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Undergraduate Science Students and Electronic Scholarly Journals

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Phase I of a 2-phase project funded by the NSF-National Science Digital Library Project used focus groups to determine how undergraduate science students perceive journal literature and how they use digital library resources. Their perceptions and use are contrasted with faculty and graduate teaching assistants in engineering, chemistry, and physics. Undergraduates have difficulties understanding journal articles. Although they consider themselves experts on the web, they rarely use online indexes or e-journals unless required to for class. E-Journals should be incrementally introduced to students starting at the time they declare a major. E-Modules developed by the library and faculty could introduce the structure and content of articles, including links to glossaries and encyclopedias, tutorials about the publishing process, and study of the structure of articles.

Introduction

A two-year project for the NSF National Science Digital Library aims to gain an understanding of what features will make scholarly electronic journals useful to and used by undergraduate science students. This will be accomplished in two phases: Phase 1, reported here, to establish (through focus groups at the University of Tennessee, a literature review, and a review of related research projects) what is needed in electronic journals systems to encourage sustained use by undergraduates. Phase 2 (2003), by working with the Department of Energy's Office of Scientific and Technical Information (OSTI) to test undergraduate and faculty reactions to selected technological and pedagogical enhancements.

To accomplish the objectives, Phase 1 involved studying several questions, including:

1. How and when are scholarly journal articles introduced in the undergraduate science curriculum?
2. What do faculty expect their students to understand about scholarly journals?
3. How do undergraduate students learn to understand the structure, purpose, and content of scholarly journal articles?
4. How do undergraduate students search for information needed for their schoolwork?
5. What features of online systems and web search engines do undergraduates understand, use, and value?
6. What role do the library and librarians play in helping undergraduates learn about scholarly journals?

The answers to these questions will help us design more useful electronic journal systems, better instructional materials and coursework involving scholarly journals, and lead to more understanding and use of scholarly electronic journals in the National Science Digital Library (NSDL) by undergraduate students.

Literature Review

There is abundant evidence that scholarly journals are not only widely read by working scientists, but they are extremely useful and important to scientists' work, whether that work be teaching, research, administration, or other activities (Tenopir & King, 2000). Studies show that many faculty and most students prefer electronic journals to print and the convenience of linked desktop access likely results in a greater amount of reading of journal articles. Research shows that the amount of reading per scientist per year is increasing, probably partly due to this increase in electronic availability (Tenopir & King, 2000).

Educators need to be able to take full advantage of tools that provide students with access to digital collections of

high quality science literature. How that is best accomplished is debatable, however. Fortner describes a "jigsaw" approach whereby students become experts on a specific scientific journal or secondary (interpretive) print medium, then introduce it to peers (Fortner, 1999). This assignment acquaints students with various categories of literature in the field of environmental communication. Students learn to ask general questions about the publications including: "How much does the publication cost? How often is it published, what subject areas does it discuss? In what ways does the tone and vocabulary target the specific audience?" (Fortner, 1999).

A chemistry professor at St. Louis College of Pharmacy teaches students to read the primary literature and was surprised by the success with which her students learned to read professional literature in microbiology. The class requires no textbook, but textbooks are made available on reserve. Most of the lecture part of the course is structured around assigned articles from primary literature. Students complete an assignment that directs them to several well-indexed resources including scientific dictionaries. Students are expected to read through the article, underline words and phrases they do not understand and look up the definitions. The students discuss the unfamiliar words or concepts and the definitions they found (Herman, 1999).

Hanks and Wright, professors of chemistry at Furman University, teach an undergraduate class in which students are expected to complete information searching assignments designed to stimulate the types of searches that a practicing chemist might be required to perform periodically. Students are exposed to a variety of printed and electronic information resources, ranging from chemical abstracts to primary literature to various compilations (Hanks & Wright, 2002).

Many faculty also support the concept of personalizing the goals of undergraduate research. Stage and Bowman recommend providing a time and structure to discuss the literature with the student. An example is given of a student who was unable to articulate her questions until the instructor generates questions such as, "What was the author's hypothesis?" (Bowman and Stage, 2002).

