Learner Adaptation to Digital Libraries by Engineering Students

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Digital library: *"A managed environment of multimedia materials in digital form, designed for the benefit of its user population, structured to facilitate access to its contents, and equipped with aids to navigate the global network ... with users and holdings totally distributed, but managed as a coherent whole."*

--Mel Collier, *International Symposium on Research, Development, and Practice in Digital Libraries 1997*

Abstract

This paper examines how digital libraries (DL) may be integrated into the learning resources of engineering students. The advent of digital libraries has opened revolutionary opportunities in engineering education. The diversity of resources offers rich opportunities to enhance engineering education, providing access to data, codes, problems and information that are far beyond what each individual teacher has time to develop. However, students are largely unaware of the DL resources, as well as the most efficient manner to utilize them. Learners still require a disciplined study scheme and expert guidance to select and convert information to lasting knowledge. To complicate matters further, professors are hindered by the lack of systematic knowledge on the attitudes, skills, and learning styles of students. This problem is most acute at for students at the freshman through graduate levels in advanced engineering programs. This paper lays out the problems and provides initial results on how students are accessing internet-based material in engineering courses, as well as ideas for improving their ability to reach the best problem-solving resources.

I. Introduction

The advent of digital libraries has opened revolutionary opportunities in engineering education. Access to technical information has literally become possible at the speed of thought. The diversity of resources offers rich opportunities to enhance engineering education, providing access to well-crafted products that are far beyond what each individual teacher can develop in a given course. Combined efforts by several government agencies led by the National Science Foundation have invested in the development of "national digital libraries" devoted to science, mathematics, engineering and technology education. Such efforts aim to bring peer review, archiving, classification and organization to digital resources. This paper examines some of the issues faced in the classroom as engineering faculty seek to effectively utilize such resources in engineering curricula.

Learners still require a disciplined study scheme and expert guidance to convert information to lasting knowledge. To exploit the true potential of digital libraries in education, one must attain the stage where individual learners do most of the searching, finding and assimilating. Currently they are inhibited in this process because the engineering content in the large national sites is not yet well known, nor easy to locate using the popular search engines. While considerable work has been done at the K-12 level to study how students access and utilize the Internet, this research is not yet available for graduates and undergraduates in advanced engineering programs. The objectives of this paper are:

1) to relate research on learner styles to the role of such digital resources for engineering students.

2) to explore some aspects on how engineering students are adapting to the use of digital library resources.

II. Learning in a Complex Educational Environment

The technology of access to information has changed drastically over the past decade, and engineering students are well informed to the technology (the Internet) itself. However, there is a dearth of published information on how students are in fact using this technology and how their learning methods change as they mature through their collegiate matriculation. Much of the available literature is focused on attempts to reverse the high attrition rates encountered at the freshman level or to address deficiencies in the preparation imparted by engineering curricula for lifelong success. Several classroom experiments have documented issues in holding students' interest and enhancing their communication skills. Experiential learning, team projects and real-life examples motivate students in the short term, but research is needed on how students find and select resources, learn skills, and integrate learning across levels (vertically) or disciplines (horizontally) using the Internet. In Table 1 are cited some principles extracted from research on technically complex educational environments. Each of these ideas becomes valuable when considering how to improve students' learning using digital libraries.

It is also important to relate students' aspirations regarding learning to the standards of learning and achievement that the faculty perceives as needed for future excellence. Students' fundamental motivation level and interest in engineering are extremely high when they arrive at their chosen university. They may come from all over the US and several other nations, and they bring a diversity of attitudes towards learning and technology. One result is that the pace of learning in courses is usually very high. The teacher's challenge is to provide useful and relevant guidance to extremely talented and independent individuals. Students use resources available over the web with confidence and comfort – the issues are to see where they find them, how they select them, and how to direct them to resources that the faculty believes to be most appropriate.

