Information Literacy of Physical Science Graduate Students in the Information Age

Cecelia M. Brown

This article reports on findings from a survey exploring the information literacy of physical science graduate students. The study also describes the graduate students' perceptions of the physical and psychological components that enhance or detract from their ability to find, appraise, and use information and how they feel during the various stages of an information search. This snapshot investigation illustrates that physical science graduate students form an information-literate microcosm despite the lack of formal library instruction. The students offer a small number of reasons why they may be inhibited from locating an information source and report experiencing little anxiety as they search for information. They also describe their ideal information-seeking environment as being within the comfort of their home or the convenience of the library. Further, they place some emphasis, but not total reliance, on the capability to connect to the Internet quickly. Relevance, quality, and speed are the cornerstones of a successful search quest. Recommendations for outreach to graduate students who are not native speakers of English are made. Also, suggestions are proposed for library instruction that is specifically designed for, and attracts a greater number of, physical science graduate students.

ver the past two decades, technology has become an integral part of the fabric of academic life. Physical science faculty and students employ technology every day on university campuses as they e-mail colleagues all over the globe, word process manuscripts, create spreadsheets of data, and search online databases for information to support their teaching and research activities. Parallel with the increasing dependence on technology for daily tasks has been the unimaginable expansion of information related to the physical sciences. Physical science librarians and information specialists have taken advantage of the new technologies to organize, provide access to, and archive this wealth of information. However, the extent to which graduate students in the physical sciences are able to identify, find, appraise, and make effective use of the vast amounts of information available to them to address a specific problem (i.e., their information literacy) has not been documented.

Cecelia M. Brown is an Assistant Professor and the Chemistry–Mathematics Librarian at the University of Oklahoma; e-mail: cbrown@ou.edu.

Background

The 1989 report from the ALA's Presidential Committee on Information Literacy defines an information-literate person as one who "must be able to recognize when information is needed and have the ability to locate, evaluate, and effectively use the needed information."[1] Information-literate persons are prepared for lifelong learning because they are able to locate the information required for any endeavor or decision that confronts them.[2]

> **The goal of the study was to provide suggestions for programs and services that would maximize the information-seeking ability of graduate students in the physical sciences.**

The ALA report contends that information literacy is essential for the promotion of economic independence and quality of life, and thus it is in the best interest of all U.S. citizens to achieve literacy in information. Similarly, graduate students in the physical sciences must achieve a high degree of information literacy to successfully complete the rigorous requirements of their degree programs and subsequently become competitive in the world market. These graduate students are the world's future leaders, innovators, and educators in a variety of areas ranging from the chemical basis of Alzheimer's disease and cancer to the development of materials for use in devices such as high-energy density batteries, fuel cells, and gas sensors. Yet, whether they have mastered the art of navigating the world of information available to them is unclear.

Related Research

Achievement of information literacy has become very challenging in the current Age of Technology. Although the 1989 ALA report placed a large emphasis on computers and networks,[3] a recently revised report by the same committee states that "technology alone will never allow America to reach the potential inherent in the Information Age."[4] This realization is accompanied by a series of recommendations for fostering information literacy, including the suggestion to conduct more research related to information literacy that emphasizes methods to benchmark information literacy abilities and progress. Indeed, several earlier papers and reports have highlighted programs aimed at enhancing information literacy, yet none have specifically addressed degrees of information literacy and how they can be assessed.[5]

Many factors enhance or diminish information literacy in university students. Academic librarians are uniquely positioned to foster the development of information literacy. This is purported to be especially successful when librarians develop partnerships with faculty and, as partners, incorporate information literacy programs into the academic curriculum.[6] Despite these efforts, however, a number of physical and psychological barriers inhibit the development of information literacy.[7] What these factors are and how they affect the information literacy of physical science graduate students has not been documented.

