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Dr Samuel Chu is an Assistant Professor and the Director of the Bachelor of Science in Information Management programme in the Faculty of Education, the University of Hong Kong. Dr Chu obtained his Bachelor of Commerce and Master of Library Science in the University of British Columbia, and received his PhD in Education in the University of Hong Kong. He was a project leader of an online Information Literacy Tutorial which has been in use since 2000 and has been featured twice on the web page of the University's Centre for Enhanced Learning & Teaching as a good model for online education. Dr Chu is working on research projects in the areas of inquiry-based learning, the use of databases in supporting teaching and learning, and KM in education.

Professor Nancy Law is the Director of the Centre for Information Technology in Education and Head of the Information and Technology Studies Division of the Faculty of Education at the University of Hong Kong. Dr Law obtained her BSc and MPhil in Physics as well as her teaching qualification from the University of Hong Kong, and received her PhD in Science Education from the University of London Institute of Education. Her research interests include international comparative studies of pedagogical innovations and information technology, models of ICT integration in schools and change leadership, computer-supported collaborative learning and the use of expressive and exploratory computer-based learning environments.

Address: Faculty of Education
University of Hong Kong
Pokfulam Road
Hong Kong
Tel: (852) 2241 5894
E-mail: samchu@hku.hk

Development of information search expertise:
Research students' knowledge of source types

SAMUEL KAI-WAH CHU* and NANCY LAW

This paper reports on a study of 12 postgraduate research students' development of information search expertise. It focuses on students' perceived importance and growing understanding of different source types as they progress through their studies. Taking an in-depth longitudinal approach, this study makes use of surveys, direct observations of students' searches through various sources, students' verbalization of their thoughts while searching databases/sources and interviews during a one-year period. After analysing the data from the surveys and the interviews of the students with regard to their use of different source types, the paper identifies three stages of students' information needs, and links them to the progress of the students' research. The paper uncovers the roles that different source types play in different stages of research, and finds that while many students were initially unfamiliar with many source types, a growing understanding of them has contributed to the students' development of information search expertise.

KEYWORDS: change and development; information need; information search; research students; training; types of source

1. INTRODUCTION

This paper reports on a study[1] of research students' development of information search expertise. It focuses on their growing understanding of (and the change in their perceptions of the importance of) different types of information sources as they progress through their research studies.

Research students, in particular Doctor of Philosophy (PhD) students who are the focus of this research, must select an original research topic and be comprehensive and current in their literature reviews in areas of knowledge related to that research. They must conduct rigorous searches with different sources/databases to support their studies. However, they are often unfamiliar with the various types of sources, databases or search methods and as such are ideal subjects for information search studies, which attempt to understand the growth and development of information search expertise. Relatively few longitudinal studies on expertise development have been conducted which examine information search behaviour of students (Barry, 1997; Libutti and Kopala, 1995; Morner, 1993).

One approach to examining students' growth in information search expertise is to determine students' need for various source types, and these

can be measured indirectly by students' perceptions of the importance of the sources. A comparison of changes in knowledge of the sources by the two groups will shed light on whether these changes are dependent on the subject areas of the research students.

Consequently, this paper focuses on answering two research questions. First, it attempts to identify the information needs (in terms of types of sources) of education and engineering research students and to investigate whether these needs change over time, and, second, it compares the similarities and differences between the two groups of students in terms of their information search needs.

2. LITERATURE REVIEW

Past research has shown that students' information search skills are initially inadequate (Bates, 1977; Chu, 1995; Drabenstott and Weller, 1996; Hildreth, 1997; Scott and O'Sullivan, 2005; Tillotson, 1995; Tsai and Tsai, 2003) even at the PhD level (Barry, 1997; Compton, 1989; Hess, 1999; Morner, 1993; Simon, 1995; Zaporozhetz, 1987). The logical question then becomes: 'what would be a good way to help students acquire the information search knowledge and skills they need to find the desired and necessary information?'. In the past four decades, many studies have examined the differences between experts and novices in different domains, and this body of research is commonly called expertise or novice-expert research. A good understanding of how people become experts may help the novice shorten his or her learning curve in becoming an expert (Larkin et al., 1980). Two major approaches to expertise research were noted in the literature: (1) novice–expert comparison and (2) developmental studies of expertise. Most research has taken the novice–expert approach (Brand-Gruwel et al., 2005; Chase and Simon, 1973; Chi et al., 1988; De Groot, 1965, 1966; Hsieh-Yee, 1993; Kuhlthau, 1999; Marchionini et al., 1991, 1993); while a few have adopted a developmental approach (Campbell and Dibello, 1996; Campbell et al., 1992; Dreyfus and Dreyfus, 1980, 1986; Walton et al., 1988; Wiedenbeck and Scholtz, 1996).

