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Information Literacy Skills as a Critical Thinking Framework in the Undergraduate Engineering Curriculum

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Abstract

Information Literacy (IL) instruction embedded into the engineering design curriculum can provide a framework for the development of critical thinking skills which are essential for students to master to solve open-ended engineering problems. At Wayne State University, a lecturer in biomedical engineering (BME) and a science librarian are collaborating in an ongoing effort to integrate IL instruction into the BME undergraduate design curriculum. The paper will provide a vision and rationale for integrating IL instruction into the engineering design curriculum, and discuss aspects of the Wayne State effort to effect this integration. A review of the place of critical thinking skills in learning theory will be presented, and student critical thinking skills will be discussed in the context of the engineering design process. The differences between a structured approach and the traditional (unstructured searching) approach to information gathering will be presented. We envision that an IL-integrated program will require the redevelopment of coursework to take advantage of the structured approach, and will also require methods of student assessment that are more appropriate to the evaluation of critical thinking skills. Examples of course activities and modules which force students to think critically about information sources, reliability and authority will be outlined. Finally, the challenges and barriers to the implementation of such a program will be discussed; these include developing library infrastructure to support the approach, and creating student assessment methods suitable for evaluating creative thinking skills.

Introduction

As engineering educators, we strive to help our students to move beyond a superficial knowledge of the basic facts associated with the field, and develop an ability to analyze and evaluate the conceptual and procedural knowledge associated with real world problems. In essence, we want our students to develop creative and critical thinking skills which will allow them to address the open ended and ambiguous problems which they will encounter once the leave the university. This type of deep learning requires that we develop exercises and assessment tools that encourage and reward the activation of higher order cognitive skills while still confirming that the basic understanding of fundamental knowledge is intact.

As with most situations, engaging student's critical thinking requires a careful balance. We do not want all of the problems we give our students to be so well defined that they never have to grapple with uncertainty in their calculations, but on the other hand we do not want the exercises we provide to include unnecessary complexity or ambiguity which distorts the student's ability to grasp the fundamental principles presented. Additionally all of this must be accomplished in a classroom environment in which there is a wide range of prior experience and mastery of prerequisite skills, and differentiated learning opportunities must be provided to suit different students' skills and learning styles.

Recently, we have begun investigating the coordination of information literacy and engineering problem solving to help students gain experience applying basic engineering principles to real world situations. Merging these two distinct domains provides a means for students to think as engineers would in the field, using higher order thinking to discover and evaluate information.

Problem solving, critical thinking, and their relationship to information literacy

Dealing with real world problems entails the development of critical thinking skills which require students to engage higher order thought processes. Once the general concepts relative to an engineering discipline have been presented, students must activate these higher order thought processes in order for their application of these concepts to be meaningfully collected. When carefully formulated assignments and projects are developed, students are able to grapple with ambiguity from the beginning of their engineering career, allowing them to begin developing critical thinking skills early on. By the time these students graduate, they will have experience not only understanding and directly applying information, but they will also be able to analyze, evaluate and even create solutions to open ended problems.

The critical thinking skills required for engineering problem solving have much in common with the skills defined in the *Information Literacy Standards for Science and Engineering/Technology*, a document created by the Association of College and Research Libraries (ACRL)[1]. This document defines information literacy as "a set of abilities to identify the need for information, procure the information, evaluate the information and subsequently revise the strategy for obtaining the information, to use the information and to use it in an ethical and legal manner, and to engage in lifelong learning", and comprises five standards and twenty-five performance indicators outlining abilities that information-literate students in the science, engineering and technology should be able to demonstrate. ACRL defines the skills that an information literate individual is able to accomplish as:

- Determines the nature and extent of the information needed
- Acquires needed information effectively and efficiently
- Critically evaluates the procured information and its sources
- Uses information effectively, ethically, and legally to accomplish a specific purpose

- Understands that information literacy is an ongoing process and an important component of lifelong learning

While the ACRL standards are written primarily to address the skills needed to locate reliable information in the STEM knowledge domain, it is apparent that many of the same cognitive and intrapersonal skills that enable a student to be an efficient and critical finder/consumer of technical information will also help the student to navigate and solve complex, open-ended engineering problems. Our claim is that by integrating appropriate information literacy training within engineering courses, students can acquire cognitive and intrapersonal skills which will not only help them in finding and evaluating information sources, but will also trigger the development of deeper learning skills which can transfer to other problem-solving tasks and domains.

Examples of using information literacy in engineering education

The classroom setting provides a wide range of opportunities for instructors to use IL in the development of their student's higher order thinking skills. However, it may at first seem challenging to implement this into traditional engineering classes, which seek to impart specific fundamental knowledge and develop skill applying this knowledge. The following descriptions are intended to demonstrate some of the ways in which IL can be incorporated into a traditional course without vast modification to the curriculum.

Use of codes, standards and certifications, and material property specifications

Standards are one of the primary ways that organizations within and across industries and across national borders are able to communicate expectations, norms and specifications. Harding and McPherson[2] state that standards can encompass technical, economic and societal arenas, and have an immense effect on how engineering design and development occurs.