Objectives

This study was undertaken to explore the information literacy level of graduate students in the physical sciences at the University of Oklahoma (OU). A questionnaire was designed to query the students about their perceptions of the physical and psychological components that contribute to, or detract from, their ability to find, evaluate, and utilize needed information. The goal of the study was to provide suggestions for programs and services that would maximize the information-seeking ability of graduate students in the physical sciences. Ultimately, the suggestions might be used to help a range of students become information literate and thus be able to find, evaluate, and use information for lifelong learning and problem solving.

Methodology

In addition to learning how graduate students in the physical sciences find, evaluate, and use information, the questionnaire was developed to elicit their perceptions of the search processes. The questions were largely open-ended and concerned the students' initial thought processes before an information search, the resources they are likely to use, and how they trace and locate individual sources. Similar questions have been used in case studies and focus groups to understand the information-seeking process from the user's perspective.[8]

Moreover, several questions were asked to discover what facilitates or inhibits the physical science graduate students' information-seeking processes and how they feel during the various stages of information seeking. These questions were patterned after those used previously to study the emotional, situational, and physical barriers that affect students' information-seeking processes.[9] Finally, ten questions were designed to obtain demographic information about the students, including gender, age, native language, year of study, semester course load, degree pursued, primary research area, stage in graduate program, projected year of graduation, and career plans.

To reduce paper use and to take advantage of electronic communication, the survey was distributed electronically (i.e., e-mail). Initially, the questionnaire was distributed to only ten graduate students in order to assess its strengths and weaknesses, estimate the time required to complete it, and ensure that it included all pertinent variables. After making minimal modifications, the questionnaire was e-mailed in February 1999 to all the biochemistry–chemistry (eighty), mathematics (forty-two), and physics–astronomy (twenty-one) graduate students at OU. Six respondents requested a printed questionnaire. Respondents were asked to return the questionnaires as quickly as possible. After two weeks, another e-mail was sent to encourage nonrespondents to return a completed questionnaire. In March, an appeal was sent to the physical science faculty members asking them to encourage their students to respond to the survey. A final query was sent to the remaining graduate students during the latter part of March. To ensure confidentiality, all data were cataloged using an assigned identification number and the returned e-mail questionnaires were deleted. Approval to use human subjects in this investigation was granted by the Institutional Review Board of OU.

Survey Population

Thirty-six of the 143 students queried responded to the questionnaire for a response rate of 25 percent. The low response rate may be attributed to a number of factors. A high percentage of the physical science graduate students are not native speakers of English and are very underrepresented in the sample of students responding. It is likely that they did not understand the questionnaire and its potential benefit. Also, the students are under extreme time constraints. Graduate students in the physical sciences are expected to excel in their course work, instruct laboratory sessions, and conduct innovative research, leaving them little time for other activities. Consequently, it is very possible that they felt too busy to answer the survey.

However, valuable information can be learned from the answers given, despite the low response rate. The students who answered the survey are a diverse group, in varying stages of their graduate program, specializing in different areas of the physical sciences. As such, they provide a heterogeneous sample of the physical science graduate students at OU. Also, they gave detailed responses to which they had given much consideration. Their answers resemble the types of qualitative responses expected from a focus group or personal interview where the survey population is traditionally small.

Student representation was 47 percent chemistry–biochemistry (21% of students responding), 31 percent mathematics (26% of students responding), and 22 percent physics–astronomy (38% of students responding). Sixteen of the biochemistry–chemistry students were pursuing a

Ph.D., and one was pursuing a nonthesis master's degree. Eight of the mathematics students were enrolled in the Ph.D. program, five of whom were specializing in mathematics education. Two of the mathematics students were taking a nonthesis master's degree, and one of these was a mathematics education major. The remaining mathematics student was working on a master's degree with the thesis option. All eight physics–astronomy graduate students were Ph.D. candidates. The average number of years spent at OU at the time of the survey was 2.8, with a range of 0.5 years to nine years. Consequently, the students responding were at varying levels in their programs, ranging from just starting to writing their dissertation. The greatest number of courses the students were enrolled in was three, and the longer they had been in their program, the fewer courses they were taking. The senior students reported being enrolled in dissertation hours only. The expected date of graduation varied from 1999 to 2004.

