Session# 1793

Integrating Information Literacy Skills into Engineering Courses to Produce Lifelong Learners

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Abstract

One criterion of the Accreditation Board for Engineering and Technology (ABET) is that engineering students must develop lifelong learning skills in order for a program to be accredited. We argue that developing information literacy skills will allow students to exert more control over their own learning within and beyond the classroom so they will develop these skills.

We have developed several methods of injecting information literacy skills seamlessly into engineering courses so students will see the value of being able to find information on their own. These activities incorporate discussions on peer reviewed materials, the appropriateness of using the Web for gathering information, and databases common to a core discipline. Pre- and post-implementation evaluations by sophomore, junior, and senior engineering students from two different engineering disciplines show that the incorporation of information literacy skills strengthens students' understanding of how to find and use information in engineering contexts. Future work would investigate whether students are indeed becoming lifelong learners by surveying their use of library information tools after they graduate.

Introduction

In this work, we advocate for the systematic inclusion of information literacy (IL) across the undergraduate engineering curricula to meet the Accreditation Board for Engineering and Technology (ABET) requirement for "teaching lifelong learning skills"[1]. Our previous paper[2] showed that IL skills can be seamlessly included in engineering courses by modifying assignments and adjusting syllabi. We showed that treating the IL skill set as an after-thought marginalized the concepts of both lifelong learning and information literacy. Much of the discussion in our previous work centered on technical strategies for transferring information literacy skills by impacting the course syllabi. In this discourse, we show more examples of how to integrate IL into engineering courses while also reporting more assessment data. We also provide an in depth argument about how IL skills contribute to lifelong learning skills.

We attempt to create a parallel learning process by infusing information literacy with regular course work. This particular teaching methodology teaches information literacy skills using the class content in a way that makes the literacy point with out appearing contrived. Research studies indicate that learning which is directly related to real life situations where the

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lesson is learned contributes to creating indelible impressions. The most effective way to educate is to teach in the context of real-life situations and real problems. [3]

Information literacy

Information literacy, according to the Association of College & Research Libraries (ACRL) "is a set of abilities requiring individuals to recognize when information is needed and then have the ability to locate, evaluate, and use effectively the needed information." [4] The concept that a skill set that allows engineering graduates "to engage in lifelong learning to keep abreast of changes in technology and new investigative tools for doing research"[5] was readily accepted by both engineering faculty and librarians when a draft of it was circulated during the Engineering Libraries Divisional meeting at the American Society for Engineering Education annual conference in June of 2001.

Lifelong learning

The term 'lifelong learning' originated in Europe in the early 1970s[6]. During that same time period in the United States, the concept was primarily used in reference to learning in the work place[7]. Developing a shared definition of lifelong learning has been a nebulous process and it remains a term not widely understood by educators, particularly on the matter of being able to evaluate it.

Currently, the term is generally defined as a continuous learning process meant to supplement one's formal education. It involves acquiring information literacy skills, and abilities that teaches one how to learn; a concept necessitated by the proliferation of information and rapid technical advancements. Central to this learning model is the belief that the responsibility for teaching learners how to learn across their lifespan is the shared responsibility of the individual and the subject specific curriculum.

Due to the rapid expansion of knowledge, there is not much room in most undergraduate engineering curricula to add additional subject content. The obvious solution is to figure out how to teach the learner how to learn what it is they need to know by promoting self-directed learning activities. Loading the curriculum with additional content at the expense of teaching one how to learn is an outdated concept that no longer works[8]. The single determining impetus towards the successful assimilation and cultivation of lifelong learning skills is an intrinsic belief that one is responsible for one's own learning.

Lifelong learning is both a process and an integrated skill set aimed at providing a learning framework based on successful learning experiences. These learning experiences can be used to create a repository of skills, both mediated by instructors and individually self-directed, that students can rely on to process knowledge. Taking responsibility for one's own learning is the first step towards self empowerment and is characteristic of an educated person. This mindset emphasizes the need to develop skills based on individual learning preferences, which can assist in the acquisition of individualized learning techniques.

The importance of information literacy and lifelong learning to engineers

Students who know how to find and how to ask for information experience positive learning encounters at a higher rate than their counterparts who do not have these skills. It appears that a positive learning experience generates confidence in one's ability to learn while negative experiences have the opposite effect. Possessing a basic skill set in retrieving and analyzing information facilitates all other learning.