While a given standard may not affect the physics behind a fundamental engineering principle, it can have a significant effect on how the principle can be applied to a give situation. For this reason, it is important for all engineering students to be able to understand the role of standards within engineering. When instruction on standards is not limited to an isolated lecture concerning its importance, but is instead incorporated into the ongoing instruction and problem solving within a discipline, an opportunity for critical thinking skill building is formed. For example, if a student studying fluid flow through closed channels is asked to solve a traditional problem, except rather than being given the pipe diameter and surface roughness, they were told it was 1/2" schedule 40 PVC, they must now use basic critical thinking and information literacy to find the information necessary to solve the problem. The information technology tools required to find the required values can be included to reduce the overall time required by the student to find the information, however, to expand the depth of the cognitive processes engaged, students could be asked to evaluate their source for the information necessary to solve the problem. At this point, an explanation of standards and their value can be incorporated into the instruction, and critical thinking can further be expanded by introducing alternate options which may take into consideration both the fundamental principle at hand as well as other critical engineering factors. In this example, the next part of the question could ask whether schedule 80 pipe would be preferable in this situation, and could clarify whether the decision should be made based on the fluid dynamics alone, or whether other factors such as cost and codes be taken into consideration.

In the same way, using IL to determine material properties or other characteristics can transform a standard homework problem from the lower cognitive domains of understanding and applying to an opportunity for students to critically analyze and evaluate where information comes from and how to best apply it. By challenging students to function in these higher cognitive domains through IL, students will become more attuned to thinking critically about all the problem solving decisions they make.

Journal articles / conference proceedings

Any information source should be critically evaluated for its reliability, accuracy, and credibility. However, this practice can be difficult for students who have only been exposed to information access through sources which have been very thoroughly edited for errors such as traditional textbooks.

Introducing other sources of information such as journal articles or conference proceedings into the classroom instruction can provide a means for students to develop skill evaluating the strength of information found, and to what extent it should be used.

An example of how journal articles can be incorporated into classroom instruction is the use of the analysis presented in an article as a framework describing how to solve a specific problem. If a well written article is provided, students can use it to determine what steps to take in solving the problem, and have results to compare with their own results.

This differs from simply following the steps provided in an example in a textbook for several reasons. First of all, many articles provide substantially more background information than could be included in a textbook example, providing valuable information demonstrating to students how knowledge is developed by building on prior knowledge which can be accessed through effective IL. Secondly, students can be asked to evaluate the assumptions that original author made in developing their analysis; this provides an opportunity for students to explore the author's resources as well. Students can then be challenged to consider the strength of these assumptions for their own analysis, especially if the results that they encounter are different than those posed by the original authors. Additionally, it can encourage students to consider finding other articles which might provide more convincing results, based on either more accurate assumptions, or results which have been confirmed based on correlation with physical tests.

This type of critical analysis of the solution is not possible with more traditional means for communicating instruction such as textbooks, which by their nature will provide well established factual material which students will rarely question.

Beyond these examples, there are many other ways to foster the development of critical thinking through the implementation of information literacy, and we encourage faculty to look carefully at their curriculum to develop options which are catered to their needs.

Addressing barriers to the adoption of information literacy in engineering curriculum

There are a number of barriers to the use of information literacy practices for the development of critical thinking skills in fundamental engineering course. These include barriers in the areas of coordination, assessment, and infrastructure.

One of the most valuable (but often untapped) resources available to engineering faculty for the development of critical thinking is the library staff. Librarians are at the forefront of the university's decisions about information acquisition and dissemination and they have the best understanding of what information is available where and how to best access it. Librarians have been trained and have substantial experiences using critical thinking to develop deeper and more skilled information literacy, and as thus are in a position to address many of the barriers encountered. Academic liaison librarians often possess subject degrees in STEM fields in addition to their degree in library/information science, and this background can aid in collaborative efforts with engineering faculty.

Coordination between IL topics and engineering assignments

IL instruction includes a diverse group of topics and skills, and learning outcomes are generally improved by introducing each topic or skill in the context of an assignment which (when mastered) adds to the critical problem solving skills of the student. A certain amount of planning is needed to coordinate the delivery of each IL topic with an appropriate assignment, and to sequence the sessions so that each new IL topic builds on prior IL topics. It may be necessary to rework assignments to adequately integrate an IL topic with the engineering lesson in a seamless and meaningful way. To maintain student engagement, it would be desirable to avoid unnecessary repetition of IL topics over the engineering curriculum.

Given these and other constraints, coordinating the delivery of IL instruction to occur at the point of need over the course of the engineering curriculum can require a significant amount of planning and flexibility. Curriculum mapping offers one approach to systematically integrating

IL instruction at the appropriate point of the curriculum; Bullard and Holden[3] have described the use of curriculum mapping methods for the integration of IL instruction into the Agricultural Science undergraduate curriculum at the University of Tennessee.

Librarians are generally sensitive to the needs and constraints of faculty, and are often receptive to working with them to integrate information literacy topics at the appropriate points into the engineering curriculum. Effective cooperation between teaching faculty and librarians is essential to the development of critical thinking assignments, and can enable the reuse of engineering specific IL materials across engineering disciplines, reducing the amount of course redevelopment required by the faculty.