Twenty-five (69%) of the thirty-six students responding reported English as their native language. Three (8%) students were native Russian speakers, and the remaining eight (22%) spoke either Arabic, Chinese, German, Hindi, Nufi, Sinhalease, Tamil, or Turkish. The students' plans after graduation included positions in teaching (31%), academia (17%), research (14%), or industry (14%). The remaining students (22%) were undecided about their career plans. The average age of the students at the time of the survey was 27.9 years, with a range from twenty-two to forty-nine years. Sixteen (44%) of the respondents were female and twenty (56%) were male.

Library Resources at the University of Oklahoma

The OU library system comprises a main library and six branch libraries, including the chemistry–mathematics and physics–astronomy branch libraries. The chemistry–mathematics library, located within the same complex as the chemistry–biochemistry and mathematics departments, holds more than 70,000 volumes and receives approximately 500 journal titles. The physics–astronomy library is located in the same building as the physics–astronomy department, and contains more than 35,000 volumes and subscribes to 185 journals. Campuswide full-text electronic access via the World Wide Web (Web) is available to the suite of American Physical Society journals and to twenty-three Institute of Physics journals. The panoply of indexes and abstracts available for use at no charge to patrons at OU and their modes of access are listed in table 1.

Findings

Information Requirements

The students were asked to check the reasons they need information on a list that included course work, dissertation/thesis research, and special projects, plus an option to describe other information requirements. They were asked to check all that apply. Twenty-seven percent of the students use information for course work, 25 percent for research, and 47 percent for special projects, including grant proposal preparation and teaching responsibilities. Four (11%) of the respondents stated they look for information for their personal interests, to either gain personal knowledge or satisfy their own curiosity.

Time Devoted to Information Seeking

The students were asked how much time they devote to seeking information on a daily, weekly, or monthly basis. Every student spends at least some time each month looking for information. Forty-seven percent of the students devote anywhere from twenty minutes to one or more hours per day seeking information. A Ph.D. candidate in mathematics reported seeking information only sporadically, whereas another, also a mathematics Ph.D. student, reported looking for information five to six hours per day, several days in a row, one to three times per semester. Similarly, a biochemistry–chemistry Ph.D. student searches for approximately twenty minutes a day, three times per week, or spends an entire day, two times a month, depending on need. One physics–astronomy student, who at the time of the study had been at OU for nine years, looks for information daily and regrets that too much of that time is simply for pleasure.

Processes Involved in an Information Search

When the students were asked to describe their initial thought process before beginning an information search and how they feel at this stage of the process, they gave a variety of responses. Eleven (30%) of the students reported beginning by thinking of authors' names and key words with which they can search OU's online computer catalog (OLIN) or another secondary source such as Chemical Abstracts, Medline, or ERIC. Others (25%) said they think about where they can get the needed information—journals, textbooks, professors, or other graduate students. Three (8%) students were concerned

TABLE 1
Indexing and Abstracting Tools Available at the University of Oklahoma for Use by Patrons Free of Charge

Discipline	Title and Access Modes
General	Article First
	via OCLC First Search Web version
	Carl UnCover
	via Web
	via Telnet
	Science Citation Index
	print
Chemistry–biochemistry	Chemical Abstracts
	print
	as CA Student Edition via OCLC First Search Web version
	MEDLINE
	via OCLC First Search Web version
	as PubMed via the Web
Mathematics	Current Mathematical Publications
	print
	as MathSciNet via the Web
	ERIC (Educational Resource Information Center)
	CD-ROM
	via OCLC First Search Web version
	Mathematical Reviews
	print
	as MathSciNet via the Web
	Zentralblatt fur Mathematik/Mathematics Abstracts
	print
Physics–astronomy	Physics Abstracts
	print
	Physical Review Online Archive (PROLA)
	via Web