The novice–expert research has contributed to componential accounts of expertise which have helped to uncover the general characteristics of experts and it has been noted that 'experts have a large body of organized knowledge in their own domain of expertise' (Chase and Simon, 1973; Marchionini et al., 1993). This knowledge, however, is not very useful in helping students trying to advance from novice to expert. Nor is it helpful for teachers wanting to help students in a specific domain make the transition to expert. The componential explanation of attaining expertise is, by itself, insufficient to reveal complexities or irregularities in the process of expertise development and, thus, developmental methodologies are also necessary.

None of the developmental studies mentioned above have touched on information search expertise. This research adopted a developmental, longitudinal approach to investigate whether there were different stages of expertise in information search for research students, and to examine what contributed to a novice student's progress from one stage of information search expertise to the next. Two major types of information search expertise are identified in the literature: (1) knowledge of source types and databases, and (2) knowledge of search skills. This paper focuses on the development of students' knowledge of source types.

Past research has examined five aspects regarding source types used by research students:[2] (1) the kinds of sources they use (Brown, 1999; Chang and Perng, 2001; Compton, 1989; Fabiano, 1996; Holland et al., 1991; Simon, 1995); (2) the extent to which they use these various source types (Chang and Perng, 2001; Compton, 1989; Fabiano, 1996; Farid, 1984); (3) students' perceived importance of or the extent of the usefulness of the sources (Brown, 1999; Chang and Perng, 2001; Cole, 2000; Compton, 1989; Farid, 1984); (4) students' reasons for using or not using certain source types (Compton, 1989; Farid, 1984), and (5) students' knowledge of certain sources (Morner, 1993). The first three of the above are related to one another and can be summarized into a single aspect: students' perceptions of the importance of the sources. Obviously, if students think certain resources are important, they will use them extensively.

In assessing the relative importance students place on different types of sources, past research has identified the following source types important to students: academic journals, books (other than textbooks), dissertations, the students' supervisors, conference proceedings, experts outside the students' own institution, and bibliographies and references in journals and books (Brown, 1999; Chang and Perng, 2001; Cole, 2000; Compton, 1989).

Little research has been done on investigating students' reasons for using or not using certain source types, apart from Farid's (1984) study which showed that the two main reasons for PhD students using personal channels were: (1) the opportunity to discuss the contents of the material with the advisors and (2) material borrowed or references recommended which had been evaluated as to their importance for the students' research.

With regards to students' knowledge of source types, Morner (1993) tested the library research skills (including source types) of 149 education doctoral students using a survey of 41 questions and found that, on average, students only answered approximately 50 percent of the questions correctly. For example, 60 percent of the students correctly answered the question 'which sources usually have the more scholarly, respected research?' The correct answer was 'refereed journals', but many, instead, chose dissertations, ERIC documents or text books.

These studies did not examine the students' use of source types over time. It is possible that some source types which might be regarded as important at some point may be regarded as less so at other stages of research, and the reasons for using or not using some source types may also change.

3. RESEARCH METHODS

This study employed both quantitative and qualitative methods of data collection. Taking a longitudinal approach, the study sought an in-depth understanding of the process by which research students moved from being novices in information search to becoming expert searchers. The researcher met with the students six times (approximately once every two months) individually during a one-year period. During the first five one-and-a-half hour research meetings, which were similarly structured for all the students and included some brief training on information search, the researcher observed the growth and development of the search capabilities of research students. Each of the first three meetings focused on the kinds of materials to be searched, and students selected one of the following source types depending on their research needs and interests at the time: theses, books, journals and conference proceedings, or freely available Web resources. For the fourth and fifth meetings, students used whatever sources they liked. The sixth meeting was a brief follow-up interview, used for clarifying various aspects of the collected data.

The study observes the growth and development of the search capabilities of research students in the five research meetings. It used the quantitative method to survey the students three times during the research period and gathered data qualitatively through observing students' information search with different sources/databases, audio-taping the students' verbalization of their thoughts while searching through different sources/databases, and interviews. This paper focuses on reporting data from the surveys and interviews of the students with regard to their use of various source types. Unlike information about specific databases (e.g. ProQuest) used by the students gathered at the five meetings gathered from direct observation and from the think-aloud protocol, few data could be collected by these two methods as to how the students used various source types. Therefore, this paper, which focuses on the students' use of various source types, will draw heavily on quantitative as well as qualitative data.

This research examines students in two disparate disciplines, engineering and education, to investigate the effects of subject area on the students' choice of source types and the development of their information search expertise. Because the study adopted an in-depth longitudinal methodology, only 12 research students (six each from education and engineering) from the University of Hong Kong (HKU) were taken as the sample. Preference was given to beginning PhD students because they represented the group of students which would do the most literature searching in terms of both quantity and depth.

Of the 12 students participating in the study, 11 were in the first year of their graduate programme when they first joined the study and one was in her third year. This third-year student was also a suitable participant since she indicated that she still needed to find substantially more information for her thesis. To minimize the gender effect, there were three male and three female participants from each of the two disciplines. With a small purposive sample of 12 students, the analysis aimed to establish qualitative differences in order to deepen understanding, rather than to establish generalizations. The use of statistical tests was adopted in this study as a means to help identify points of interest for further exploration. Similar to Yuan's (1995, 1997) longitudinal studies on end-users' information search behaviour, the data collection of this study was accomplished over a period of one year.

