Learning Objectives
So that you can guide students to appreciate the role of information literacy in learning, upon reading this chapter you should be able to

• Articulate four fundamental outcomes of information literacy
• Describe how information literacy relates to critical thinking, problem-solving skills, and lifelong learning
• Understand how the Information Search Process (ISP) model describes the information gathering processes used by students
THE NEED FOR INFORMATION LITERACY

The previous chapter identified different conceptual approaches to engineering design and some of the factors that can improve successful design outcomes. One of the recurring themes is the need for strong information management skills, what librarians commonly refer to as information literacy. With the explosion of information technology capabilities, the availability of vast amounts of content on a user’s desktop, and the concept of the new generation of “digital natives,” who are supposed to navigate these resources effortlessly (Prensky, 2001), instructors can be lulled into believing that they don’t need to guide students in locating information resources, let alone understanding and extracting information to be used in their projects.

However, instructors keep complaining that students can’t write papers, use poor sources, and have trouble documenting those sources (often resulting in plagiarism, made easier to commit by cutting and pasting text from the Web, and to detect by cutting and pasting suspicious passages into a search engine). With all the information purportedly available, our future engineers still have challenges incorporating information effectively into a report, project, or presentation and solving complex problems.

In the professional sphere, engineers struggle to manage and apply information effectively to solve design problems, leading to delays in product development, overreliance on rules of thumb and prior knowledge that reduces innovation and application of cutting edge technologies, and reinvention/reconstruction of knowledge, all of which lead to reduced profits and competitiveness for the company. Timeliness, accuracy, accessibility, cost, and relevance, in addition to the core content itself, can be barriers to appropriate integration of information by engineers (Court, Culley, & McMahon, 1997; see also Chapter 3).

There are several definitions and models of information literacy, such as the United Kingdom’s Society of College, National, and University Libraries (SCONUL) Seven Pillars of Information Literacy: identify, scope, plan, gather, evaluate, manage, and present (SCONUL, 2011) and the Big6 approach geared toward K-12 students: task definition, information-seeking strategies, location and access, use of information, synthesis, and evaluation (Eisenberg & Berkowitz, 2000). However, the definitions have substantial overlap. For the ease of discussion, in this handbook we will focus on the Association of College and Research Libraries (ACRL) definition widely used by universities in the United States, that information literacy encompasses the ability to “recognize when information is needed and have the ability to locate, evaluate, and use effectively the needed information” (American Library Association, 1989, para. 3). Locate, evaluate, and use effectively each indicate a facet of the information gathering process, and each is essential to the research process.

FACETS OF INFORMATION LITERACY

Recognizing the Need for Information

Of course, without a recognition of the need for information, the search for information never starts. Beyond that, if students cannot articulate what specific information they need, and what information they already possess, they typically resort to ineffectual, often one-word search strategies. We the authors see the same websites crop up on student papers be-
cause they are in the first five hits of a Google search on climate change, or electric cars, for example. Trusting Google to do the thinking for them can lead to disastrous results. Rather than seeking out information to confirm or refute theses or fill in gaps in knowledge, many students just try to mix and match their top five sources of information into a report, letting the results determine their research question, rather than their question determine their search for information.

Alternatively, when students first try to scope out a problem, analyze it to determine what they know and what they don’t know (including, sometimes, the foundational subject knowledge), they can actually use sources to inform the solution to their problem. They may find general information to get a sense of the big picture before delving into a particular potential solution. With an increased vocabulary, they can use more targeted search terms and use their new knowledge to quickly determine whether a particular source is helpful or even relevant to their problem.

**Locating Information**

One typically does not think about the ability to locate information as a challenge for students in the Internet age. After all, with several billion pages (certainly more than any one person could possibly hope to look at in their lifetime), the open Web, that is, the part anyone can freely access, would seemingly contain the answer to any question. Digital natives, having grown up with the Internet, are supposed to effortlessly navigate through it. However, more recent findings seem to indicate that students overestimate their information technology abilities and that they have less developed skills than was previously thought (Holliday & Li, 2004). Students rely heavily on the open Web, which is successful for certain kinds of information, such as the weather, stock prices, or even troubleshooting computer problems. As students begin more scholarly and sophisticated inquiries, however, the ability of the open Web to provide the depth of information they need is insufficient.