about the quickest way to get the information needed. One biochemistry–chemistry Ph.D. candidate "hope[s] it's there," whereas an MS mathematics student believes "it's going to be trouble!" In general, the students reported feeling positive at this point in their information quest, using words such as "fine," "confident, " "curious, " "enthusiastic," or "hopeful." However, five (14%) students expressed frustration with not being able to find exactly what they need, saying they "know there's stuff out there but don't know how to access it." A mathematics education Ph.D. candidate was "amazed at the junk that comes up during a fairly simple search … stuff that has no logical relation." Frustration also is generated by the lack of available online databases precipitating the need to search print versions of Chemical Abstracts, or Dissertation Abstracts, or to physically come to the library. A biochemistry–chemistry Ph.D. candidate drew an analogy with a chef, having "all the ingredients (and some nonvalue ones) without a recipe."

The students were then asked to specifically identify and appraise all likely sources used in a search for information. Eighteen (50%) of them stated that journal article reference lists are good to excellent sources for information. Carl UnCover received mixed reviews ranging from "not that great" to "not very satisfying" to "excellent" by ten (28%) students. One of these students noted that Carl UnCover Reveal, a table of contents alerting service available to all faculty and graduate students at OU free of charge, is an excellent information source. Although thirteen (36%) students cited professors as good to excellent information sources, three of these students also reported that their professors are often too busy to be helpful. Six (16%) biochemistry–chemistry students described the excellent utility of Chemical Abstracts Student Edition via FirstSearch, and one lauded the thoroughness of printed Chemical Abstracts. However, two (6%) students found printed Chemical Abstracts to be "bad" and "time-consuming." Three of the five mathematics education Ph.D. candidates touted the virtues of ERIC but did not describe their mode of access. Three (8%) Ph.D. students, one from each discipline, declared the Internet to be a good source of information but were not specific about particular sites. Four (11%) students listed OLIN as a good to excellent source. Science Citation Index was mentioned as a "good way to move forward to more recent research on a topic" by a biochemistry–chemistry Ph.D. student, and a mathematics master's student observed that amazon.com was a good resource for books. A mathematics Ph.D. candidate found MathSciNet to be only an "average" information resource, and a physics–astronomy Ph.D. student highlighted NED, an extragalactic database from NASA, as an "excellent" source of information.

Twenty-six (72%) students follow a similar pathway when tracing and locating individual resources. In essence, they obtain a citation using the methods described above, search OLIN either in the library or remotely, retrieve the material from the library shelf, photocopy it, and then read the information. Six (23%) of these twenty-six students read the abstract or the entire article to ascertain its relevance before photocopying. Three (8%) respondents indicated that they find articles on the Web and either print the pages out or read them with their Web browser. The remaining seven (19%) students did not outline their search strategies but, rather, reported either difficulty using OLIN, difficulty limiting their searches, or a high reliance on obtaining articles via interlibrary loan (ILL) and/or Carl UnCover.

The students were then asked to describe the point at which they stop looking for an individual information source and how they feel at this point in their information quest. Two (6%) people, Ph.D. candidates in biochemistry–chemistry and mathematics education, claimed they never stop searching for information.

Eleven (31%) students said they discontinue looking if the item cannot be found in the OU library system, and an additional eleven (31%) said they discontinue their search after placing an ILL request. Four (11%) students discontinue when they believe the information they are looking for either does not exist or simply cannot be found, and a mathematics education master's student quits after having exhausted all the sources known. Three (8%) students abandon their search after a short time (approximately five minutes) and pursue an alternative route. Two (6%) students consult friends and colleagues before they cease looking, and two (6%) others end their search if the item is not written in English. Four of the eight physics–astronomy Ph.D. students terminate their quest if the information cannot be accessed and downloaded from the Web for free.