III. National efforts to develop a SMET&E Digital Library

Deliberations on the development of the National Science Digital Libraries [16-21] have led to the creation of approximately 43 funded projects on the NSDL, in addition to several large projects under the Digital Libraries Initiatives numbered 1 and 2. Points relevant to the present paper are summarized from Ref. 16 below. DLs can be used for the following:

- Incorporate inquiry and collaborative learning in large classes
- Help assess learning outcomes

- Document learning gains at departmental and institutional levels
- Provide learning resources directly to undergraduates

In utilizing digital libraries, teachers must be concerned with the following:
- How often will undergraduates access the DL?
- What is the need for intelligent search techniques?
- What techniques can be used to inspire and facilitate user contributions of material?
- What does the DL need to satisfy user needs: "inspire learning of undergraduate SME&T"?
- What is the need for adaptive, flexible and responsive to unforeseen needs and problems?

While the aim is to bring digital resources into the hands of students in technical disciplines, the approach to the above problems so far has been conducted from the perspective of the librarian and the social scientist. In the 1990s, there was a major thrust at NSF to bring psychologists and researchers in the cognitive sciences into the business of engineering education, and to apply the research literature on cognitive sciences to the teaching of engineering. However, there has not been a commensurate effort to educate the social scientists about the true nature of advanced engineering and the people who learn and teach engineering subjects. To put it succinctly, engineering faculty positions are not usually held, nor courses taught by social scientists, and with good reason. As a result, much time and effort appear to be dedicated to discussions on conflicts between teaching and research, inspiring undergraduates to try getting experience in "professional" environments, etc.

Table 1: Summary of principles from previous work [1-15]

Using anecdotal evidence to implement target standards, usually erring on the side of mediocrity, is very detrimental to SME&T education and research
Schema acquisition is the primary component of skilled problem-solving performance
Learning through schema acquisition is hindered if instructional material misdirects attention and imposes a heavy cognitive load
Instructional material that requires integration of disparate sources of mutually referring information (e.g., text and diagrams) imposes a heavy cognitive load.
Radical recasting of instructional formats in most technical areas needed
Focusing on objects and mediating artifacts of actual processes of collaborative problem solving is useful in horizontal dimension of expertise.
Small-group learning, both cooperative and collaborative, promotes greater academic achievement, more favorable attitudes toward learning, and increased persistence through SMET courses and programs.
Technological advances allow vertically integrated schemes to be considered, with students learning by iteration.
Rote memorization provides little basis for the transfer of information from one class to another (near transfer) or from school to work (far transfer)
Re-organization of the order of presentation, homework and evaluation schemes can produce a large increase in the amount of "material" absorbed by students in the same time.
Material must be presented in multiple contexts for clarity to ensure that students can retrieve information in non-context (near and far transfer) problems.

The reality at a modern engineering school is vastly different. Professors literally have to scramble to stay ahead of the soaring aspirations of students, and teachers are always starved of resources to enable eager students to work on research/design problems. The synergy between research and teaching is complete, and even freshmen are a part of this coordinated team environment. So one must ask: "Are these students taking advantage of the valuable resources developed by NSF at such great cost for their benefit? If so, how? If not, why not? In either case, what can engineering faculty do to enhance this experience and improve the utilization of these resources?

In the next section, this paper examines whether current students, with their hectic schedules, are likely to find existing DL resources, and once they find the DL, what resources are there to help with the learning process. This is examined using a simple search experiment mimicking current student practice, confirmed by student inputs at all collegiate matriculation levels.

IV. Experience of Seeking Aerospace Engineering Resources on Digital Libraries

A recent progress report on the NSF funded NSDL cites archival collections of over 10,000 items cleared through formatting and quality control processes. To determine how easily students could utilize the DL, simple experiments were conducted to simulate the most usual practices among engineering students at Georgia Tech who seek resources on the internet. A search for engineering resources created/available through NSDL was made using "Google", (www.google.com), which is today considered to be one of the most popular web search engines, to confirm the growing awareness of the situation through quantitative metrics.