To identify students' perceptions of the importance of various source types, a questionnaire of 26 source types (see Table 1) was used, based on a review of those included in related studies (Compton, 1989; Simon, 1995) and guide books (Paradis and Zimmerman, 1997; Rosenthal, 1994). The questionnaire asked the students to rate the level of importance of the source types on a scale of 1 to 5 (with 1 being 'not important', 5 being 'very important', and 0 as 'don't know' [never used or heard of it before]). To identify the changes in the students' perceptions of the importance of the types over time, students were given the questionnaire three times, in meetings one, three and five. To clarify the rationale for the students' ratings for certain items, a 30-minute interview with each student was conducted in meeting six. The interviews were taped and transcribed for data analysis.

4. FINDINGS AND DISCUSSION

A ranking of the students' perceived importance of various source types will be presented first, followed by an examination of the differences in students' ratings of source types across time, both as a group and individually, and between the two disciplines. There will then be an investigation of how the growth of knowledge in their research areas affected the students' needs for various source types. The research will then identify source types that were unknown to the students initially but proved to be important at some later stages. Finally, the paper explores how increasing knowledge of source types contributed to the development of the students' information search expertise.

To show the relative importance of the source types as perceived by the research students, the students' average ranking of this importance over the three meetings as a whole is presented in Table 1.

Table 1. Average ranking of the 26 kinds of information source types from questionnaire returns over the 3 meetings

Rank	Source types	Average important score of 12 students	Source types	Average important score of 6 education students	Source types	Average important score of 6 engineering students
1	Refereed journals	4.7	Refereed journals	4.5	Student's supervisor	4.9
2	Review articles	4.6	Review articles	4.3	Refereed journals	4.8
3	Student's supervisor	4.5	Free web sources	4.2	Review articles	4.8
4	Books	4.3	Books	4.2	Books	4.4
5	Free web sources	4.3	Bibliographies	4.2	Free web sources	4.3
6	Bibliographies	4.1	Student's supervisor	4.1	Conference papers	4.3
7	Researcher of this study	3.9	Theses	3.8	Researcher of this study	4.2
8	Outside experts	3.9	Researcher of this study	3.7	Attending conferences	4.2
9	Conference papers	3.8	Outside experts	3.7	Bibliographies	4.1
10	Attending conferences	3.8	Attending conferences	3.5	Outside experts	4.1
11	Theses	3.7	Conference papers	3.4	Theses	3.6
12	Theses writing guidebooks	3.5	Theses writing guidebooks	3.4	Theses writing guidebooks	3.6
13	Interlibrary loan	3.4	Interlibrary loan	3.3	Interlibrary loan	3.6
14	Other local libraries	3.2	Other local libraries	3.0	Technical reports	3.6
15	Reference librarians	3.1	Reference librarians	2.9	Other local libraries	3.4
16	Technical reports	2.6	Government publications	2.8	Standards	3.4
17	Online discussion groups	2.5	Newspapers	2.6	Reference librarians	3.4
18	Government publications	2.4	Books on studying PhD	2.5	Online discussion groups	3.4
19	Books on studying PhD	2.3	Statistical sources	2.5	Magazines	2.4
20	Statistical sources	2.3	Encyclopedias	2.3	Patents	2.4
21	Standards	2.3	Magazines	2.1	Books on studying PhD	2.2
22	Magazines	2.3	Trade journals	2.1	Statistical sources	2.2
23	Newspapers	2.1	Technical reports	1.7	Trade journals	2.1
24	Trade journals	2.1	Online discussion groups	1.6	Government publications	2.1
25	Encyclopedias	2.1	Standards	1.1	Encyclopedias	1.9
26	Patents	1.8	Patents	1.1	Newspapers	1.6

The first column was the ranking of the 26 source types by the 12 students. The second column lists the source types in the order of ranking (from most important to least important) by the 12 students. The third column was the 12 students' average rating score for each source. The other columns are listed in a similar fashion.

4.1 Ranking of the perceived importance of the 26 source types

Past research has found the following source types important to research students: refereed journals, books, theses, students' supervisors, conference papers, outside experts and bibliographies (Brown, 1999; Chang and Perng, 2001; Cole, 2000; Compton, 1989; Holland et al., 1991). This research confirms such findings, since all these types were among the top 11 sources, with an average rating of 3.7 or above. Moreover, this research identified other important source types rarely mentioned in other articles. These included review articles, attending conferences and guidebooks on theses writing.

In order to further understand the similarities and differences between the two groups of research students in terms of their ranking of source types, the sources are further categorized into six groups, shown in Table 2.

The relative importance of these source categories for the two groups of research students is summarized in Table 3:

The relative ranking for research-oriented sources, research community sources and bibliographic support sources were the same for both groups of students, while differences were observed for the other three source categories.