Enough efforts have been initiated in scientific information literacy that educators can share perspectives and identify potential pitfalls. Brem discusses implications of current science literacy movement in college teaching. Some primary literature includes only the scientists' conclusions without providing adequate details about the data and processes that support their claims. Brem warns that when students read articles that omit information, they tend to supply "unsubstantiated narrative explanations" when evidence is lacking. Assignments focusing on critical reading of primary scientific literature should require students to discern between what is evident and not evident within the article. Brem supports teaching students to question covariational information by techniques. One such technique involves creating a matrix by crossing the presence or absence of the proposed cause with the presence or absence of the target effect.

Students do not come to college with an inborn knowledge of the importance of scholarly scientific literature, nor do many of them possess the skills and knowledge necessary to evaluate quality, read and understand scientific literature, or know when to use journal literature in their work. Recent studies have shown that undergraduate students often use the sources that are most convenient to them, rather than carefully selecting the highest quality materials. Easy availability of full-texts of articles is the one overriding factor that undergraduate students take into account when selecting a digital resource for research – even if another source may provide indexing and abstracting data for higher quality literature (Tenopir 1999).

As college students grow in experience and knowledge, part of the learning process is recognizing quality science reported in peer-reviewed journals. This learning process takes place in the classroom, through library instruction classes, or through feedback from professors in graded papers, but is rarely, if ever, incorporated into the digital library systems that provide access to this journal.

Method

Focus groups were used to gain an understanding of how students use journals and online systems, and how they might be incorporated into the undergraduate classroom. All group sessions were tape-recorded and transcripts were prepared from the tapes, with the anonymity of participants protected in the transcripts. Analysis of the transcripts provides insights into the opinions and motivations of university science faculty and students.

Focus groups were held for lower division undergraduate students, graduate students who are also graduate teaching assistants (GTAs), and faculty. Participants were selected from the chemistry, physics/astrophysics, and engineering departments at the University of Tennessee. A total of 7 undergraduates, 4 graduate students, and 8 faculty participated in 6 sessions. Faculty were recommended by subject specialist librarians and students were recommended in turn by the faculty participants. Focus group participants are likely high end library users (faculty) and honors students. Two rounds of focus groups were scheduled, the first to discover how the participants used print and electronic journals in their classes and the second to concentrate on the use patterns of specific features of electronic information retrieval systems.

Analysis

Analysis of the focus group transcripts reveals five themes that emerged in the discussions by all three groups:

- Variations by grade level;

- Variations by subject discipline;
- Access means for articles and search strategies;
- Variations in types of literature required;
- Problems with understanding journals or accessing information.

Variations by Grade Level

Lower division undergraduate science students in our focus groups report little knowledge or experience with print or electronic scholarly journals. Their coursework is concentrated on textbooks and classroom lectures, and is perceived as being difficult and time-consuming just to learn basic concepts. Journal literature appears too difficult, they are not familiar with the library, they prefer to work from their homes, and, their professors do not require use of journals. For these reasons, there is limited journal usage in most classes.

Although libraries typically offer introductory classes for library resources and information technology, undergraduate students who do not participate may not be exposed in the library capabilities. Whereas some chemistry and physics students in our groups have visited the library for assignments, the engineering students in our focus groups have not.

Undergraduates are not usually required to read journal articles in science classes. The students and faculty feel they are overworked with the regular course load and do not need to master scholarly journal literature until they are committed to a major and in upper division classes. Some believe, however, that it might be appropriate to expect all students to achieve a measure of familiarity and mastery with journal literature.

Although faculty generally do not assign specific articles to lower division students, seniors might receive an assignment to pursue a topic and research it through journal literature and possibly discuss in class. From time-to-time, students may be assigned a project requiring them to locate bibliographic information about articles.

The lower division students also feel scholarly literature is too difficult for them, which may be a result of academic immaturity and experience more than from true exposure to the journal literature. Faculty believe the students consider articles to be a snapshot of the most recent discovery and do not include much preamble. Students do not seem to understand the evolution of the research, discoveries, and subsequent publication. Faculty believe students are unable to understand the theoretical content of scientific journals, and even if they did, they wouldn't understand the background and continuity. It is thus very difficult for students to understand and use journals effectively.