While many high-quality information sources exist on the open Web, including a large amount of federal and state government information, the bulk of scholarly journals, handbooks, data sources, and books, what we generally think of as traditionally published materials, even if electronic, are behind subscription walls. Indeed, a research library spends several million dollars a year providing access to just these resources. Understanding how and where to find information that is valuable enough to sell, rather than just give away, provides a large conceptual leap for many students.

Locating information requires not only looking in the correct place (the open Web, an index of journals, perhaps a government database or a product spec sheet), but also navigating through that resource to find the specific information needed. Using appropriate search terms and logic, implementing logical search strategies to refine results, understanding how to take advantage of the functionality of different search systems, and capturing and organizing the results all make locating information easier and more effective.

**Evaluating Information**

Once they have located information resources, students must determine which ones to use and how to use them. They must establish the validity, authority, and relevance of sources rather than taking the information at face value. Students should look for resources with different perspectives, even if just competing products, so that they can critically think
about which sources make the most convincing arguments and how those claims can be substantiated or refuted. In general, people remember facts but to a much lesser extent the source of those facts. As a result, a concept can become integrated into one’s working knowledge without it ever having been vetted as a reliable piece of information.

Novice information seekers tend to treat any text as reliable, whether from expediency or from a lack of discriminatory skills. Without a well-formulated process for vetting a text—for example, determining the background of the author, whether the author is writing in a field of his or her expertise, or corroboration from other experts in the field—students see every author as having equal standing and may not be able to resolve conflicting claims. Consequently, students will determine that a text that agrees with their prior preference or conveniently fits their thesis is the most reliable. Alternatively, students may consider the competing claims to be a matter of opinion and not seek to determine which side has a more valid argument (King & Kitchener, 1994).

Once they have sufficiently analyzed information from a source, students need to determine whether it matters. Is the information convincing enough that they are willing to change a deeply held belief? Is it important enough to incorporate into their working knowledge? Is it something that they believe in enough to stake a professional or personal relationship on? Without a conscious engagement with the information on a deep level, facts remain facts and are not transformed into knowledge.

**Applying and Documenting Information**

Once information has been located and deemed credible, it needs to be applied to inform the solution to the original problem. Students must extract the particular information relevant to the problem and then organize, synthesize, document, and communicate that information. Unless something is done with the information, it remains in a state of abstraction—as interesting facts rather than usable knowledge.

Extracting appropriate information from a text first requires students to understand what they are reading. This means that students need to find information that is at an appropriate level for them. First-year students likely will find scholarly texts incomprehensible, so they need to be steered to the kinds of resources written at their level. When asked to explore more advanced concepts, students should be directed to overview articles, technical encyclopedias, or other background sources to obtain context and conceptual foundations from which to build a deeper understanding. Techniques such as note taking and restating or discussing with peers provide opportunities for students to go beyond the passive intake of information and to transform it into an active engagement and synthesis of the content.

In addition to understanding an information source, students also need to use information ethically and appropriately. Contrary to current political discourse, in which increasingly the goal appears to be creating impressive sound bites without regard to accuracy, in the scientific and technical spheres, persuasion, while still important, needs to be grounded in solid fact. Bridges will not remain standing because of pithy quotes or convenient cherry-picking of facts. Rather, tragedies will only be avoided if a bridge is built according to standards and within the limits of the materials and methods employed in its construction.

In order to ethically use information, then, students need to understand what it is they are asserting, whether the information is credible,
and under what conditions it is valid. Students might report a particular value for a material property but not indicate at what temperature or pressure, at what atmospheric condition, the property was measured in. In a more trivial example, a student was calculating the cost savings for moving to a more efficient lighting system. She found a website with utility rates and calculated the expenses without realizing the utility rates were for the Northeast rather than the Midwest, which uses completely different fuels (nuclear versus coal) to generate power at substantially different costs.