Among these six categories, research-oriented sources were considered as the most important by all 12 students, with all seven sources within this category falling within the top 11 most important sources. The next most important source category was contact with the

Table 2. Six categories of source types

Research-oriented sources
Refereed journals, review articles, books, free web sources, bibliographies, conference papers, theses

Contact with the research community
Student's supervisor, outside experts, attending conferences, online discussion groups

Bibliographic support sources
Researcher of this study, interlibrary loan, other local libraries, reference librarians

Professional sources
Technical reports, standards, patents, trade journals

Academic tool books
Theses writing guidebooks, books on studying for the PhD, encyclopedias

Media and statistics
Newspapers, magazines, government publications, statistical sources

Table 3. Comparing the relative importance of the 6 categories of source types between the 2 groups

Ranking	Education students	Engineering students
1	Research-oriented sources	Research-oriented sources
2	Research community	Research community
3	Bibliographic support	Bibliographic support
4	Academic tool books	Professional sources
5	Media and statistics	Academic tool books
6	Professional sources	Media and statistics

research community. With the exception of online discussion groups, the remaining three source types in this category were ranked among the top 10 in importance. The third most important source category was bibliographic support, ranking between the seventh and the seventeenth most important by the two groups, together or separately.

Professional sources were the fourth most important category for the engineering students, but the least important for the education students. Both groups of students found academic tool books more important than media and statistical sources.

4.2 Differences in students' ratings of source types over time and between the two disciplines

Going beyond the examination of the average students' perceptions of the importance of source types and source type categories, this section analyses the 12 students as a group to see if there is any difference in their ratings of different source types over time. It will then examine students' ratings over time on an individual basis and also differences between the two groups of students.

4.2.1 Differences in students' ratings over time as a group and between the two disciplines

The ratings of as many as 11 of 26 source types changed over time by an average score of 1.0 or higher (Table 4). Major changes in students' ratings of the importance of the source types were observed at the beginning of the research as indicated by the differences between the scores of meeting one and meeting three; only minor changes occurred during the later part of the study as indicated by the differences between the scores of meeting three and meeting five.

Regarding the differences in students' ratings between the two disciplines, Table 4 indicates that seven of 26 source types had a difference in students' average score of 0.8 or above. In terms of categories of source types, major differences across the meetings can be found

Categories of source types	Source types	Differences across the 3 meetings*			Differences between the 2 disciplines**
		mt3-mt1	mt5-mt1	mt5-mt3	
Research-oriented	Conference papers				−0.9
	Theses	1.5	2.3	0.8	
Research community	Student's supervisor	−1.2	−0.3	0.8	−0.8
	Online discussion groups				−1.8
Bibliographic support	Researcher of this study	1.7	1.5	−0.2	
	Interlibrary loan	1.2	1.3	0.2	
	Reference librarians	1.0	0.8	−0.2	
Professional	Technical reports				−1.9
	Standards	−1.2	−0.5	0.7	−2.6
	Patents				−1.8
Academic tool books	Thesis writing guidebooks	−1.0	−1.2	−0.2	
	Books on studying PhD	1.6	1.4	−0.2	
Media & statistics	Newspapers	−0.8	−1.0	−0.2	1
	Government publications	−1.5	−1.5	0	
	Statistical sources	−1.2	−0.8	−0.3	

Table 4. Differences in students' average rating on source types across the 3 meetings and between the 2 disciplines

* The differences between the 12 students' average scores between the meetings (e.g. mt3-mt1 is meeting three scores   meeting one scores) are presented here. Only the source types with a difference of at least 1.0 for two of the meetings are listed.
** Education students' average scores minus engineering students average scores. Only the ones with a difference of 0.8 or more are listed here.

for almost all of the six categories of source types, while the main differences between the two groups of students lie in their ratings for research community sources and professional sources. The following discussions will identify the reasons behind these various differences.

4.2.2 Changes in students' ratings of the source types across time

When examining the 12 students as a group above, fairly significant changes (with a difference of an average rating score of 1.0 or higher between the meetings) were observed for 11 source types. However, when each of the students' ratings of the source types was looked at individually, major changes[3] were observed for one or more students for all 26 source types. For some types, major changes occurred for as many as eight (for 'Books on studying for the PhD') and even nine students (for 'Trade journals'). There were two primary reasons for these changes:

4.2.2.1. Lack of knowledge of relevant sources or the ability to search for needed information

For example, education student TZ's[4] ratings of 'Books on studying for the PhD' increased from 1 in the first meeting to 5 in the third meeting due to his increased knowledge of this source type. He said:

> At first, I thought I was familiar with the kinds of information provided by this type of source and so I rated it as not important. But later on I realized that I was actually not familiar with it. I consulted it and found it very useful.

Education student CK's ability in searching for theses increased over time and so did his rating for this source type – from 3 in the first meeting, to 4 in the third, and to 5 in the fifth. He said:

> In the beginning, I found only a few theses which were related to my topic, so I didn't give a high rating for theses. Later, I was able to find many theses that were closely related to my research, so they became more important to my research.