Students overlook the concept of peer-reviewed journals especially because they do not understand the publishing and the peer-review process. All levels of students believe this concept is for someone who is a serious researcher and not important for most undergraduates. Only when a person wants to publish their thesis or important work does the quality of the journal becomes important.

Some faculty participants spoke from a cognitive perspective about the use of journal literature being a creative, critical, evaluative and scientific skill that should be taught as part of the educational structure. Literature use is an intellectual skill that is part of the ability to reason logically, make critical selection, and applies equally to research as it does to browsing through the library.

In summary, the undergraduates in our focus groups neither perceive the need for nor want exposure to scholarly scientific journal literature. They feel overworked with the science and general education curriculum and seem to lack an academic maturity to effectively absorb and use the information. However, once these students make a commitment to a major, usually in their junior year, they should be introduced to the journal literature of that discipline, which would be useable for thesis, research, and graduate school. As students mature, they become more serious about their studies and might pay more attention to journal articles.

There is a consensus by faculty and students, however, that a class should be offered on proper research and journal literature in perhaps as early as the sophomore year to offer familiarity and instruction for later use. It was suggested such a class might be a 1-hour seminar course.

Variations by Subject Discipline

There are differences in the use of journal literature between the fields of chemistry, engineering and physics. Chemists at the University of Tennessee place more importance on journal literature and introduce it more systematically - for example, there are undergraduate classes at U.T. that focus specifically on the literature of chemistry. It seems to be less important in U.T. engineering classes, and the participants in our focus groups reported that chemists use literature more than engineers. Faculty focus group members believe eprints and eprint archives are not used in chemistry and engineering due to a concern about poor quality and duplication.

Physics faculty reported that original literature isn't introduced until a student's senior year when they are assigned a special topic or project. The use of original literature by undergraduate physics majors in physics courses is minimal and journal literature is not an undergraduate requirement.

In astronomy, undergraduates at U.T. demonstrate use of journal articles through written assignments and discussions. Some specific online sources are required, for example, astronomy students were referred to the "Nine Planets" website by professors. Physics undergraduates and graduates use Google and other general search engines, but,

for more scientific research, they use The American Chemical Society's system "SciFinder" for better focus, reliability, completeness, better citations and a higher level of professionalism. The students compared Google to newspapers and scientific engines to "professional" literature. Physics professors direct their graduate students to eprint archives such as arXiv.org or its subset astro-ph and believe they are able to judge quality.

Engineering students said the point when students are assigned journal literature in their U.T. classes varies widely; however, faculty believes it depends on the class. For example, one professor might assign a research article for students to analyze and give a report, while in a Civil Engineering class, a professor might require a general search to find information. An example of the latter was given by one professor who recalled helping students locate information on the failure of bridges. The first accounts come from newspaper articles of bridge collapses; later in time, there are computer models that show how the bridge will sway. Students track the history of the collapse through the literature.

Access Means for Articles

Faculty commented that there is not much writing in undergraduate science classes, therefore, there will not be much journal reading. Also, undergraduates have so much in their curriculum to cover, where would faculty include perusing journal literature?

Over the past few years, the main difference in journal literature access is the Internet. Only a few graduate students referred to doing manual research in the library.

All faculty believe students use more electronic resources now than in the past because of accessibility. Electronic resources are plentiful today and they don't have to go to the library to get them, but can access them from home or dormitories. Full-text databases are the most frequently used sources.

All of the graduate students estimate they use Internet search engines or full-text sources anywhere from every day to five times a week from home or school. Graduate students also estimated they used abstract and indexing database systems such as SciFinder and Web of Science, ranging from daily to once a month or so. All are accessed through the library homepage.

Professors believe the problems students encounter when they search for relevant journal articles center on searching knowledge and techniques. Students often have difficulty with database acronyms so they are unable to identify correct databases and may search in incorrect databases. There are numerous databases to choose from which lends to their confusion; they will use the path of least resistance and if they find a database with few articles on their topic they will stop there.

