

Information Literacy: A Critical Component in Engineering Practice in the Twenty-First Century

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Abstract - As available information proliferates, the necessity of being able to correctly select, interpret, and measure the “goodness” of the information, and therefore how much it should be relied upon, becomes more and more critical to all fields, but especially to the practice of engineering. However, this is a skill which is not taught or stressed in many engineering education programs today. Ranging from when, or whether, a certain method or process or theorem is applicable to a hypothetical problem in the classroom, to what sources of data and what software simulations should be used to estimate hardware failure probabilities in crisis situations such as the Columbia space shuttle takeoff damage leading to the breakup of the shuttle upon reentry, ability to select, evaluate, and apply the best available information is critical to success. Yet while most engineering educators and practitioners would agree that this is a vital skill set, the burdens of assessment required by ABET EC2000 have led some programs to concentrate almost exclusively on the ubiquitous ABET a-k. The question then arises as to how, or whether, information literacy fits in with the current ABET accreditation requirements. Also, in an era when more and more state legislatures and university administrators are reducing the number of hours engineering programs are allowed to include in their graduation requirements, educators reasonably ask how anything else can possibly be squeezed into already time-crunched programs. This paper presents common standards of information literacy, a discussion of why it is necessary to engineering study and practice, how information literacy meshes with current ABET requirements, and how it can be incorporated into existing courses without an undue burden on faculty or students. The conclusion is that information literacy is more than a necessary element of education: it is the very *essence* of education.

Keywords: Information literacy

INFORMATION LITERACY

What Is It?

What is Information Literacy? Common definitions run the gamut from a set of library search proficiencies to knowing whether a source of information meets required specifications to a full range of critical thinking skills. Two of the most accepted sets of defined skills come from the American Library Association (ALA): a set of information literacy competency standards for higher education as a whole, approved by the Board of Directors of the Association of College and Research Libraries and endorsed by the American Association for Higher Education and the Council of Independent Colleges [1] and a draft set of information literacy standards specifically related to science and technology [2]. While the two sets are similar, the second set, more closely tied to engineering, is presented here. A joint task force formed by the American Library Association and the Association of College and Research Libraries developed the set of five standards listed below, along with twenty-six performance indicators and associated outcomes. According to the science and technology draft standards [2]

The information literate student:

1. Determines the nature and extent of the information needed and constructs a course of action for obtaining the information;
2. Procures needed information effectively and efficiently;

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3. Critically evaluates the procured information and its sources, and as a result, decides whether or not to modify the initial query and/or seek additional sources;
4. Understands and respects the economic, ethical, legal, and social issues surrounding the use of information and its technologies and either as an individual or as a member of a group, uses information effectively to accomplish a specific purpose;
5. Recognizes the need to keep current regarding new developments in his or her field and understands that information literacy is an ongoing process and an important component of lifelong learning.

How do these elements relate to education? According to French psychologist Jean Piaget

The principal goal of education is to create [people] who are capable of doing new things, not simply repeating what other generations have done – [people] who are creative, inventive, and discoverers. The second goal of education is to form minds which can be critical, can verify, and not accept everything they are offered... We have to be able to resist individually, to criticize, to distinguish what is proven and what is not. So we need [students] who are active, who learn early to find out for themselves, partly by their own spontaneous activity and partly through material set up for them; who learn early to tell what is verified and what is simply the first idea to come to them. [3]

When one considers the implications of the information literacy standards--that a person would be able to recognize the need for information, find it, assess it as to quality and applicability to the problem at hand, critically evaluate the context of the information and all its implications including societal, ethical, and legal ramifications, and engage in a life of continuing pursuit of knowledge--and compares them to the goals of education in the quote above, one can see that information literacy is more than a necessary element of education. It is the very *essence* of education.

Do Engineers Need It?