The best teachers know that instruction in information retrieval is most effective if it is course-integrated, and delivered at the time of need.[9] Given the huge amount of technical information generated across the various engineering disciplines, students can develop and refine their skills in locating and analyzing information more effectively in a parallel learning process where information skill building is incorporated into their regular course work. Engineers today require a high degree of proficiency in a range of abilities outside of the traditional course content. In fact, it was in part due to the lack of information literacy skills demonstrated by new engineering graduates that so concerned the engineering industry that ABET felt prompted to include in its 2000 guidelines a requirement, requiring teaching students "to learn how to learn." [1] We discussed in our earlier work how to use syllabi to impart goals and information to students, specifically how to use the syllabus to identify opportunities for incorporating IL into an engineering course[2]. Before showing some specific techniques for integrating these skills into engineering courses, we will review some recent assessment data about what students know about information literacy skill sets at several levels in our curricula.

Pre-Incorporation Assessment Data

The National Science Foundation has suggested for several years now that educational assessments are stronger when they use both numerical and open-ended questions to evaluate a project[10-11]. We will follow this format in this work. The survey shown in Figure 1 was given to a sophomore chemical engineering class (ChE) and to a senior class in systems and industrial engineering (SIE) at the University of Arizona in the Fall of 2003. The first four questions were designed to have the students self evaluate themselves on their ability to find and assimilate information related to engineering problem solving. The open ended questions were created to have the students now back up their self evaluation with some specific details about what they really do know about finding information.

Twenty-seven students returned the survey from the SIE 495 class and had an average self-rating of 7.9 on their ability to find reliable information, with a zero implying they had no skills in this area to a 10 implying they were near experts. Similarly, they self rated themselves at 7.87 on their ability to use library resource, 7.74 on their ability to judge the accuracy of materials, and 7.83 on their ability to read technical papers. Interestingly enough, these self-evaluated scores are very high compared to other times when this survey has been given[12] in the past for similar evaluations.

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Name______________________________ Course ___________________________

Information Literacy and Library Skills Pre-Assessment

Rate your knowledge in the following areas from 0 (no knowledge) to 10 (expert knowledge):

Ability to find reliable information for solving engineering problems 0 1 2 3 4 5 6 7 8 9 10

Ability to use library resources to find specific information: 0 1 2 3 4 5 6 7 8 9 10

Ability to judge the accuracy of materials you have found: 0 1 2 3 4 5 6 7 8 9 10

Ability to read technical papers: 0 1 2 3 4 5 6 7 8 9 10

Answer the following questions with a short answer of a few bullets or sentences:

Describe up to three primary sources you use when looking for information on a topic that is new to you. Be specific, i.e. don't just say "the Internet" but instead describe which tools you use there.

Describe what formal or informal training, if any, you have had on how to use the library system effectively at the university.

Figure 1 - An abbreviated form of the pre-survey to evaluate students on their IL skills.

Forty-three sophomore ChEs took the same survey in Fall of 2003 and had lower self-evaluated scores with averages of 5.26, 7.3, 6.07, and 6.33 in the same categories. Only on the ability to use the library resources did the sophomores feel they had the same level of skills as the seniors from SIE. Seven senior ChEs and five graduate student ChEs took an earlier version of the survey that did not have the first numerical question in the Spring of 2002. They reported scores of 6.67 on their ability to use the library to find information, 4.42 on their ability to judge the accuracy of information, and 5.33 on their ability to read technical papers.

A comparison of the presurvey results leads to some interesting observations. Although there is explicit training on how to use the library system in a freshmen english course, only 26% of the SIE seniors recalled this training while 41% of the sophomore chemical engineers did. An additional 11% of SIE seniors and 5% of chemical engineering students had received training from either library staff or from a mentor on a research project. The rest of the students reported receiving no training of any kind, either formal or informal. While some of the students may be transfer students or have used Advanced Placement courses to miss the courses that instruct them in how to use the library, this would be a small percentage compared to the number that say they have never had any training at all.

Before comparing the first open ended question results for the pre-surveys, some general comments should be made. While we requested that students list up to three primary resources they would use to find information on a new topic, some students listed fewer than three and others listed more than three. Some interpretation had to be made on the responses to address what the students meant in some cases, which always occurs in any open ended response process. For example, if students listed three general search engines as their search technique, then their response was recorded as 1 "internet engine" response. However, if students said they used the library search engine to find relevant books, a score of 1 went towards "library engine" and 1 toward "library books". The following categories were identified as being distinctive enough to be included: internet engines (Google, Yahoo, etc.), library books, people, online library reference materials, the library search engine, journal citation search engines, magazines and newspapers, journals, professional organizations, contacting the original source of the information, text books, commercial/company websites, governmental websites, and using bibliographies from other primary sources.