Overall, students and faculty report they use general search engines, most likely Google, for most work, however, if the search is technical, the following are used:

For all disciplines: SciFinder, Vivissimo, Web of Science.

For physics and chemistry: SciFinder, Web of Science, Copernicus, Nine Planets, Inspec.

One method undergraduate students use to judge the credibility of websites and web publishers is by the domain name, such as ".edu", ".gov", and ".org". They will also look at the site design. For example, if it is "pink with flowers", they will not look at it seriously; if it is "black and white with a lot of text", it is probably interesting.

Undergraduates scan images, pictures, and charts in articles for illustration of concepts. The pictures usually include a simplified caption as an indicator of the content. They will use the caption as a clue to the relevance of the article.

Although they are familiar with them, the graduate and undergraduate students in our focus groups do not use preprints or preprint databases. One student reviews them to increase his breadth of knowledge, but if he finds any useful information in preprints, it is by accident.

Variations in Types of Literature Required

Undergraduates were asked about what was required reading in their classes in chemistry, physics and engineering. Their responses include textbooks, lab journals, chemistry magazines, fiction, and interpretations in chemistry class. In Engineering they also receive specific handouts, such as details for design types. Upper division undergraduates may be required to locate journal articles, but they are usually for general information rather than a specific research project. For example, if they read a certain article it might help them better understand what they are doing in class assignments.

GTAs and undergraduates rely on publishers and aggregators such as Elsevier, IEEE journals on applications and physical science, *Physics Review* and The American Chemical Society. One GTA commented that the general research engines we have mentioned here such as Lycos, and Google, are very good for general topics, particularly outside their field, but they aren't as useful as they could be for details within the field.

Graduates perceive there is junk in journals. They mentioned some journal titles that they believe are "pretty bad", even though the journals are peer reviewed. They feel, "If you give an article to some people that like you, your article will be accepted". "If the editor selects the reviewer, then that article has a less likely chance of making it through, especially when they are anonymous

and the reviewer can just tear it to pieces. Many times you will get better quality journals that way."

Although not required, faculty believe all students should be aware of society publications such as those by the American Chemical Society. The students might know the names of the societies, but not the names of particular journals. Students also need to know the difference between newsmagazines such as *Newsweek* and journals. Faculty believe students do not understand "refereed".

Journal articles are seldom assigned by the faculty in our focus groups. Even if students are looking for standards and patents, it does not mean they necessarily need journal articles. Sometimes they are encouraged to read journal articles if the professor thinks it is important for the topic, but usually not.

Faculty also emphasized the highly specific character of journal articles. When they make an assignment in an undergraduate course it is necessary to give them a route into the paper by allowing them first to start with a simple encyclopedia. Then move from the encyclopedia to a more technical treatise, then perhaps from the treatise to a monograph, then review articles, and then into the article. This is a process that is not restricted to undergraduates and is done often to ease a student into the background material and bring some clarification so the journal article is meaningful.

Physics, chemistry and other disciplines have "intermediate journals" or even newsletters that provide a semi-popular discussion of the research forefront in the various fields. The writing in them is brief, succinct, and meant to be relatively simple. Faculty do not have misgivings in referring students to this literature. For example, *Chemistry and Industry* was mentioned as a good intermediate journal as a gateway they will refer students to in order to give them an overview, quicken their interest, and move them toward the research frontier.

Faculty also think many students do not understand there is a library reference department. They believe that students do not know they can get help with a handbook, literature, tables of data, standard spectra collections, etc. For example, in chemistry, if they need the melting point of a compound, they don't know where to find it. Although much information is becoming available electronically, they need to know the basics. Physics faculty believe handholding is necessary.

Problems with Understanding Journals or Accessing Information

Faculty explained that when they ask a student to search for something, the student might input one word and retrieve more than one hundred items, which tends to be discouraging. Pages have so much information that students do not know what to do. Perhaps a Pop-Up (context sensitive) Help function would be beneficial – something to help them and tell them how to search. Intrusive, context sensitive Help would also help develop critical thinking and force students to think about the search process. ("Push it toward their eyes so they can see it.") One faculty does check "Help" to see what is there.