In contrast to the positive feelings cited at the onset of an information search, the students reported feelings of frustration, puzzlement, fatigue, disappointment, ineffectiveness, anxiety, and being lost when they decide to stop looking for an information source. One biochemistry–chemistry Ph.D. student wondered if the information from ILL or Carl UnCover was worth the paperwork and manpower required to obtain it, and another was concerned about missing "something simple." Two (6%) biochemistry–chemistry Ph.D. candidates were bothered by the time-consuming nature of the process but were hopeful that the needed information would arrive eventually. Two (6%) other Ph.D. students in biochemistry–chemistry said they feel happy when they stop looking because they have the information they need. Finally, the student who made the chef analogy earlier in the survey wrote: "the chef has found the recipe, has the ingredients; however, the pots and pans have been stolen, not to mention he forgot to pay the utilities and has no gas or electric to begin his masterpiece."

When asked how they decide which individual sources of information will be of use, sixteen (44%) students cited the correct topic being of the greatest importance and thirteen (36%) were concerned with the standing of the information source. The reputation of the article's authors was important to seven (19%) students, whereas three (8%) noted that the number of times the article has been cited indicates its usefulness. Seven (19%) students said they read the abstract or the article before they are able to evaluate its usefulness. The physics–astronomy Ph.D. candidate who had been at OU the longest commented that ease of access is an important factor in an information source's value.

Although nothing deters ten (27%) students from finding information, eleven (31%) cited problems with online databases.

The next question asked the students to describe how they use the information obtained. All of the students read the information source, and eight (22%) subsequently file the item in their homes or offices. Six (17%) students take this one step further and enter the citation into a citation database such as EndNote. Reading for three (8%) students consists of scanning for needed information, such as a chemical structure or the reagents used in an experiment, whereas seven (19%) students annotate as they read. Three (8%) other students read and then cite the source in a class project or in their thesis. The longest-term Ph.D. physics–astronomy student reads the information and then either files it or, if it is not useful, recycles the paper or deletes the file from the hard drive.

Finally, in learning about their information-seeking processes, the students were asked how they know when their search is complete and how they feel at this final point. More than half the students (55%) reported knowing their search is complete if they either find what they are looking for, obtain the answers to their question(s), or are able to solve the problem(s) at hand. Four (11%) students believe their search is complete when they exhaust all the sources available, whereas one concludes the search if the information cannot be located. Eight (22%) students perpetually seek information because, as one biochemistry–chemistry Ph.D. student wrote, "one idea bleeds into another, so it feels never ending." Two mathematics students, one master's and one Ph.D., claimed they do not know when their search is complete. Finally, four (11%) students deem their searches over when either time runs out, the project is due, or "the time involved has become more important than the discovery." At this ending point in their information searches, the students reported emotions ranging from relief, satisfaction, accomplishment, and success to disgust, frustration, exhaustion, and uneasiness. The mathematics education Ph.D. student who reported feeling uneasy said that "there is too much out there to choose from and [I] may have missed the very best one." Two analogies were drawn at this point. Again, the Ph.D. biochemistry–chemistry student feels like "the chef [who] bought some better pans and is cooking outdoors as nature intended," whereas a mathematics Ph.D. likened his feelings to those experienced when finding a good pair of shoes on sale.

Inhibitors and Facilitators to Finding Information

After being queried about their information-seeking processes and tactics, the students were asked to comment on factors that inhibit or facilitate their searches. Although nothing deters ten (27%) students from finding information, eleven (31%) cited problems with online databases, including not knowing the correct keywords, the Internet being down, the databases being too complicated to search, the item not being on the shelf, and there being no method to access individually authored chapters within books. Five (14%) students complained that time constraints inhibit their information searches, whereas one biochemistry–chemistry Ph.D. student reported being inhibited when the journals are housed in the main library and valuable time is wasted on physically retrieving the information. Being inhibited in their information searches created negative feelings in all the respondents. Descriptions of their feelings included "despondent," "lost," "frustrated," and "helpless." A biochemistry–chemistry Ph.D. student believes the "work would have been better if [I] had just found the material as originally envisioned," whereas another is ready to "rip [out my] hair!" Another biochemistry–chemistry Ph.D. student becomes "determined to do better next time," and yet another feels "deprived of useful information." One of the physics–astronomy Ph.D. students declared that when inhibited from finding information, the resources at OU feel "too restricted."