Another aspect of ethically using information is the appropriate documentation of that information. Students frequently complain about having to cite their sources, without understanding the purpose of doing so (other than avoiding expulsion for plagiarism). By documenting sources of information, readers have the ability to go back to the original source and make their own determination of its credibility. Otherwise, readers can only assume that the student is the one asserting the statement, which could make it seem less credible. In this way, documentation protects the students. It gives them a proxy of expertise they can tap into, so that the reader can dispute those experts, rather than the expertise of the student. However, it does not stop the reader from disputing how information gained from sources was applied by a student, or questioning the student’s judgment regarding whether a particular person is in fact an expert.

Appropriate documentation also allows students to go back to the original source material itself, rather than trying to remember where they found a piece of information. Let’s say a proposal to build a project has been accepted. A student may, instead of just reporting that it is possible to build a part with a particular set of properties, actually need to know how to build that part. Instead of trying to reconstruct the previous search for that information, the student could just look back at the references to find the details of fabrication.

LEARNING HOW TO LEARN

Tightly connected to information literacy is the notion of lifelong learning. Once out of the academy, and despite the availability of conferences, workshops, advanced degrees, and online course work, the bulk of professional learning takes place individually and informally. The development of self-directed learning skills, then, becomes paramount to the continued success and viability of engineering professionals in the workplace. Knowles (1975) requires that self-directed learners identify their learning need, determine a learning plan to acquire the skills or abilities to meet the need, actually implement the plan, and be able to determine whether they met their learning goals.

The Knowles (1975) model of self-directed learning mirrors that of information literacy, where, for example, Knowles’s learning need translates as recognizing the need for information. Not all self-directed learning requires a search for information, and not all information gathering activities are self-directed, but the core concept of learning something new to address a specific need provides a large degree of overlap in pedagogy.

The National Academies publication How People Learn (National Research Council, 2005) presents three main findings, all of which relate to the absorption of information and the creation of new knowledge. The first finding is that students “come to the classroom with preconceptions about how the world works” (p. 2), and if those preconceptions are not engaged and addressed in the presentation of new
information, students might, for instance, learn content for a test but still use their core preconceptions outside of the classroom context. This is often referred to as the *transfer problem* in education. In the world of information literacy, this occurs in the evaluation of information and extraction of knowledge from sources. If students treat information only as something they need to finish an assignment, then no real long-term knowledge has been created. Only by reflecting on what the information means, how it relates to their previous knowledge, and whether they should change those beliefs based solely on that knowledge (or subsequent investigation) do students really learn something from the process. In a meta-sense, information literacy itself can be a subject of analysis. Students have preconceived notions about information, whether they believe that all the knowledge of the world is accessible through Google, or whether a one-word search string should enable a search engine to know what they are really looking for. Or, that all websites are created equal and contain reliable information. Without engaging those preconceptions, students may find five scholarly articles to complete an assignment, but for the next class or after graduation, will likely revert to taking the first Google result as the best possible answer to their question.

The second finding in *How People Learn* (National Research Council, 2005) discusses the development of competence. In particular, students need a foundation of factual knowledge, but they also need to “understand [those] facts and ideas in the context of a conceptual framework” (p. 12), and organize that knowledge so it can be used. Fundamentally, this finding addresses the question of how we can turn novices into experts, able to make profound judgments of a situation and ready to enter the professional world. With a solid conceptual foundation, experts can rapidly determine what information is relevant, and thus quickly hone in on the needed information, ignoring superfluous details. Creating an expert mindset is a lengthy process and one that needs to be consciously cultivated, and information processing is central to that development.

Finally, in *How People Learn* the National Research Council (2005) reports that taking a learner-centered, “metacognitive” approach allows students to control their own learning and monitor their progress. If provided the language and tools to question their own understanding and level of competence, students can become expert self-directed learners. The same tools that allow one to determine the validity of a particular source of information—its credibility, authority, and relevance—play an important role in students’ developing the metacognitive skills for learning in the classroom and beyond.

**A PROCESS MODEL FOR INFORMATION GATHERING**

In teaching information literacy and lifelong learning skills, one first needs to understand how students approach the information gathering process. From the previous section, we see that we need to situate learning in a student’s experiences. The Information Search Process (ISP) (Kuhlthau, 2004) provides a structure that students can identify with, especially since the ISP includes affective and cognitive characteristics of the information gathering stages and not just a description of tasks undertaken.