4.2.2.2. Change in learning needs

Sometimes, students' ratings of a source type changed over time due to a change in their learning needs. For example, engineering student YH's rating of review articles was higher at the beginning and lower later on because review articles served as a good first step. Once

a research focus is chosen, review articles become less important, because students like YH now need more specific sources of information – e.g. articles from refereed journals. Therefore, YH rated refereed journals lower in the beginning and higher as her research progressed.

4.3 The change of students' needs over time and within each of the six categories of source types

This section will first explore the relationship between students' information needs and their research progress in general. It will then examine in detail how students' needs for various source types (and source categories) change as they make progress in their own research areas.

4.3.1 Students' information needs and research progress

The main concern of research students is to become experts in their specific research area, with the specific goal of producing a thesis on their research topic. The 12 research students were initially novices in both their research areas and in information search skills, but while they were advancing from one stage to another in their subject knowledge expertise, they were also developing their information search expertise. It was also observed that the nature of their information needs changed too, as a result of the development in their subject knowledge.

4.3.1.1 Students' information needs change from general to specific

In the beginning stage of their research, students knew relatively little about their fields of study and would search for general information to enrich their knowledge of their areas. After gaining sufficient knowledge about their needs for research, they were able to search for more specific information. As education student BW said in meeting four:

> There are two steps in my information search. First, I wanted all kinds of materials on scientific literacy because, in the beginning, I did not know what to focus on for my research. Now, I am at my second step. I know what I will research and so I only want very specific information sources. It is still difficult to find this kind of information.

4.3.1.2 Students' information needs change from specific to the most current

The change from general to specific searching applied to all 12 students. In addition to these two stages of information needs, there seems to be one further stage – finding the latest information sources relevant to the research topics. In meeting six, education student CD considered the ability to find the latest information sources in her research area as the biggest change in her information searching skills. Engineering student PW also said that one of the most valuable things she had learned from participating in this research was the methods of accessing the newest information in her research area. She found

that she could do this through joining online discussion groups and from searching company and research centres' websites using search engines. Other students like engineering student JC also emphasized newer information. He said that when he searched IEEE Xplore, he would limit his search to conference proceedings in order to find newer information. An examination of the 12 students' ratings together on source types (conference papers and online discussion groups) that lead to the latest information also suggests the same with the difference in students' scores between meeting three and five as 0.8 and 0.3 for the two source types respectively.

Since research students, especially PhD students, are supposed to make an original contribution in the area of their research, it is important that they are concerned about getting the latest information in their research areas.

4.3.2 The change in students' needs within each of the six categories of source types

This section discusses how students' needs for various source types change within each of the six categories as they advanced in their expertise in subject knowledge and searching skills.

4.3.2.1 Research-oriented sources

In the early stages of their research, students found books and review articles particularly useful. These two sources provide a comprehensive overview and discussion for a research topic. Engineering student PW (ratings 5, 3, 5)[5] said:

> In the beginning, I would read many books because they were more comprehensive. However, later in my research, books became less important because the information is not very new. However, when my supervisor asked me to provide a conclusion for something I wrote, I found that books were useful for that purpose, and so I gave it a high rating again.

Education Student ZJ (ratings 5, 5, 5) commented on review articles:

> I like reading articles because they review the past literature on various topics . . . I can save lots of time by reading them. They usually generate models taken from research.

The 12 students' rating on theses as a whole increased from an average of 3.1 in meeting one to 4.2 in meeting five. Most of them had read very few before starting their graduate study, but once they understood that theses provided relevant information and served as good examples in illustrating what they were expected to produce at the end of their research, they gave theses higher ratings across the meetings. As engineering student JC (ratings 1, 4, 4) said:

> In the beginning, I thought other people's theses were not related to my research and so they were not important. Later on, I realized that there are many theses that are

unpublished, which usually contain some things that might be important to me, so I rated them as more important.

Once the students had gained enough background for their research, they found books and review articles too general. They needed more specific sources, refereed journals for example, which contained more detail on their specialized research areas. Engineering student YH compared review articles (her ratings were 5, 5, 4) to refereed journals (ratings 2, 5, 5):

> In the beginning, review articles were more important than refereed journals because I did not have sufficient background in my subject. Later, refereed journals became very important, once I had gained more knowledge in the area of my research.

In the later stages, conference papers became particularly important as the focus of research was now on the newest information available in students' subject areas. As engineering student HL (ratings 3, 1, 5) said:

> Conference papers are becoming more and more important to me. I didn't know too much about them in the beginning. Then I learned from my supervisor that many new ideas are presented in conference papers. Information in journals is often behind by two or three years. Ideas at conferences are usually much more current.

Some differences (–0.9; see Table 4) were found between engineering and education students in their ratings of conference papers. Engineering, electrical engineering in particular, is a field where many researchers present much of their latest findings at conferences. This is why two electrical engineering students rated conference papers as very important in all three meetings. Some engineering research findings quickly become outdated if they do not appear speedily and it is quicker to get published in a volume of conference proceeding than in a high quality journal. Education research, for its part, is mostly about people and ideas. Although there might be no hurry to present such findings at conferences, it may still be desirable to get such research findings published in good time. Educational researchers can often wait for their articles to get published in quality journals. In contrast to this view, education student LM (ratings 1, 2, 1) commented:

> Conference papers are usually not well developed. Good papers are usually published in journals, so I believe it is always better to read journal articles than conference papers.