The skill set implied by the ALA standards is especially critical for engineers. As one author observed

Many engineers lack skills in accessing and retrieving information. Yet the ability to monitor, access, retrieve, evaluate, use, and communicate information will be critical in a global information society characterized by rapid technological change. Engineers who possess a more thorough knowledge of information retrieval strategies and information resources will be more effective in educating themselves, will develop more creative solutions to problems, will practice more efficiently, and will be more competitive in the global economy. [4]

Multiple studies have indicated the need for additional information literacy skills in engineering students. For example in [5] authors indicate that engineering students tend to be less aware of, and less able to make use of, the literature of their discipline than students in other science-related majors. Yet a two-university study [6] found that the percentage of engineering faculty by discipline who felt that some sort of bibliographic instruction was necessary in the first years of engineering study ranged from 93% for chemical engineering to a low of only 55% in mechanical engineering. While the percentage of mechanical engineering faculty seeing this as necessary in the later years increased to 67%, this still leaves a significant portion who do not see instruction in literature usage as necessary in their engineering programs, although "...it is quite possible for ...engineering undergraduates to avoid the library, if not completely, at least until relatively late in their educational experience" and "...another common faculty perception was that students who had not learned to do library-based research by their upper years were unmotivated, uninterested, or just poor students." [6]

Yet ability to find information is not enough. While many, if not most, engineering students might feel that they are adept at information retrieval because of the facility with which they roam the internet, it is the author's observation that today's students are considerably less likely than their counterparts even four years ago to look any farther than the internet for information. It has also been observed that some students, even

those nearing graduation and professional practice, seem to have no concept of the relative credibility of sources.

The ability to determine whether information is credible and whether it applies to the problem at hand is particularly critical to the practice of engineering, and yet is one which professionals, as well as students, find problematical. While for some professions correct use of information may be a trivial matter, in some cases in engineering practice it is literally a matter of life or death. For example, in the report of the NASA investigation into the disintegration of the space shuttle Columbia upon re-entry on February 1, 2003 leading to the deaths of all on board, some of the causes cited as direct or indirect causes were incorrect evaluation of information, inappropriate use of data sources, and failure to seek additional information when necessary. Some of the causes cited in the NASA report were

- I. Ignoring the previous history of similar foam strike incidents;
- II. False perception that since strikes of foam fragments had occurred in past launches with no negative effects that the probability of drastic consequences in this incident were negligible;
- III. Failure to honor requests for additional data after a foam strike on take-off was observed in video taken of the launch due to incorrect "chain of command" issues;
- IV. Inappropriate use of simulation software developed for much smaller fragments;
- V. "...management--including Shuttle Program, Mission Management Team, Mission Evaluation Room, and Flight Director and Mission Control--displayed no interest in understanding a problem and its implications." [7]

Each one of these examples violates at least one of the information literacy standards presented earlier, and some, more than one. It can easily be shown that instance I. above violates literacy standards 1 through 3, II. violates 1 and 2, III. and IV. violate standard 3, and example V. violates standards 1, 4, and 5.

Looking at incidents such as these in which incorrect use of information or lack of proper information caused tragic loss of life, it is easy to conclude that information literacy is indeed necessary, perhaps even paramount, for engineers. However, students do not necessarily recognize this.

In fall 2005, University of Tennessee at Chattanooga senior Electrical Engineering students completed a major, semester-long information research project and paper related to societal effects of communications technology and ethical engineering responses to these effects. When the students were surveyed at the end of the project using the survey included in Appendix A, the students demonstrated a wide range of reliance on sources, ranging from 100% internet search engines for some students to 100% IEEE technical publications for others. In-class discussions had included importance of authors' credentials, publication venue, and potential conflicts of interest created by funding of research quoted in determining credibility of sources. Yet while all students in the survey said reliability of data was a key consideration, few demonstrated a reasoned strategy for determining whether sources were, in fact, credible, and 62.5% of the students gave "easy to find" as one of the primary selection criteria for information. Unsatisfactory responses as to how students determined credibility of sources ranged from "got something from the library" to acceptance of all government sources as valid without question. Less than 20% considered both author and publication venue, and none mentioned research funding as a consideration.

How Does It Fit In with ABET Requirements?