The first portion of the experiment was to determine how easy it was to find a digital library containing engineering resources. A "Google" search under *"math science digital library*" in April 2001 brought 27,000 responses. The same search in January of 2002 resulted in 176,000 responses. A similar search for *"engineering digital library"* brought **zero** responses in April 2001, while in January 2002, the search resulted in 583,000 responses. Clearly the DL effort is making rapid strides in making material available via conventional search engines.

As part of this search, the content of the top responses was evaluated to determine if the searches yielded actual useful information. Student response has been to look at the first 10 to 20 citations returned in a search. After that, the students have indicated that they will attempt different searches. The first 100 sites located under each of these searches in April 2001, yielded a total of three sites with appreciable content suitable for engineering courses. In January 2002, the top 40 sites located under the "engineering digital library" yielded only 4 sites suitable for collegiate investigations, as shown in Table 2. These sites were listed as sites 1, 2, 30, and 38. These sites found with engineering course modules, problems etc. usable by students were:

1) #1, the SMETE Digital Library, http://www.smete.org. This web site provides materials at all educational levels and is headquartered at the University of California, Berkeley.
2) #2, the NEEDS site, http://www.smete.org Lesson modules and tools developed under NSDL were found at the NEEDS site [22] by searching specifically for that site.

3) #30, the "Aerospace Digital Library"[23-25] created by the present PIs. This was found to have been spontaneously reviewed under a Science Education site [26] as being suited for learners at all levels, K-12 and upwards in science and engineering.
4) #38, the "Australasian Digital Library", http://avel.edu.au/. This web site contains a plethora of material from online textbooks to an online bookstore to purchase copies of texts.

Table 2: Top 40 sites found in Google Searches for Engineering DL content

Segment	True DL Collections	Technical Paper Collections	Computer Research	"404" or irrelevant	"Paper" Library Portal	Project description site Or Press Release	Misnamed - <10 examples
Top 10	2	4	1	1	1	1	
11-25		2			8	5	1
26-40	2	6	1	1	2	3	

There are several obvious problems with setting students to try and find an appropriate digital library. While in the context of this paper the definition of digital library is one where the actual content is viewed on the web, the term "digital library" is utilized on the web indiscriminately. Thirty percent of the top 40 sites are nothing more than technical paper collections by universities or professional societies that require payment of some fashion to access. Another 27.5% are simple digital portals to view the card catalog of "paper" libraries. Almost another 25% are sites advertising or describing digital library initiatives or projects. Because of this "clutter" in search results, students will get very frustrated unless the professor actually identifies the digital libraries that the students should utilize.

Table 3: Aerospace Engineering Content in Top 4 EDL Sites

Digital Library	Aerodynamics	Airfoil	NACA0012	Flight Mechanics	Avionics	Longitudinal Control
SMETE						
NEEDS	3	0	0	109	0	94
ADL	404	196	0	82	34	6
AUST	10	0	0	2	2	0

Once the digital libraries have been identified, the next step is to find relevant material to the problem being researched. In order to test the applicability of these digital libraries to Aerospace Engineering needs, several test searches were accomplished. First, the general categories "Aerodynamics" and "Flight Mechanics" were searched, followed by "NACA0012" and "Beam". The results of these searches for the four digital libraries found by the Google searches are shown in Table 3.

Aerodynamics - Airfoil - NACA0012

The NEEDS site returned 3 hits on the keyword *Aerodynamics*, but of these only one was a citation on the computation of aerodynamics, and that was for a bicycle. A more specific search for a NACA0012 Airfoil using the keywords *NACA0012* or *airfoil* yielded no hits,

The ADL web site returned 404 hits on the keyword Aerodynamics, including course notes from Freshman to Graduate levels, examples, demonstrations, and research papers and results. 196 hits were returned for the keyword *Airfoil*, none for *NACA0012*.