The ISP contains six stages: initiation, selection, exploration, formulation, collection, and presentation. Briefly, these stages are defined as follows:
Initiation: when a person first becomes aware of a lack of knowledge or understanding and feelings of uncertainty and apprehension are common.

Selection: when a general area, topic, or problem is identified and initial uncertainty often gives way to a brief sense of optimism and a readiness to begin the search.

Exploration: when inconsistent, incompatible information is encountered and uncertainty, confusion, and doubt frequently increase and people find themselves “in the dip” of confidence.

Formulation: when a focused perspective is formed and uncertainty diminishes as confidence begins to increase.

Collection: when information pertinent to the focused perspective is gathered and uncertainty subsides as interest and involvement deepens.

Presentation: when the search is completed with a new understanding enabling the person to explain this or her learning to others or in some way put the learning to use.

These stages roughly define a research process that starts from problem definition and scoping to topic selection, thesis formation, documentation and, finally, communication. The first three stages are characterized by the search for relevant information, while the last three stages are characterized by the search for pertinent information. While this model may look like it is most relevant for a full-blown research project, even quick lookups of information may require multiple steps in the ISP, especially if the subject area is not very familiar to the student.

Note that the process described here is conceptual and, consequently, does not discuss the particulars of locating, accessing, or evaluating information. Rather, those concepts would be dealt with in the context of the stage of information search in which the student is currently engaged. For example, if students are in the exploration stage of their ISP, they will be looking for more preliminary information such as encyclopedia or review articles to describe the overall topic, while in the collection phase students will likely need to find technical literature or handbooks or similar materials. Instruction targeting the appropriate stage will provide the tools needed at that time for those students.

CRITICAL THINKING, PROBLEM SOLVING, AND INFORMATION

There are several other cognitive theories that impact information literacy skills. The body of knowledge around critical thinking mirrors the evaluation and application concepts of information literacy. The model of reflective judgment described by King and Kitchener (2002) sheds light into the effect of the developmental stage of students on how they interpret information and use it to make decisions. Finally, common fallacies of reasoning lead to inappropriate and potentially unethical use of information. Each of these areas provides insights into the need for information literacy skills, and aspects that need to be considered when teaching those skills.

Critical Thinking

Critical thinking skills are important to every discipline in the academy. Scriven and Paul (as cited in Critical Thinking Foundation, 2011) describe critical thinking as the

intellectually disciplined process of actively and skillfully conceptualizing, applying, analyzing, synthesizing, and/or evaluating infor-
mation . . . as a guide to belief and action. . . . Critical thinking can be seen as having two components, 1) a set of information and belief generating and processing skills, and 2) the habits based on intellectual commitment, of using those skills to guide behavior. . . . The development of critical thinking skills is a lifelong endeavor. (“Critical Thinking as Defined by the National Council for Excellence in Critical Thinking, 1987,” para. 2)

The Association of American Colleges and Universities (2012) has developed a Valid Assessment of Learning in Undergraduate Education (VALUE) rubric for critical thinking as one of the essential learning outcomes for a liberal education that mirrors in many ways the core tenets of information literacy (see Table 2.1). The correspondence between critical thinking and information literacy skills is quite robust, and many concepts can be easily applied across those domains. As mentioned above, information that isn’t applied remains mere inert facts. Similarly, critical thinking isn’t complete unless it leads to actions taken in response to the process.

**Reflective Judgment**

Students come into the university at different stages of cognitive development. For example, many college students are still in the transitional stage between being concrete and formal reasoners, in the Piagetian model. Similarly, King and Kitchener (1994) found that students faced with an open-ended problem exhibit different levels of development in their ability to make judgments about the problem (see Box 2.1). They found that the average student enters the university in a pre-reflective stage and graduates in a quasi-reflective stage. One of the common misperceptions students have when using information is that “if it’s on the Internet, it must be true.” The reflective judgment model defines this behavior as characteristic of pre-reflective thinking. The development of reflective judgment skills goes hand in hand with the development of evaluation and application information literacy skills.

As students seek to extract meaning from information and, further, to act on that information, they need to develop reflective reasoning skills, and instructors need to understand that this is a process that students go through. Students, especially in the first year, typically cannot effectively incorporate information without specific instruction to support those skills (see Jackson, 2008; Pascarella & Terenzini, 2004).