The burdens of assessment required by ABET EC2000 accreditation criteria have led some programs to concentrate almost exclusively on the ubiquitous ABET a-k. The question then arises as to how, or whether, information literacy fits in with the current ABET accreditation requirements. The ABET a-k standards are quoted below [8]

- (a) an ability to apply knowledge of mathematics, science, and engineering
- (b) an ability to design and conduct experiments, as well as to analyze and interpret data
- (c) an ability to design a system, component, or process to meet desired needs
- (d) an ability to function on multi-disciplinary teams
- (e) an ability to identify, formulate, and solve engineering problems

- (f) an understanding of professional and ethical responsibility
- (g) an ability to communicate effectively
- (h) the broad education necessary to understand the impact of engineering solutions in a global and societal context
- (i) a recognition of the need for, and an ability to engage in life-long learning
- (j) a knowledge of contemporary issues
- (k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

Some of the ABET requirements, e.g., requirement (i) on lifelong learning, can be easily matched to similar information literacy standards. However, it is clear that every one of the ABET requirements is contingent on the ability of the students to properly acquire and use relevant information. In Table 1, similar to the table in [9] mapping general information literacy standards to ABET outcomes, each of the a-k can be mapped to one or more of the science and technology information literacy standards for higher education.

ABET Outcomes Mapped to Information Literacy Standards	Information Literacy Standards										
	a: an ability to apply knowledge of mathematics, science, and engineering	b: an ability to design and conduct experiments, as well as to analyze and interpret data	c: an ability to design a system, component, or process to meet desired needs	d: an ability to function on multi-disciplinary teams	e: an ability to identify, formulate, and solve engineering problems	f: an understanding of professional and ethical responsibility	g: an ability to communicate effectively	h: the broad education necessary to understand the impact of engineering solutions in a global and societal context.	i: a recognition of the need for, and an ability to engage in life-long learning	j: a knowledge of contemporary issues	k: an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.
Standard 1	X	X	X		X				X	X	X
Standard 2									X	X	X
Standard 3	X	X			X			X		X	X
Standard 4	X	X	X	X		X	X	X		X	X
Standard 5						X			X		X

Table 1. ABET a-k Mapped to Information Literacy Standards

While many engineering schools do not specifically recognize the concept of information literacy, it is nevertheless critical for the success of their students in practice and for successful demonstration of competency in the ABET a-k standards.

Is Anyone Taking This Seriously?

A brief examination of the sites related to information literacy on the internet shows very quickly that not only are libraries and library associations, who have historically been in the forefront of the push for information literacy, stressing this area, but so are K-12 and university educators; universities such as Australia's Queensland University of Technology, which has developed its own set of guidelines and plans [3]; and states such as Colorado, which has developed its own set of information literacy requirements for K-12 [10]. However, although engineering faculty are beginning to be aware of, and take an interest in, the concept of information literacy, studies show that engineering students tend to begin to develop serious

information retrieval skills later in their programs of study than students in other majors and that engineering and science faculty hold bibliographic instruction in particular as having less relevance to their professions than do other disciplines [6]. This must be changed for engineering students to be successfully prepared for engineering practice in a rapidly changing world.

INCORPORATING INFORMATION LITERACY INTO ENGINEERING EDUCATION

There are three major ways in which information literacy can be incorporated into education: full curriculum reform, dedicated courses, and inclusion in existing courses. Some researchers are actually looking at a major reform of science and/or engineering curricula to include information literacy throughout. The rationale for such an approach is that “embedding information skills within a disciplinary framework establishes context, meaning, and relevance for learners,” that the professional literature and the “approach to seeking and using information” may also be strongly discipline-specific [11]. However, due to the considerable requirements of ABET accreditation and the faculty time necessary to plan and implement such changes, many engineering faculty would agree that this is an impractical solution for many programs.