Fifteen (42%) students found that access to online databases such as OLIN, ERIC, and Chemical Abstracts Student Edition facilitates their information-seeking processes. Human resources, including library staff, fellow graduate students, and professors, were reported by thirteen (36%) students to be of assistance in an information pursuit. Carl UnCover and ILL were said to facilitate information seeking by three (8%) students, whereas another three commented that the order of the books and journals in the library are useful in locating the necessary materials. The senior physics–astronomy student is aided in information searches by a "good, fast Internet connection." The students expressed positive feelings when their information search is made easier. These feelings included "good," "happy," "pleased," and "satisfied." A Ph.D. student in mathematics education feels that "[my] time is actually respected by someone," whereas, physics–astronomy Ph.D. student felt that "the universe is functioning as it was intended to."

Presentation of Information

The physical science graduate students were next asked to describe how they present the information they have found.

Twenty-one (58%) students present it as a citation in a paper or in their dissertation. Six (16%) of the students said they present the information in a seminar, and five (13%) reported filing the information for future reference. Four (11%) students apply the information in their research, and another four use it when talking to their faculty advisor. In addition, three (8%) students noted presenting the information in their course work. Also mentioned by one student each was using the information for personal knowledge and when talking with a colleague. A master's student in mathematics education simply reported not presenting the information located.

Measurement of the Success of an Information Search

The students responding to the question on how they measure the success of an information search use one of five approaches. Ten (27%) students consider a search successful if they find what they are looking for, whereas nine (25%) deem a search successful if the information leads to an understanding of the topic or question at hand or their research project. Saving time marks a successful search for six (16%) students, and three (8%) based the success of their search on the grades they earn. The quality of the end product is important to three (8%) students, especially, as one biochemistry–chemistry Ph.D. said, "when a project comes out as well as I could do it, even if I had worked on it for much longer."

Choice of Information-seeking Environment

After being questioned in detail about their processes of information seeking, the physical science graduate students were asked to check on a list where they prefer to carry out their searches for information. They were asked to check all that apply. The majority (86%) of the students indicated the library, 42 percent their home, 39 percent their office, and 33 percent their laboratory as good locations to look for information. Four (11%) students also noted the OU computer laboratories as good information-seeking sites. One student, a Ph.D. biochemistry–chemistry candidate, also likes to look for information in old bookstores so as to have "materials permanently on hand."

When asked why they designated the above as their preferred places to look for information, convenience and/or comfort were cited by most of the respondents (92%). The fourteen (38%) students who found the library the most convenient place to look for information claimed they did so because the library has all the books and journals in one place, computer access to databases, and staff to provide assistance. Home was listed as being convenient by six (16%) students because they can be near their families and also have access to their personal computer. The advantage of searching for information from home is comfort for three (8%) students. Two (6%) students mentioned that they search for information in the most readily available and easiest-to-access location, and therefore search in all four places suggested.

After questioning the students about where they look for information, the next item on the survey asked, "Please describe your ideal information-seeking environment." For eleven (31%) students, the library is ideal. In contrast, one student desired "any place comfortable, NOT the library." Eight (22%) students declared that their ideal setting is anywhere there is a computer, preferably with a "fast Internet connection." A place that affords a quiet setting was ideal for five (14%) students, especially if there are either "big soft chairs," "minimum distractions," or "a good selection of printed materials." A biochemistry–chemistry Ph.D. candidate remarked that the ideal setting is one that "has what [I] need, [is] well organized, [is] user-friendly, and [is] accessible when [I] need it." Another Ph.D. candidate in biochemistry–chemistry commented that in the ideal location the search tools would be easily found and everything needed would be "on hand." Carl UnCover was given as the ideal information-seeking environment by another biochemistry–chemistry Ph.D. candidate, whereas another's ideal situation includes a "big desk, paper handy, bright room, [and at] room temperature."