Faculty also believe students have problems with literature because much of it is just over their heads. They do not have the background to absorb what is published in a journal.

Faculty commented that students need to at least be able to get to a journal title, with an assignment such as, "Find volume so-and-so", "Page so-and-so". Then the system could give them the link to that journal title so they navigate through and get the article.

Faculty believe students have lost their physical perspective because everything is the same. They don't know the difference between the catalogue and the databases because it's all on the computer– all on the web – and they don't know the difference because they never saw it physically. Another faculty member responded that surfing the web and making them go through all of "that stuff" is not necessarily critical thinking, it is just "information gathering".

A major effort needs to be made to identify the deficiency students have in searching for information. No systematic development of information literacy is in place "They get a scrap here, a scrap there". Faculty try tiny bits in some courses, but it is heterogeneous with no homogeneous, dedicated effort to make information literacy a part of the discipline. Being optimistic, if the budding professionals in various fields are made aware of information resources, it will have some effect on future performance. One faculty member feels it would be a wonderful thing for a student to come into a junior course, when he is beginning the advanced part of study, knowing how to get into the literature without the instructor having to make the effort to introduce it individually.

Faculty had several ideas for improving use of general web search engines. First, make sure students understand no search engine is complete and if they are looking for a generalized topic, don't stop with just one. One faculty member has a rule to always ask students to use at least three search engines when looking for any topic.

Another suggestion is having students look at the way a search engine operates, how it uses parentheses, quotation marks, how entries are made, etc., although that may be as difficult as getting them to read the introductions to their textbooks. Students are likely to miss a great deal if they don't understand how to use search features, such as how to put in the Boolean operators.

Having faculty responsible for information literacy introduction may be a problem. One faculty member

commented that, "We are all doomed with the utter volume of content we want to communicate and bring across to the students. This utopian idea of education, which they love, is wonderful, but when you push most of us to these other aspects, our content overwhelms us and we say, Good heavens, we are five lectures behind! Are we going to assign nine chapters in the last week? We can't possibly get through this course without teaching this really deep thing, which happens to be my specialty."

Faculty say searching depends on the keywords. If a searcher misses a keyword, information is missed. "It's a matter of luck. Look at a few and see what's in there. Maybe you can pick up some keywords other people use and try to use them. It might be more useful if they could provide things like whether the search is missing, whether those are similar words."

SciFinder is a favorite because it retrieves good information with minimal stress on keywords and compensates for misspellings. Faculty also noted that it is important to remember that SciFinder has the American Chemical Society and all of its financial resources behind it.

Faculty discussed what happens when students get out into the national labs and industry - where are these people going to work? One guessed that the quality of searching is going to be much more important than the speed and the time constraints. The question then becomes, are the students willing to do the work that will prepare them to go into that environment? That is what the educational process is all about.

Conclusion

The focus groups of students and faculty identified many barriers to use and understanding of scholarly journal articles by science undergraduates, but also highlighted the desirability of exposure to such literature during the second or third year of the undergraduate experience. Students feel comfortable with general search engines, but are less familiar with specialized sources and journals.

Several positive suggestions to make undergraduates become more information and journal literate emerged from the focus groups. Because faculty do not have time to develop information content, class modules that introduce journal articles and the publishing process to science students would help faculty. Such modules need to explain the structure and content of the articles and include links to other materials that would help students understand the content. For example, links to glossaries and encyclopedias would help early readers of scholarly articles. Highlighting the hypothesis and main conclusions would help students focus on the main points of the articles. Academic librarians should work with science faculty to develop these modules and help introduce journal articles within the context of the science classes.

Much introduction to search systems and journals is now "hit or miss" in the science curriculum. A coherent information literacy plan that builds over all four years of the undergraduate experience would help students better understand search engines, search strategies, and content. A first or second year student may not be ready to understand scholarly article content, but can be introduced to general sources and the publishing process. At the time they select a major, they should be introduced to the databases and search systems of their discipline. Structured e-journal modules could be the first exposure to the peer-review process and to peer-reviewed literature, before students begin finding and understanding journal articles on their own. By their senior year, the science students should be able to build on their experiences to fully understand the importance and content of scholarly literature.

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