A second means of including information literacy explicitly is in having dedicated courses in the curriculum. Some universities, such as York College of Pennsylvania, have special information literacy courses which are required of all students in all majors [12]. Other universities, such as Tennessee State University, have an information literacy course specifically for engineering students with a goal of ensuring

... that Tennessee State University engineering graduates are information literate, lifelong learners who can efficiently and effectively determine the nature and extent of information they need, access and evaluate the information and its sources critically and incorporate selected information into his/her knowledge base and value systems, use the information effectively to accomplish a specific purpose and understand the economic, legal and social issues about the use of information and uses it ethically and legally. [13]

Again, while many engineering professors would agree that such a course could be very helpful, the pressure exerted by state legislatures in states such as Tennessee to cut a four year program of study to 128 semester hours or less, makes adding any course, however useful, to the existing program of study a nonviable solution.

Incorporating Information Literacy into Existing Courses

Information literacy can be incorporated into existing courses at many levels, and ways in which information literacy can be included and introduced vary widely in scope, type of information sought, and primary emphasis.

One tactic employed by several universities is incorporation of information literacy concepts and information search skills very early in the curriculum. This can take the form of a formal library orientation provided to students soon after arrival on campus, in either a lecture format or a hands-on, interactive exploration. Researchers trying both types of presentation concluded that students seem to enjoy the interactive format more than the lectures, and students appear to retain significantly more information-related skills from the interactive sessions [14]. Information literacy can also be incorporated into existing assignments in freshman classes or labs. In [15], authors describe a series of assignments in which teams of students are required to work with a librarian to research background material for a laboratory report and for which they are “graded on the quality of their research [and] the variety and appropriateness of the selected resources.” Students are also introduced, through this means, to specific journal search indices such as *Applied Science and Technology Abstracts*, and to on-line library catalogs.

The difficulty with introducing in-depth information literacy primarily at the freshman or sophomore levels is that engineering students are not, at that point, yet knowledgeable enough about their prospective fields to be able to appreciate the depth and breadth of technical literature available in, and necessary to, the successful practice of the profession. Information literacy can also be incorporated in natural ways in upper division courses. The simplest of these, described in [16], is alteration of typical problems assigned to students in a junior level Thermodynamics class: instead of using textbook problems with all data given, the students are given the framework of the problem, but are required to find and cite “published peer

reviewed data . . . in an appropriate source.” This approach is unusual in its emphasis on hard technical data which students can see is necessary to perform their calculations, rather than more esoteric research or opinion, the necessity for which students might find it harder to understand.

Short assignments such as those discussed above can have emphasis on aspects of information literacy other than simple acquisition of information. In a previous paper by the author [17], a sequence of short assignments based on major engineering disasters relevant to the discipline is described. The goal of these assignments is first to graphically illustrate the consequences of lack of information literacy competencies in engineering practice, and second to lead the students through a process of information evaluation and critical thinking by asking a series of questions such as [17]

- What information sources are available for evaluation?
- Is the information directly applicable to the situation at hand?
- If not, how close is it to the current situation?
- What underlying assumptions have been made in the data?
- Is there any reason to suspect bias of any sort in this data source?
- How good is the evidence given by (or cited) in the source?
- Is there any potential conflict of interest?
- Is any significant data omitted?
- Are there any other data sources which should be consulted?
- Are there conflicting potential causes for the event?
- Are there any fallacies in the reasoning?
- What reasonable conclusions are possible?

Comparing this set of questions to the information literacy competency standards in the first section of this paper shows clear correlation between this exercise and the information skills desired for our graduates. This type of series of assignments can also incorporate ethical considerations—another critical component of EC2000.

Semester-long, major assignments can also be used to teach a variety of information literacy elements and information types in meeting more complex goals. In the author’s earlier paper [18] an assignment from the senior level Analog and Digital Communications course was discussed which requires students to research and evaluate information of multiple types. This assignment required both a written paper of 8-10 pages with at least 3 references, and an oral presentation to the class, using appropriate visual aids. The assignment is stated on the syllabus as follows:

Identify a way in which a communications technology has impacted society, for better or worse. Discuss both the technical aspects and the societal impact of the technology, and support what you believe to be an ethical engineering response to that issue.

