Evaluating the Impact of IT on Information Activity in Academic Research: Developing a Qualitative Research Solution. *Library and Information Science Research*, *17*(2), 107-134.

Bates, M. J. (2002). Speculations on browsing, directed searching, and linking in relation to the Bradford distribution. In H. Bruce, R. Fidel, P. Ingwersen, & P. Vakkari (Eds.) *Emerging Frameworks and Methods: Proceedings of the Fourth International Conference on Conceptions of Library and Information Science* (CoLIS 4), July 2 1-25, Seattle, WA. Libraries Unlimited, Greenwood Village, 137-149.

Barrett, A. (2005). The Information-Seeking Habits of Graduate Student Researchers in the Humanities. *Journal of Academic Librarianship*, *31*(4), 324–331.

Boyce, P., & Daltero, H. (1996). Electronic publishing of scientific journals. *Physics Today* (January).

Brockman, W. S., Neumann, L., Palmer, C. L. & Tidline, T. J. (2001). Scholarly work in the humanities and the evolving information environment. Retrieved October 30, 2003, from http://www.clir.org/pubs/reports/pub104/contents.html.

Brown, C. M. (1999a). Information literacy of physical science graduate students in the information age. *College and Research Libraries, 60*(5), 426-438.

Brown, C.M. (1999b). Information seeking behavior of scientists in the electronic information age: Astronomers, chemists, mathematicians, and physicists. *Journal of the American Society for Information Science*, *50*(10), 929–943.

Brown, C. M. (2001). The Coming of Age of E-Prints in the Literature of Physics. *Issues in Science and Technology Librarianship*, *31* (Summer). Retrieved July 22, 2005, from http://www.istl.org/01-summer/refereed.html

Callinan, J. E. (2005). Information-seeking behaviour of undergraduate biology students: A comparative analysis of first year and final year students in University College Dublin. *Library Review*, *54*(2), 86 - 99.

Case, D. O. (1991). The collection and use of information by some American historians: a case study of motives and methods. *Library Quarterly*, *61*(1), 61-82.

Dixon, A. (1999). The twelve ages of electronic journals. *Vine,* (111), 3-9.

Ellis, D., Cox, D., & Hall, K. (1993). A comparison of the information seeking patterns of researchers in the physical and social sciences. *Journal of Documentation*, *49*(4), 356-369.

Ellis, D., & Haugan, M. (1997). Modelling the information-seeking patterns of engineers and research scientists in an industrial environment. *Journal of Documentation*, *53*(4), 384-403.

Fidzani, B. T. (1998). Information needs and information-seeking behaviour of graduate students at the University of Botswana. *Library Review*, *47*(7), 329-340.

Fox, J. W. (200?). From Lander to Massey: History of physics, space science and astronomy at University College London, 1826 - 1975. Retrieved October 30, 2005, from http://www.phys.ucl.ac.uk/department/history/BFox1.html

Fry, J. (2004). The cultural shaping of ICTs within academic fields: corpus-based linguistics as a case study. *Literary and Linguistic Computing*, *19*(3), 303–319.

Fry, J. (2006). Scholarly research and information practices: a domain analytic approach, *Information Processing and Management, 42*(1), 299–316.

Fry, J., & Talja, S. (2004). The cultural shaping of scholarly communication: explaining e-journal use within and across academic fields. In *Proceedings of the American society for information science and technology annual meeting on managing and enhancing information: cultures and conflicts*. Providence, Rhode Island, 13–18 November, 2004.

Gorman, G. E., & Clayton, P. (2005). *Qualitative research for the information professional: a practical handbook* (2nd ed. ed.). London: Facet.

Guerrero-Bote, V. P., Reyes-Barragan, M. J., Moya-Anegon, F. and Herrero-Solana, V. (2002). Methods for the Analysis of the Uses of Scientific Information: The Case of the University of Extremadura (1996–7). *Libri*, *52*(2), 99–109

Hagstrom, W. O. (1970). Factors related to use of different modes of publishing research in four scientific fields. In C. E. Nelson & D. K. Pollock (Eds.), *Communication among scientists and engineers* (pp. 85-124). Lexington, Massachusetts: Heath Lexington Book.

Hjørland, B. (2002). Epistemology and the socio-cognitive perspective in information science. *Journal of the American Society for Information Science and Technology*, *53*(4), 257–270.