Library Instruction Experiences

Finally, the physical science graduate students were asked whether they had received any form of library instruction while at OU, and if yes, to describe their experiences. Fifty percent of the students had received some type of library instruction, but few were able to comment on the usefulness or nature of the sessions. Comments ranged from "hands-on demonstration" to "group tour" to "someone talked to my math class last summer." A biochemistry–chemistry Ph.D. candidate admitted needing more knowledge, whereas another mentioned asking for help at the front desk. In fact, 83 percent of the students consult the librarian and/or the library staff when searching for information. They described their encounters as "positive," "helpful," "friendly," and "wonderful."

Discussion

This snapshot investigation of the information-seeking abilities and behaviors of thirty-six physical sciences graduate students at the University of Oklahoma illustrates that this is an information-literate microcosm. In accordance with the definition of an information-literate person given by the ALA's Presidential Committee on Information Literacy, these students are indeed "able to recognize when information is needed" and possess the "ability to locate, evaluate, and effectively use the needed information."[10]

The students demonstrate their information literacy ability by first realizing that they need information to support their research and course-related activities. After an information need is recognized, they search the panoply of information-locating tools available using authors' names and appropriate keywords. The students are aware that they must exhaust all available resources before ending a search and must employ rigorous criteria for evaluating the information obtained. They then present the information as a citation within a seminar, a paper, or a thesis.

These abilities surprised the investigator for a number of reasons. First, previously published information on the information literacy of undergraduates suggests that this population is not reaching its potential, and thus it seemed unlikely that such a great leap could be made between undergraduate and graduate school.[11] Second, the investigator has conducted a number of hands-on workshops demonstrating FirstSearch databases and Carl UnCover specifically for physical science graduate students. These sessions were poorly attended, especially by the mathematics and physics–astronomy students. The students themselves reported receiving little, or unmemorable, library instruction while at OU. Third, the investigator interacts daily with physical science graduate students who generally seem distracted and rushed when seeking information. It appeared to the investigator that thorough searches were not being conducted. It was these anecdotal experiences that led the investigator to believe that physical science graduate students are not reaching their information literacy potential. Yet, the students' thoughtful and often impassioned responses to the survey questions indicate otherwise.

The cause of the apparent transition in information literacy between the undergraduate and graduate years is not clear from this study, but one can conjecture that the students surveyed were more highly motivated than those previously studied. This suggestion is in spite of the positive relationship previously observed between academic achievement, and library anxiety and avoidance.[12] Alternatively, perhaps the observations can be attributed to the maturity of the physical sciences graduate students. College freshmen have been shown to experience a high level of library anxiety and avoidance, and this level declines linearly with each year of study.[13] Also, longitudinal case studies that tracked the information search processes of four students in their senior year of high school and again after four years of college found that the students developed a sense of ownership of the search process as they matured.[14] This was also the case in this investigation. The students became highly involved in their information-seeking quests as they considered how they should approach the search, weighed their options, and evaluated their results. The physical science graduate students at OU exhibited their maturity by being able to redirect their search if it originally failed by seeking assistance from the library staff when necessary and by realizing that, as scientists, their search for information is a lifelong endeavor.