This assignment, which counts 20% of the course grade, requires students to find technical information related to one of the issues, techniques, or technologies covered in the course, information related to societal effects, which typically comes from news sources, and ethics information, which can come from such diverse sources as interest groups, professional ethics documents such as the IEEE ethical standards, and the student’s own moral or religious code. In addition, references are required to be credible, attributable, and non-ephemeral, which rules out most internet sources, and which requires the student to evaluate each source using questions similar to those in the critical thinking discussion above, and which closely mirror the information literacy competencies.

CONCLUSION

Information literacy--the ability to recognize the need for information, find it, assess it as to quality and applicability to the problem at hand, critically evaluate the context of the information and all its implications including societal, ethical, and legal ramifications, and engage in a life of continuing pursuit of knowledge--is the very *essence* of education. It not only *can* be incorporated in engineering education in order to meet ABET requirements and the future professional needs of our students, but it *must* be. However, this can be accomplished by making relatively minor changes to existing courses, making it practical for implementation in all engineering programs.

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APPENDIX A: SURVEY REGARDING SOURCE USAGE FOR 473 RESEARCH PAPER

As part of our process of continuous program improvement, we request your input and comments regarding information usage on your 473 research assignment.

Directions: Circle the appropriate reaction, where 4=Used Heavily, 3=Used Moderately, 2=Used Slightly, 1=Did Not Use, and X=Did Not Know This Existed.

1. Sources Used:

i. internet search engines	4	3	2	1	X
ii. library books	4	3	2	1	X
iii. talked to people	4	3	2	1	X
iv. textbooks	4	3	2	1	X
v. professional organizations (e.g., IEEE)	4	3	2	1	X
vi. work-related sources	4	3	2	1	X
vii. library search engines	4	3	2	1	X
viii. commercial websites	4	3	2	1	X
ix. government sources	4	3	2	1	X
x. on-line library reference materials	4	3	2	1	X
xi. professional journals	4	3	2	1	X
xii. other (explain)	4	3	2	1	X

2. What source did you rely on most heavily? Why?

3. How did you decide which sources to use? Circle the appropriate reaction, where 4=Strongly Agree, 3=Mostly Agree, 2=Partly Agree, 1=Totally Disagree, and X=Did Not Consider.

i. easy to find	4	3	2	1	X
ii. fit well with viewpoint	4	3	2	1	X
iii. covered topic well	4	3	2	1	X
iv. gave unusual or unique information	4	3	2	1	X
v. reliability of information	4	3	2	1	X
vi. had cool pictures to use in presentation	4	3	2	1	X
vii. excellent technical resource	4	3	2	1	X
viii. excellent resource on societal effects	4	3	2	1	X
ix. excellent ethical viewpoint	4	3	2	1	X
x. other (explain)	4	3	2	1	X

4. Had you already selected your ethical stance before you searched for sources?

If so, what caused you to form this opinion?

If not, what source(s) most influenced your opinion? Why?

5. How did you determine whether each source met the requirement of being credible?

Attributable?

Non-ephemeral?

6. How well prepared do you feel in being able to find technical information for an assignment such as this?

7. How well prepared do you feel in being able to find social impact or ethical information for an assignment such as this?

8. How do you feel that you could be better prepared for finding information?

9. How do you feel that you could be better prepared for evaluating information?

10. How could this assignment have been improved?

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Dr. McCullough received her bachelor's, master's, and Ph.D. degrees in electrical engineering from Vanderbilt, Georgia Institute of Technology and the University of Tennessee, respectively, and is a registered professional engineer in the state of Alabama. She is a member of I.E.E.E., Tau Beta Pi, Sigma Xi, and Eta Kappa Nu. She is currently a Professor of Electrical Engineering at the University of Tennessee in Chattanooga, and teaches courses in such areas as Communications, Controls, and Signal Processing. Dr. McCullough has over 20 years experience in engineering practice and education, including industrial experience at the Tennessee Valley Authority and the US Army Space and Missile Defense Command. Her research interests include Image and Data Fusion, Automatic Target Recognition, and Steganography.