The Australasian site returned 10 hits on the keyword *Aerodynamics*, including an online textbook at the sophomore-junior level, research web pages at Australian Universities, technical papers on aerodynamics, and professor web pages. No hits were returned for the keywords *NACA0012* or *Airfoil*.

Flight Mechanics - Avionics - Longitudinal Control

The NEEDS web site returned 109 hits on the keywords *flight mechanics*, including course notes demonstrations, applets and research results. Many of these were not applicable to flight, as the search engine provided results for the Boolean phrase *flight or mechanics*, and so approximately 80% were not applicable to flight mechanics. No hits were found for *avionics*. 94 hits were found on *longitudinal control*, but again a large percentage had no connection with longitudinal control. Of the hits that did completely match, there were contained discussions, demonstrations and applets.

The ADL web site returned 82 hits on the keywords *flight mechanics*, including course notes and research results. 34 hits were found for *avionics*, primarily as part of course notes, and 6 hits were found on *longitudinal control*, primarily as research results.

The Australasian site returned 2 hits on the keywords *flight mechanics*, including a discussion on flight data recorders and a university web site with class information. Two hits were found for *Avionics*, but they were both industry company web pages. No hits were returned for the keywords *longitudinal control*.

V. How these Digital Resources Can Be Utilized Effectively in Engineering Courses

Research on learning using internet resources has been growing over the past decade, but most of the available work on engineering learners is at the freshman level, and much of that is related to the problem of improving retention of students, not on improving the level of excellence that students can achieve using these new capabilities. Since Fall 1998, usage of internet-based resources has been incorporated into engineering courses in the authors' School. The Georgia Tech-based digital library (ADL) is provided to the student as a starting point in the process. The experiences are discussed briefly below.

a. Freshman Design-based Introduction to Aerospace Engineering [28]

In this course students use the internet to find data on aircraft and spacecraft design parameters, and they then use them to get a "feel" for numbers, a simple version of the process of developing benchmark data as part of the conceptual design process. Introductory material is given on pre-developed web resources through the ADL, and links are provided to appropriate resources at NASA, Air Force and aircraft manufacturers' sites. Later on, students use the internet to work in teams of two and post their designs to their own web pages.

b. Sophomore-level Low-Speed Aerodynamics

This course imparts basic knowledge with illustrations and equations through the ADL. Links are provided to resources developed by several instructors with markedly different teaching styles. Links are also provided to executable programs for computing wing aerodynamics at the websites of other universities, and students are asked to use these along with indigenously–developed programs, to validate their own calculations. Flow visualization resources developed at Georgia Tech are supplemented with resources found elsewhere on the internet.

c. Junior-level Gas Dynamics and High Speed Aerodynamics

Again, course notes and teaching styles from different instructors are provided through the Internet via ADL. One valuable aspect of web-based open resources is seen in this course as students find themselves able to revisit content from the lower level courses. At this level, students are asked to take on larger projects, such as calculating the performance of typical aircraft configurations using the knowledge from the various courses, then validating those results against the actual performance data on the aircraft.

d. Senior Aeroelasticity and Flow Diagnostics [29,30]

At the senior level, the Internet allows students to perform at a greatly increased level of independence and initiative. Both individual and team projects are assigned. Here students are asked to perform projects involving substantial effort in searching for resources using the Internet before applying them to problem solving. Project results are posted as web resources.

e. Graduate Unsteady Aerodynamics and High Speed Aerodynamics[29,30]

In these two first-year graduate courses, the notes and assignments are provided over the internet (in addition to regular classroom lectures and textbooks). Students are encouraged to use internet search resources to solve problems, but so far this has been a frustrating experience as students in these classes come with very stiff prejudices regarding learning styles, generally not being enthusiastic about open-ended work outside the "expected" methods of teaching. This is problematic of a group of students from different ethnic, social, and academic backgrounds, and where the utilization of DLs hold much promise.

f. Multilevel team projects [31,32]

Internet usage is heavy in team projects involving students at all levels, such as projects associated with NASA Microgravity Flight Tests, or the development of business plans for Space Commercialization around ideas for technology-based startup firms.