**Common Fallacies of Reasoning**

When developing critical thinking skills, students need to be aware of common errors of reasoning. When judging the merits of a

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**BOX 2.1**

**Reflective Judgment Stages**

- **Pre-reflective**—Student gains knowledge through firsthand observation or from an authority figure, not through evaluation of evidence. No ambiguity in beliefs.
- **Quasi-reflective**—Student acknowledges a level of uncertainty in a claim, usually attributed to missing information. Uses evidence, although not effectively. Believes that judgments are a matter of opinion, rather than the best-reasoned conclusion.
- **Reflective reasoning**—Student acknowledges that claims are not certain and makes judgments based on what student evaluates to be the most reasonable conclusions. Willing to reevaluate judgments as new data becomes available.

Data from King & Kitchener, 2002.
particular information source, for example, students need to analyze whether the author has made an honest, supported argument, or whether the author has engaged in sloppy or misleading reasoning. Although using rhetorical tricks can be an effective way to influence others in the political arena, because the results of the engineering design process yields artifacts that impact safety, a high standard of information gathering needs to be enforced for students.

A typical example is students collecting product information by using an Internet search engine to find, for example, air conditioners or noise cancellation devices. Commonly students will not systematically attempt to compare products. Instead, they may make their decisions about which device to use based solely on marketing claims, such as customer testimonials or expert endorsements, rather than by evaluating product specifications.

Francis Bacon (1676) developed one of the early categorizations of common fallacies of reasoning. He called them the four idols, which need to be demolished in order to engage in clear and rigorous thinking.

### Idols of the tribe
As human beings we have certain physiological and psychological biases in how we observe the world and assign meaning to what we perceive. How we are wired affects how we understand the world.

### Idols of the cave
We each live in our own “cave” of individual experience, “where the hight of
Nature is obscured and corrupted” (p. 5). We each have developed our own construction of knowledge, based on what we’ve read or not, who we’ve talked to, if we’ve been in traumatic situations, and so forth.

*Idols of the marketplace.* Misapprehensions occur in the communication between people in society, as imprecise and “improper imposition of words doth wonderfully mislead and clog the understanding” (p. 5). Ideas can be obscured by the limitations of language to convey those concepts.

*Idols of the theater.* This refers to the effect of ideologies or systems of thought that are embraced because of “tradition, credulity and neglect” (p. 5), rather than critical examination. Uncritical acceptance of a particular philosophy or scientific model leads to people’s arguing about the particulars of the idea and ignoring whether the model is based on solid evidence.

This is not to say that Bacon’s idols are without value. For example, the ability for people to make patterns out of data (sometimes erroneously) has survival value, when, for example, the one time in a hundred, it is a nefarious person and not an oddly shaped tree trunk you see when walking alone after dark. Questioning everything leaves little time to actually do something. However, when asked to make an important judgment, it is important to understand how well a fact or concept is known and its limits of application.

Since many, especially informal, information sources use faulty logic, we describe in Box 2.2 a few of the most common as examples of what students need to watch out for both in reading and in making their own arguments. Some of these fallacies are intertwined with stages of reflective thinking (for example, appeals to authority), others with sloppy thinking, and sometimes these appeals are used deliberately as rhetorical devices. Rhetoric can be quite influential and effective, but words alone cannot trump physical reality when it comes to developing proficient and ethical engineers.

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**BOX 2.2**

**Common Fallacies of Thinking**

*Ad hominem/appeal to authority*—Attacking the person rather than the idea. Either vilifying the character of the person, or, conversely, exalting the person’s credentials or morality.

*Appeal to common knowledge*—Everyone knows something is true; therefore I don’t need to justify a particular point.

*Appeal to ignorance*—If we haven’t found something, it must not exist.

*False choices*—Framing a problem as having only two solutions or two causes, rather than allowing for a variety of options. Usually, one solution is ill-crafted, so the preferred solution is introduced as the one to follow.

*Confirmation bias*—Discounting occurrences that don’t fit a model, and emphasizing occurrences that do.

*Proof by example (inappropriate generalization)*—If it happened once, it must be true in general.