This investigation also delved into the feelings experienced by the physical science graduate students during various stages of an information search. These questions were posed to ascertain the level of anxiety experienced by these students when looking for information resources. Constance A. Mellon has reported that 75 to 85 percent of undergraduate students experience an overwhelming sense of fear or inadequacy that inhibits their success in a library search.[15] Although some of the physical science graduate students surveyed in this investigation experience feelings of dread or frustration when beginning a search, none of them approach information searches fearfully. Qun G. Jiao and Anthony J. Onwuegbuzie described four antecedents to library anxiety that cause students to avoid the library: barriers with staff, affective barriers, comfort with library, and knowledge of the library.[16] The physical science graduate students surveyed did recall several aspects that inhibited them from locating needed information, but nothing that caused them to avoid the library. In fact, several students found the library to be the ideal information-seeking environment and have no difficulty asking the library staff for assistance. The majority even described their experiences as pleasant.

As we approach the new millennium and access to information becomes even more challenging, the investigator desired to learn what physical science graduate students envisioned as an ideal information-seeking environment. The purpose of the question was to stimulate their imaginations with regard to the possibilities that existed for an ideal information-seeking setting in the future. None of the students proposed anything unusual or fantastic, favoring the library or their home for information seeking. Comfort, convenience, and time saving were the key aspects. The physics–astronomy students showed the greatest concern for technology as the cornerstone of an ideal information environment, simply requiring a computer with a high-speed Internet connection. Similarly, physics–astronomy faculty members demonstrate a high degree of reliance on electronic journals and databases for information seeking.[17] This electronic-based information-seeking process of physicists and astronomers is perhaps the early model for the information-seeking behavior that will emerge in the future for all physical scientists.

Conclusions

Graduate students in the physical sciences at OU exhibit a high degree of information literacy. They are able to find, effectively use, and evaluate information to meet their specific needs with minimal anxiety. How they become information literate is not apparent from this study and warrants further investigation. Learning how this is achieved may help foster information literacy in the undergraduate population.

Even though academic librarians are uniquely positioned to foster information literacy, library instruction intended for the benefit of physical science graduate students at OU has not been well attended, or remembered, despite encouragement by faculty advisors, flexible scheduling, and the hands-on nature of the sessions. It is recommended that future library instruction be tailored to meet the students' specific needs. Students are more receptive at the beginning of their academic careers, yet they require expert information-seeking ability as they progress in their program. Therefore, separate programs should be planned for the beginner, intermediate, and advanced searcher. For students still involved in course work, the workshops should highlight the needs of a particular class problem or assignment, including patent searching or use of Chemical Abstracts. For senior graduate students, the sessions should be designed to address problems and topics related to particular research specialties in the physical sciences, such as heterogeneous catalysis, supernovae, or number theory. When creating library instruction programs, the importance of convenience, comfort, and time saving to the student audience, should be kept in mind. Strong partnerships with faculty are imperative for these plans to succeed.

Although the respondents were information literate and experienced minimal library anxiety, only a small fraction of the total number of graduate students in the physical sciences responded. Particularly absent were those students whose native language is not English. High levels of library anxiety have been reported in these individuals, yet very little has been written about their library experiences.[18] Special attention must be paid to this unique group of students to ensure that they are able to locate, evaluate, and use the library resources available. One means to this end may be the production of multilingual Web-based library instructional materials.

It also is important to note that even though the physical science graduate students at OU are information literate, they have not entirely embraced the Internet as the key to the world of information. It is but one tool in their kit for information seeking within the entire framework of the academic library. The potential of the Internet is great for the development of information literacy, yet, as the physical science graduate students demonstrate, it should not be considered the only means to achieving that end. Consequently, for lifelong learning to take place, an individual must be able to find, use, and evaluate a range of information sources, including, but not limited to, technology and computers.

Notes

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12. Jiao, Onwegbuzie, and Lichtenstein, "Library Anxiety," 158.

13. Mellon, "Attitudes," 137–39.

14. Kuhlthau, "Longitudinal Case Studies of the Information Search Process of Users in Libraries," 257–304.

15. Mellon, "Library Anxiety," 160.

16. Jiao and Onwegbuzie, "Antecedents of Library Anxiety," 373.

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