Assessment of critical thinking skills and information literacy

In order to evaluate the effectiveness of any means for developing critical thinking skills, a methodology for assessment is necessary. However, assessment of open ended and ambiguous problems can take on a drastically different form compared to assessment of the application of fundamental engineering principles. Without effective tools for evaluating both the lower cognitive domains of remember/understand/apply as well as the higher cognitive domains involving analyze/evaluate/create, faculty may find themselves at a loss as to how to evaluate students.

Fortunately, the question of how to assess open ended problem solving has been addressed by a number of academic organizations, resulting in efficient, intuitive rubrics for the use of evaluating critical thinking. Alfrey and Cooney[4] developed a rubric for assessing critical thinking in open ended problems, breaking the problem solving process down into the following 5 steps:

1. Define the problem
2. Explore a variety of solutions without limiting ideas (at this phase)
3. Determine ‘best’ solution using a pre-defined analysis technique
4. Plan and implement the solution
5. Evaluate results

Using these skills, criteria were established to evaluate the competency level demonstrated for each. This rubric uses a four-point scale which evaluates whether a student is Beginning, Developing, Competent or Accomplished in a specific skill. It also includes descriptive adjectives which help to clarify the scope of the accomplishment level for each skill.

Another rubric designed for evaluating critical thinking in engineering students was developed by Ralston and Bays[5]. This rubric, which was developed based on the Paul-Elder critical thinking framework, addresses the critical thinking involved in how information is collected, evaluated and used in solving open-ended real-world problems. They demonstrated how this rubric could be utilized either for assessment of a specific assignment or in evaluating the overall critical thinking performance of an engineering student.

Comparison of these problem solving skills and information literacy skills defined by ACRL demonstrate that these skill sets overlap in many dimensions, and therefore, evaluation of IL and critical thinking involve assessment of the same skills, indicating that rubrics which are designed primarily for critical thinking assessment can be applied with only minor modification to specific information literacy components of an assignment.

Use of rubrics design for information literacy and critical thinking can eliminate much of the concern associated with assessing critical thinking in engineering courses. With a clear description of expectations, both students and faculty know what is required for successful development in this area, and efforts both in developing assignments and in completing them (by the student) can target those specific performance criteria which are most critical for higher level critical thinking.

Information infrastructure

Another consideration in developing course-integrated IL instruction is the ability of the library collection to support the range of topics and materials needed for instruction over the course of a 4-year curriculum.

In order to effectively find and utilize a wide range of sources, students must have appropriate access to specific resources relating to their field. In engineering this will often include controlled documents such as journal articles, monographs, standards and patents. Many of these documents are not readily available on the open web, but require specific (and often costly) access to specific data bases or peer reviewed journals in order to be able to read full-text copies of the documents.

Without an academic infrastructure which facilitates locating and accessing these sources on the deep web, most students will default to using open web search engines which provide information which often lacks authority and may be incomplete, incorrect or out of date. It is difficult to help a student understand the difference between a reliable, citable source on the internet and the majority of the citations found on the open web when they do not have access to credible, controlled online sources.

Ideally, instructor and librarian would work together to proactively identify materials which could support specific assignments over the course of the curriculum, and to acquire any material not already accessible to students (or to identify adequate substitutes within the collection). In addition, this sort of planning provides feedback for the library's collections efforts and allows them to better identify materials needed to support the engineering curriculum.

Conclusion

Information literacy (IL) training develops and engages many of the same critical thinking skills needed for the effective solution of complex, real-world engineering problems; the integration of IL training into engineering assignments can simultaneously develop critical thinking and information assessment skills. Barriers to the creation and deployment of course-integrated IL training have been identified; these include finding methods to assess critical thinking skills, determining how to appropriately coordinate the delivery of IL topics with engineering assignments, and ensuring access to the library materials that support assignments. We are confident that, with sufficient and proactive collaboration between instructional faculty and academic librarians, these barriers can be overcome to the benefit of the students.

Bibliography

[1] Association of College & Research Libraries. (2006). *Information literacy standards for science and engineering/technology*. Available: http://www.ala.org/ala/mgrps/divs/acrl

[2] B. Harding and P. McPherson, "Incorporating standards into engineering and engineering technology curriculum: It's a matter of public policy," presented at the ASEE Annual Conference and Exposition, June 14-17, 2009, Austin, TX.

[3] K. Bullard and D. Holden, "Hitting a moving target: Curriculum mapping, information literacy and academe," presented at the LOEX 34th Annual Conference, May 4-6, 2006, College Park, MD.

[4] K. Alfrey and E. Cooney, "Developing a rubric to assess critical thinking in assignments with an onen-ended component," presented at the ASEE Annual Conference and Exposition, June 14-17, 2009, Austin, TX.

[5] P. Ralston and C. Bays, "Refining a critical thinking rubric for engineering," presented at the ASEE Annual Conference and Exposition, June 20-23, 2010, Louisville, KY.