*Repetition*—If you say something often enough (or see it enough in print), it is true.

*Part to whole*—If an item belongs to a group, it has all the properties of other members of the group (not just the group properties).
INFORMATION GOALS FOR ENGINEERING STUDENTS

The ABET (2013) accreditation criteria guides the development of engineering programs. Criterion 3 delineates the student outcomes required of the program (see Box 2.3). Librarians have frequently focused on criterion 3 (i), “a recognition of the need for, and an ability to engage in life-long learning,” as the area most aligned with information literacy. However, this potentially relegates information literacy to that which happens after graduation, rather than integrating information literacy directly into the problem solving process for engineers. Riley, Piccinino, Moriarty, and Jones (2009) and Sapp Nelson and Fosmire (2010) both have mapped ABET criteria to ACRL information literacy standards. While their analysis is not repeated here in great detail, it is important to understand that information gathering takes place in all but the most trivial of problem solving situations (i.e., except when working computational textbook problems).

Some of the more saliently overlapping outcomes (ABET, 2013; Riley, Piccinino, Moriarty, & Jones 2009; Sapp Nelson & Fosmire, 2010) include the following:

“An ability to design and conduct experiments” (ABET, 2013, “General Criterion 3. Student Outcomes”). Every experimental design includes a literature review as a hypothesis is being formed and frequently when data has been collected and analyzed.

“An ability to design a system . . . to meet desired needs within realistic constraints” (ABET, 2013, “General Criterion 3. Student Outcomes”).

BOX 2.3
General Criterion 3. Student Outcomes

(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 within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability
(d) An ability to function on multidisciplinary 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) A the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, 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

From ABET, 2013.
“An ability to identify, formulate, and solve engineering problems” (ABET, 2013, “General Criterion 3. Student Outcomes”). Engineering is a human-centered activity, and consequently information must be gathered from stakeholders to understand a problem fully. Furthermore, when meeting the variety of constraints listed, substantial information needs to be gathered about the particular situation in which the students are working so that they can apply their methodologies appropriately and understand the consequences of their decisions.

“An understanding of professional and ethical responsibility” (ABET, 2013, “General Criterion 3. Student Outcomes”). Information ethics (see Chapter 5) are quite important for engineers. How information is documented, communicated, and utilized all have consequences for ethical behavior.

“Broad education necessary to understand the impact of engineering in a global, economic, environmental, and societal context” (ABET, 2013, “General Criterion 3. Student Outcomes”).

“Knowledge of contemporary issues” (ABET, 2013, “General Criterion 3. Student Outcomes”). Similar to (c), the engineer needs to be able to find information to maintain currency in societal issues surrounding engineering.

The “recognition of the need for, and an ability to engage in life-long learning” (ABET, 2013, “General Criterion 3. Student Outcomes”).

The preceding discussion provides a template for acquiring lifelong learning skills and abilities. In addition, the recognition of the need for lifelong learning is quite analogous to an internalization of the ISP, starting with recognizing the need for information.

**INFORMATION LITERACY AND DESIGN**

Engineering design provides an ideal situation for practicing information literacy and lifelong learning skills. A typical design problem is *ill-structured*, a term meaning a complex problem without a well-defined solution. As such, the students will, or should, come into contact with concepts, ideas, and details they are unfamiliar with, and a measure of their success will be in finding appropriate information to apply to those problems. Just because a process wasn’t mentioned in a textbook doesn’t mean it is not the best solution. Indeed, engineering design problems provide the most authentic situations for students to practice skills they will need after graduation, including gathering information in ways that they will likely encounter in their careers after graduation.

**SUMMARY**

This chapter has introduced a variety of concepts related to cognition, lifelong learning, and information literacy. Information literacy comprises more than just how to find information—it encompasses the ability to understand the need for information, interpret the information, and appropriately apply and document the information. Perhaps most important, information literacy requires metacognitive skills that allow students to make the most of their learning experiences. In order for a student to develop an informed approach to acquiring new skills and maintaining currency in a field, information literacy needs to be a component of his or her lifelong learning strategy. Design projects, as authentic learning activities, are ideal environ-
ments for learning the skills necessary for professional success for engineering students.

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