VI. Usage experience with the Aerospace Digital Library

The Aerospace Digital Library (ADL) at Georgia Institute of Technology (GT) (www.adl.gatech.edu) [23-25] is a learner-centered resource for solving engineering problems across levels and disciplines. ADL was originally inspired by the commissioned papers listed in Wilson et al [18] as the authors sought ideas to enhance learning by iteratively presenting the same material in different classes and problems rather than the traditional sequential curriculum. ADL has been in existence for 3 years. Current usage rate averages several hundred users per day. In March 2000, roughly 70% of the usage came from outside Georgia Tech, and 18% from outside the United States. Today the usage is more heavily from the US, as usage within Georgia Tech has grown substantially with the progress of students who were exposed to such resources as freshmen, through the curriculum. The ADL certainly lacks many formal features of the established DL projects, as it is being developed as needs and spare time of the faculty present themselves, but it does enjoy several features which have proven successful in getting engineering students to use these resources:

1. A design-centered portal to the knowledge base that engages the learner's mind, tailored to learners at the undergraduate level and beyond.
2. A learner-centered organization with a simple fractal structure repeating over a cascade of levels.
3. A Concept Engine structure for knowledge transfer across levels and disciplines, providing a centripetal, cohesive dynamic to the ever-expanding knowledge base.
4. A worldwide collection of basic and advanced knowledge on aerospace engineering,
5. A new archiving system for papers and research.

User experience at levels from freshman through graduate school at GT is accumulating rapidly, and provides an interesting perspective on how the students' learning habits and expectations are changing in this technological environment. Assessment of the resources is conducted in each class where ADL is used with students responding freely with detailed comments on how their learning styles are evolving. The results are given in [23-25, 29-30].

VII. Conclusions

The Internet, through the Digital Libraries being formed as initiatives throughout the world, is poised to aid engineering students significantly during their collegiate years. However, with the overwhelming amount of material being linked on the Internet, the professor needs to provide the specific links to Digital Libraries that the students should be accessing. This is important since out of four "true" digital libraries, it required examination of 38 hits to find them. This is especially important for "small" engineering groups such as Aerospace Engineers because the most applicable digital libraries for collegiate coursework were found at hits 30 and 38. In the resources developed via the original Digital Libraries Initiative, its successor, DLI-2, and the newer NSDL, topics related solely to Aerospace Engineering have been extremely hard to find.

Utilization of the material found in these Digital Libraries have resulted in the ease of providing data for design projects, opportunities to examine research data, and applets to understand physical concepts.

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IX Biosketches

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Narayanan Komerath, Professor in AE and director of the John J. Harper wind tunnel, leads the Georgia Tech Experimental Aerodynamics Group (EAG). He has taught over 1600 AEs in 19 courses in the past 15 years. He is a principal researcher in the Rotorcraft Center of Excellence at Georgia Tech since its inception in 1982. He is an Associate Fellow of AIAA. EAG research projects have enjoyed the participation of nearly 100 undergraduates over the past 14 years. EAG is a leader in multidisciplinary team-oriented projects, including the Aerospace Digital Library Project at Georgia Tech: http://www.adl.gatech.edu

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Marilyn J. Smith earned her Ph.D. in aerospace engineering at the Georgia Institute of Technology in 1994. She joined the faculty as an Assistant Professor in the School of Aerospace Engineering at Georgia Tech in 1997 after fifteen years of industry experience at Lockheed-Georgia (now LMAS), McDonnell-Douglas Helicopter (now Boeing Helicopter-Mesa), and the Georgia Tech Research Institute. She was awarded the 1999 Outstanding Faculty Member by the GIT Women's Leadership Conference. She is an Associate Fellow of AIAA and a past member of the AHS Fluids Technical Committee.