Data were aggregated into meaningful comparisons by summing up the total number of responses given by the students in each class first. The individual sum of each category was then divided by this total number of responses to see which percentage of the responses were from each category. This will allow us to compare the pre-survey results for each class.

A comparison of which methods students use most is very instructive now that some of the details of aggregating information from the open ended questionnaires has been discussed. Using only the responses that showed up 10% of the time or more on student open-ended questionnaires, one can see which methods are used most by students to find information, as shown in Table 1. First, 33.7% of the total number of responses by SIE seniors indicated that students would use general internet search engines like Google or Yahoo to search for information about a new topic. This answer was given by 96% of the students in SIE. The percentage of responses by the sophomore chemical engineers was only slightly lower. Similarly, nearly 20% of SIE responses would use library books and 14% of ChE responses would use them. Only 10% of SIE responses would use the library search engine, but 25% of the ChE responses would. This difference is possibly this large because more ChE students recalled receiving training on this tool in their earlier courses and this tool has never been used by the SIE students in SIE courses. Another resource widely used by SIE students is interpersonal communication with knowledgeable people who are familiar with the topic and 19% of the SIE students reported this as a primary source. Only 4% of the ChE responses reported this, possibly due to their much less experience in engineering. Finally, 10% of the ChE responses were for using a journal search engine to find peer reviewed information. This compares to only 3% of the SIE responses. Again the difference is probably due to the training recalled more often by the sophomore students compared to the senior students.

Table 1 - A summary of the percentage of responses for each category from the pre-surveys.

Category	SIE	ChE
internet search engines	0.34	0.31
library books	0.19	0.14
people	0.19	0.04
online library reference materials	0.01	0.05
library search engine	0.10	0.25
journal search engine	0.03	0.10
magazines	0.04	0.03
journals	0.01	0.03
professional organizations	0.01	0.05
contact the original source	0.01	0.00
text books	0.04	0.00
commercial website	0.01	0.00
government website	0.00	0.00
bibliographic information	0.00	0.01

Although the students rated themselves highly on being able to find new information, we find that students are most likely to report using a general internet search engine first. Other resources that may be regarded as more trustworthy like peer reviewed publications or books are reported much less frequently. We must expose students to and get them to use higher quality sources of information if we think information literacy is a cornerstone of lifelong learning skills. The pre-assessments show that students just do not know many of the resources that are out there or do not know how to use them effectively, calling into question their ability to judge the accuracy of the information they find. Let us now turn to techniques for incorporating IL skills directly into engineering courses where students receive training and feedback.

How to Incorporate IL into Engineering Courses

We discuss briefly two separate courses and how IL skills were incorporated into them. One course was a senior level SIE course that was the first course in the 2-semester senior design sequence, while the other course was a junior level ChE thermodynamics course that covered equilibria and non-ideal systems. Both of these courses are traditional engineering courses in the sense that they would not normally require IL as a component of the course. The SIE course integrated the IL skills content in Fall 2003, while the ChE course integrated them in Spring 2004.

SIE 495 is the first semester of the capstone sequence where students "put it all together" and design a solution to an actual problem. Students go through the entire systems design process from “need” to "implementation" and "evaluation." The projects have external clients/sponsors and for many students this is the first experience at managing and completing a project. Students write reports and make oral presentations as part of the class. The course also contains seminar materials to help with the transition from undergraduate study to graduate school or industry. The course has the following goals:

1. Understand and implement all steps in the design process and use tools and techniques appropriate for each step.
2. Construct and deliver oral presentations.
3. Construct and deliver written reports.
4. Understand engineering ethics and professionalism related to dealing with a client and in the workplace.
5. Ability to work in teams with clients and take on different roles of the team.

We included IL in the class by having library personnel construct and present content materials and assignments within the seminar format. The content materials covered the basics of the library databases and an example search was solicited from the class. The students were then given laptops and a "scavenger hunt" to complete in class with their design team. The items on the search list were constructed to be SIE relevant (discussion between the librarian and the 495 instructor). Anything not completed in class was given as an assignment. The library team returned 3 weeks later to go over the results and to collect the completed assignments. For most of the students, this was the first time that they were asked to do internet searches using tools other than standard search engines.