The findings regarding conference papers agree with those of other studies in the literature. In Holland et al.'s (1991) and Yitzhaki and Hammershlag's (2004) studies, academic engineering researchers ranked conference papers as the second and fourth most important source types in a list of 17 and 26 source types respectively, while in De Tiratel's (2000) study, social science researchers[6] gave a lower rating for conference papers. In a list of six source types, they ranked conference papers as second last.

4.3.2.2 Research community sources

This section will highlight three source types under this category: students' supervisors, outside experts and online discussion groups.

Students' supervisors: Table 1 shows that engineering students rated their supervisors as the most important source of information, giving them an average score of 4.9, while education students ranked this source type as the sixth most important with an average score of 4.1. Why did the engineering students give a much higher rating to supervisors as a source of information than the education students?

One reason may be the fact that the research of many of the engineering students originated from the faculty's research grants, and the engineering students tended to do research that was closely related to what their supervisors were doing. In this way, the engineering supervisors were generally knowledgeable about their students' topics and were able to pass on important information sources. The education students, in contrast, tended to choose their own topics, and in some cases these topics were outside the core expertise of their supervisors. In responding to a question on the relationship between supervisors' research grants and students' research topics, engineering student TZ commented:

> There are two situations: one is that the supervisor has received a research grant and the students will do their research in the area of the research grant. Another situation is that the supervisor is interested in certain fields and wants to start doing some work in those areas. He may later apply for research grants for those areas.

A difference of –1.2 (see Table 4) was found between the students' rating of supervisors in meetings one and three, which suggests that supervisors were rated as less important at later stages of the students' research.

Why did the students need their supervisors more at the beginning? All students except one were in the first year of their programmes when they joined this research. As new research students, many are uncertain of the direction they should take in their research and so guidance from their supervisors was very important at this early stage. Engineering student TZ (ratings 5, 5, 5) commented: 'My supervisor plays an essential role in my searching for certain important information. For example, he knows who the key researchers are in my field.' Later on, students probably needed to explore more on their own, so that the research would be 'their research' rather than 'their supervisors' research'. The role of the supervisors thus became less important.

The change in the importance of supervisors happened mainly with the education students. Four of the six students who rated the importance of consulting a supervisor one or two points lower in meeting three

were education students. In contrast, four out of six engineering students consistently gave the highest rating of five points to the importance of consulting their supervisors in each of the three meetings. The decrease in the engineering students' perceptions of the importance of consultations with supervisors was minimal. This reflects that engineering students worked very closely with their supervisors, and hence the role of their supervisors continued to be important throughout the entire period of their research.

Experts outside the students' institution: Similar to the findings concerning students' supervisors, outside experts were found to be more important in the early stage of the students' research, since these experts had the knowledge and 'connections' to point students in the direction of key sources or important researchers. In the later stages of the students' research, however, outside experts became less important, as students at these stages had to learn to proceed on their own. Engineering student YH's ratings of overseas experts dropped from 5 in the first meeting to 2 in the third and fifth meetings. The researcher asked YH whether this was because she did not have important things to ask during the latter part of her research. She replied: 'No, it is not because there are no important things to ask, but because there are problems that I need to solve on my own. Otherwise, my research will not be original.'

Online discussion groups (mailing lists and newsgroups): This source type was rated as the eighteenth most important item by the engineering students and the twenty-fourth by the education students. Overall, engineering students rated it as fairly important (with an average score of 3.4), while education students rated it as not important (with an average score of 1.6).

To understand the reason behind the difference between the ratings of the two groups of students for this source type, we need to look at its substance. Online discussion groups are mostly international in nature and the students' comments show that they serve three purposes: (1) sharing of ideas and opinions on a subject (e.g. environmental microbiology); (2) a quick-turnaround troubleshooting aid for using/managing a software/system (e.g. Tru64-UNIX-Managers); and (3) working groups on setting certain standards (e.g. Internet secure payments).

Both education and engineering students belong to online discussion groups serving the first purpose. For example, education student CK (ratings 2, 4, 4) said:

> I mainly use two discussion groups. One is Sportpsy, which is mainly US and actually we can say it is universal. It has all kinds of members including professors and students who discuss issues in sports psychology. Another mailing list I use is the PE Talk Digest for teachers to discuss their ideas. For example, what to play during a class.

The second and third purposes of online discussion groups are rather technical in nature and so they mostly serve technical researchers. For example, electrical engineering student YH (ratings 4, 4, 4) said:

> I belong to many working groups' mailing lists of IETF (Internet Engineering Task Force). For example, Quality of Service, Mobile IP, TCP over Satellite and NPLS. Another one I use is a newsgroup on software for programming (NS Network Simulator). It is used by many academics.