Hjørland, B., & Albrechtsen, H. (1995). Toward a new horizon in information science: domain-analysis. *Journal of the American Society for Information Science*, *46*(6), 400–425.

Institute for the Future. (2002). E-Journal user: report of Web Log data mining. Retrieved April 25, 2000, from http://ejust.stanford.edu/logdata.html

Jankowska, M. A., Hertel, K., & Young, N. J. (2006). Improving Library Service Quality to Graduate Students: LibQual+™ Survey Results in a Practical Setting. *Portal: Libraries and the Academy*, *6*(1), 59–77.

Kelly, R. A. (1997). Digital archiving in the Physics literature: author to archive and beyond-the American Physical Society. *The Serials Librarian*, *30*(3-4), 163-170.

Langer, J. (2001). Physicists in the new era of electronic publishing. *Learned Publishing*, *14*(2), 131-137.

Majid, S., & Tan, A. T. (2002). Usage of information resources by computer engineering students: a case study of Nanyang Technological University, Singapore. *Online Information Review*, *26*(5), 318-325.

Nelson, D. (2001). The uptake of electronic journals by academics in the UK, their attitudes towards them and their potential impact on scholarly communication. *Information Services & Use, 21*(3-4), 205-214.

Nicholas, D., Huntington, P., Rowlands, I., Jamali, H. R., & Haynes, J. (2005). An investigation of physicists' information seeking behaviour, publishing practices, and views on the scholarly publishing system: with special reference to the Institute of Physics and its journals, Report of an international survey. London: University College London, CIBER.

Nicholas, D., Huntington, P. and Watkinson, A. (2003). Digital journals, big deals and online searching behaviour: a pilot study, *Aslib Proceedings*, *55*(1/2), 84-109.

Nicholas, D., Huntington, P. and Watkinson, A. (2005). Scholarly journal usage: the results of deep log analysis, *Journal of Documentation*, *61*(2), 248-280.

Palmer, C. L. (1999). Aligning studies of information seeking and use with domain analysis. *Journal of the American Society for Information Science*, *50*(12), 1139-1 140.

Rusch-Feja, D. & Siebeky, U. (1999). Evaluation of Usage and Acceptance of Electronic Journal. *D-Lib Magazine*, *5*(10), Available: http://www.dlib.org/dlib/october99/rusch-feja/10rusch-feja-full-report.html

Singleton, A. (1997). Journal and the electronic programme of the Institute of Physics. *The Serials Librarian*, *30*(3-4), 149-161.

Smith, E. T. (2003). Changes in faculty reading behaviours: the impact of electronic journals on the University of Georgia. *The Journal of Academic Librarianship, 29*(3), 162-168.

Talja, S., & Maula, H. (2003). Reasons for the use and non-use of electronic journals and databases: a domain analytic study in four scholarly disciplines. *Journal of Documentation*, *59*(6), 673–691.

Tenopir, C. (2002). Online Serials heat up. *Library Journal,* October 1, 37-38.

Tenopir, C. (2003). *Use and users of electronic library resources: a overview and analysis of recent research studies. Report for the Council on Library and Information Resources*, Retreived October 30, 2005, from www.clir.org/pubs/reports/pub120/pub120.pdf

Tenopir, C., & King, D. W. (2002). Reading behaviour and electronic journals. *Learned Publishing*, *15*(4), 259-265.

Tenopir, C., King, D. W., Boyce, P., Grayson, M., & Paulson, K. (2005). Relying on electronic journals: reading patterns of Astronomers. *Journal of the American Society for Information Science and Technology*, *56*(8), 786-802.

Tomney, H., & Burton, P. F. (1998). Electronic journals: a study of usage and attitudes among academic. *Journal of Information Science, 24*(6), 419-429.

Valauskas, E. J. (1997). Waiting for Thomas Kuhn: First Monday and the evolution of electronic journals. *First Monday*, *2*(12). Retrieved July 22, 2005, from http://www.firstmonday.dk/issues/issue2_12/valauskas/

Washington-Hoagland, C., & Clougherty, L. (2002). Identifying the Resource and Service Needs of Graduate and Professional Students The University of Iowa User Needs of Graduate Professional Series. *portal: Libraries and the Academy*, *2*(1), 125–143.

Whitmire, E. (2002). Disciplinary differences and undergraduates' information-seeking behavior. *Journal of the American Society for Information Science and Technology*, *53*(8), 631 - 638.

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