Interviews with the students show that most of the engineering students (electrical engineering students in particular) found online discussion groups useful, while only some education students found them helpful, and most did not find them relevant. Education student LA (ratings 2, 1, 2) commented: 'I seldom use them. I've tried before, but I couldn't find discussion groups for the area of my research.'

Four out of the six engineering students participating in this study were from electrical engineering and of these, three rated online discussion groups as important (an average rating of 4). Electrical engineering researchers, especially those who work on topics related to the Internet, need up-to-date information (e.g. a way to solve a specific programming bug or the current standard for IP authentication) to solve various problems as part of their research. Online discussion groups are thus particularly important to them.

4.3.2.3 Bibliographic support sources
The 12 students gave much higher ratings in meeting three than meeting one for the three source types in this category: researcher of this study, interlibrary loan and reference librarians (see Table 4). The students said that they did not know what the researcher of this study could offer in the beginning, but once they had learned how much he could help them in finding crucial sources for their research, their ratings for 'the researcher of this study' increased by 1.7 points. Similarly, a few students were not aware of the usefulness of interlibrary loan at first, but once they knew about it and started using it, they found it important for their research. Some students also found reference librarians more important to them in the later stages of their research. Education student LA explained:

> In the beginning, what I needed was easy to find and so the importance of reference librarians to me was low. Later on, I needed to dig deeper into my information search and certain information was hard to find; I got more help from reference librarians.

4.3.2.4 Professional sources
Some students found trade journals a good start for their research, because they were not technical and could be easily understood. However, in the later stages of students' research, they needed more scholarly information. As engineering student YH (ratings 5, 3, 3) said:

In the beginning, journals for practitioners are easier to understand. Later on, they became less useful because they are not academic, not in-depth enough.

The link between the professional and the research communities: There are probably many more professional sources in the field of engineering than in education. Sources such as technical reports, standards and patents, for example, are mainly for engineering researchers. It is not surprising, then, to see that the engineering students rated all these three professional sources significantly higher than did the education students (see Table 4). This would seem to indicate that there is a closer interaction between the professional and the research communities in engineering than there is in education.

In engineering, the transfer of technology between the academic and the professional communities happens frequently. For example, some academic researchers have recently developed a fast motion estimation algorithm for multimedia communications, and it has been recognized internationally as a new standard for MPEG-4 (Moving Picture Experts Group). We can expect that such a standard will be adopted quickly by the professional community in developing and enhancing their multimedia products. The professional community in engineering also produces many things (e.g. patents) that are of interest to the academic community. The link between academic and professional communication in engineering is very strong.

In education, the link between academic and professional discourse is rather weak and the only significant kind of publication shared by both communities is trade journals. Education professionals rarely adopt findings from academic research as quickly as their counterparts in engineering. It seems that very few teachers have the time and energy to read journals to see how they can apply the latest educational research to improve the quality of their teaching.

4.3.2.5 Academic tool books
Books on studying for the PhD were most useful in the beginning stages of research because they gave students an overview of what to expect from graduate study, the kinds of problems they might encounter and suggestions for dealing with potential problems. Once they gained the knowledge provided in these books, students had little need to read them again. Table 4 also indicates a decrease in students' rating for this source type in the later stages of their research. Education student CD's (rating 2, 3, 4) comment illustrates the perceived usefulness of this source type:

I mainly read the book 'How to get a PhD?' Why is it useful? Because while I am doing my PhD, certain doubts arise. For example, 'It is only me doing the research', 'Nobody knows what I am doing', 'I don't know whether

my research is worth doing', or 'I don't know if I should continue my research'. Reading these kinds of books will help me deal with feelings like these . . . They help me tune in better. I have found that they are becoming more and more useful.

Most of the students had not read any theses writing guidebooks in the beginning and so this source type was important to them and they still rated it as fairly important in the later stages. As they got closer to start writing their theses, the formats and guidelines for writing a thesis discussed in these books would become very useful.

4.3.2.6 Media and statistical sources
Overall, the 12 students gave a rather low average score for newspapers, government publications and statistical sources, and a difference is noted between the two groups of students' ratings on newspapers (see Table 4). Although the education students only gave a score of 2.6 for newspapers on average, three education students actually rated newspapers as important (a rating of 4) or above at least once. The engineering students gave a much lower average score (1.6) for this source type. Educational research belongs to the social sciences, and information in newspapers reflects current social views and trends. In contrast, the social dimension of engineering research is much more limited and newspapers are rarely useful to engineering students.

An education student CD (ratings 4, 5, 3) gave the highest rating for newspapers among the 12 students. Her research topic was media education and she found certain topics in newspapers useful. Examples of these topics were freedom of speech and sociopolitical public opinion.

4.4 Source types that were little known but important to students

The 11 source types in Table 5 represent the least known sources among the students; two or more students did not know about them in meeting one.

Table 5 shows that 17–33 percent (two to four out of 12) research students did not know 42 percent (11 out of 26) of the source types initially, but in the latter stages of the study, 82 percent (nine out of 11 of these 'unknown' sources) were rated as fairly important (a rating of 3) or above at least once by one or more students.

Gradually, students became more knowledgeable about different source types and because of that they were able to obtain better search results. Education student CD commented in meeting five:

In the past, I] which ones were useful to me. If I was lucky, I would find something useful. If I was unlucky, then I would find nothing. Now there is a clear scheme in my mind – books, journals, theses, news, etc. I know which databases can help me. The resources are the same,

Table 5. Source types little known to the 12 students		
Source types	Number of students chose 0 at meeting one	Number of students chose 3 or higher at subsequent meetings
Books on studying PhD	4	2
Patents	4	0
Standards	4	0
Trade journals	3	2
Reference librarians	3	2
Interlibrary loan	3	2
Theses	2	2
Researcher of this study	2	2
Encyclopedias	2	1
Technical reports	2	1
Online discussion groups	2	1

but the way I look at them is different. It is like creating drawers of information inside me and I know which ones to open according to my information needs.

In short, it was found that a growth in students' knowledge of source types contributed significantly to the development of their information search expertise.

5. IMPLICATIONS OF THE STUDY

Major implications for two areas can be drawn from the analyses presented in this paper: training for research students and handling theses.

Training for research students

The discussion above shows that different groups of students have different information needs, so training should be organized on a disciplinary basis. For example, newspaper and magazine sources should be introduced to education students, and for engineering students, patents and standards should be emphasized. Such training should give students an overview of the role of different source types in the various stages of a research project. Besides including the key source types in discussions with the students, the training should also point out that the less important source types could become important when there is a need for them.

Handling theses

Earlier discussion has shown that theses are an important source of information for students. However, many librarians believe that theses are not useful for research students, because the good ones would have been published in journals. This is true only to a certain extent because a number of students do not bother to get their high quality theses published. Moreover, journal articles usually omit certain details that research students want to see. Probably because of this misunderstanding of students' needs, many libraries treat their students' theses as a special collection, kept separate from the general collections. Some libraries do not even allow their own students to browse the theses. Those who want to read them often have to check the library catalogue first and then have the theses brought to them by library staff. Why should such an important source of information be locked up and only used with special permission?

In recent years, however, more and more libraries have adopted an 'open door policy' regarding their students' theses. These libraries treat their students' theses as books which can be borrowed by their own users, as well as by users from other libraries via interlibrary loan. Projects like the Networked Digital Library of Theses and Dissertations (http://www.ndltd.org/) even made many theses in member institutions available online. The policy of many libraries to put theses in special collections accessible only via special permission needs to be reviewed and revised. It would be useful to students if libraries around the world would adopt the open door policy for theses.

6. LIMITATIONS OF THE STUDY AND SUGGESTIONS FOR FURTHER RESEARCH

Due to the qualitative nature of this study, the sample size of the participants was small, and the findings of the study, though interesting, cannot be generalized as a common phenomenon for a big population. To follow up on this study, more longitudinal investigations on different groups of students' perceived importance of various source types in different stages of research would be worthwhile. Using a much bigger sample size is recommended for these studies, so that results can be generalized. It would also be useful to repeat the study with research students who are not in their first year of study in order to see whether this would generate different results from this study, which used first-year research students as key participants.

7. CONCLUSIONS

This research not only confirms previous findings (Brown, 1999; Chang and Perng, 2001; Cole, 2000; Compton, 1989; Holland et al., 1991) with regard to the

various source types (e.g. theses, students' supervisors, conference papers, and outside experts) important to research students, but it also identifies some source types rarely mentioned in other articles as important. Compared to the one-off studies which are common in most previous related literature, the longitudinal nature of this study provides much greater depth to our understanding of students' perceived importance of different source types over time. We learned how and why the changes happened to the students. The study also contributes to the literature by presenting a way to categorize these different source types into six cohesive categories. The paper also points out the similarities and differences between two groups of students in terms of their perceptions of the importance of the various source types and source categories.

This study identifies three stages of students' information needs: general, specific and the most current. These various stages of information needs are closely linked to the students' research progress, and this paper presents the role of different source types at different stages of a student's research. It further shows that many students were initially unfamiliar with many source types important to their research, and the growth of knowledge of many of these sources has contributed to the students' development of information search expertise.

NOTES

1. This paper reports a portion (research students' knowledge of source types) of a research findings; other parts of the project's findings (research students' knowledge of databases and search skills) are available at Chu's (1995) and Chu and Law's (2005) publications.
2. Since very few studies on education and engineering research students can be found, this review will discuss source types used by research students in general.
3. A major change is noted when a student's rating on a source type is 2 or more points higher/lower than the subsequent meeting.
4. TZ – To protect the privacy of the participants' information, all students' names have been coded in such a way that they cannot be identified.
5. 'Ratings 5, 3, 5' refers to the ratings for a source type in the first, third and fifth meetings respectively.
6. No studies can be found regarding education researchers' use of conference papers. Hence, social science researchers, which cover education researchers are discussed in here.

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