ChE 326 is the second semester of thermodynamics required for all chemical engineers. While some of the techniques for incorporating IL directly into the chemical engineering course were covered in our previous work[2], more details are furnished here, including some "before and after" descriptions of how assignments were changed to have an IL component. We have found that it works very well to assign a short IL assignment by asking students to find some information relevant to the course material early on. This is done without providing any training on any of the library resources while explaining to the students that they should explore the library. A sample of how to do this is shown in Figure 2.

Here, students are expressly asked to find some vapor-liquid equilibria data for one binary chemical system. There are approximately 30 articles that have been published on these two chemicals either alone or in conjunction with a third substance. However, only four or five of the references actually have the published VLE data. The data will be difficult for students to find. In light of this, students have the option of fulfilling the library informational objective of learning how to search for specific information by describing their search strategies and documenting the search results. Students are asked to document their search strategy so that credit can be given for their attempt to find the information.

> Attempt to find Pxy, Txy, or xy data for the acetone-cyclohexane system in a published reference. If you do find one, compare the published data to your plots by showing the data on the same graph. Verbally describe how well your data agrees with the published data.
>
> If you cannot find any data for this system, describe specifically how you searched for published data. This will enable you to get full credit for this portion of the assignment.

Figure 2 - a sample homework demonstrating the introduction of information literacy skills.

On the day the assignment is handed in, a short discussion with the students about the resources they used and the problems they encountered with each resource is held. This introduces all students to the resources and helps them in formulating a plan for handling new instances of having to find information. Specifically, students should be made aware of journal search engines, how to find texts in their library, the importance of the library reference section, the dangers of using only general internet search engines, and discipline specific handbooks and reference texts that are either online or in print form. A follow-up assignment requiring students to repeat this exercise for another chemical system will have them practice their IL skills.

Let us now demonstrate how to change a standard textbook problem so that it will have some IL skill content as was done in this class. The problem shown in Figure 3 as the "before" version is an abridged form of a problem taken from Smith, Van Ness and Abbott[13]. Notice that it gives the information the students need and asks them to mostly do a simple algebraic manipulation. A rewritten version of this problem is shown as the "after" version as it would be given in a handout.

Before: The following vapor pressure data is available: at 32°C, P*(psia) = 0.08854, at 34°C, P*(psia) = 0.09603. Estimate the heat of vaporization of water.

After: Find vapor pressure data for H_2O and estimate the heat of vaporization of water. Give a full citation to the data you used and include a photocopy of the data itself.

Figure 3 - Changing an assignment to include IL content when there was none.

The problem now has an IL component by asking students to find and cite the data they use in their example. The discussion that was held in class after the first IL assignment will aid them in being able to find the information. It is extremely important to assign scores for the IL component and to penalize students if they are not finding highly accurate information. This will demonstrate to students that you are serious about the assignment while also encouraging them to learn the IL concepts.

Another example is shown in Figure 4 here. The "before" version again comes from Smith, *et al.*[13].This "after" example is an addendum that would be handed out to students telling them what to do with the original problem. They are not told specifically what information they will need to find, but are asked to cite any data they looked up and used. This is an activity where students are becoming more independent and directing their own search activties as no suggestions are given on where to look.

Notice also that the assignment has been changed to move to higher levels of questioning. Now students are asked to evaluate and compare instead of just plugging numbers into formulas to arrive at an answer. One caveat should be mentioned now that this example has been covered. Fewer problems were assigned once the IL and higher level questions were incorporated in this class because each question now took students longer to answer and process the information. However, the trade-off of losing a few problems during the semester was worth it because students seemed to become more self-reliant and able to solve problems independently of the instructor.

Before: For the acetone(1)/methanol(2) system a vapor mixture for which $z_1 = 0.25$ is cooled to temperature T in the two-phase region and flowes into a separation chamber at 1 bar. If the liquid composition is 0.175, what is T and the composition y_1? For liquid mixtures of this system, a good approximation is:

$$\ln \gamma_1 = 0.64x_2^2 \quad \text{and} \quad \ln \gamma_2 = 0.64x_1^2$$

After: Do not solve this problem as listed. Instead,

- Use the given activity coefficient models for acetone and methanol to generate a Txy diagram at 1 atm and make a plot of your data. Cite any additional sources you use for information you may need.
- Repeat the calculations using Raoult's law.

Find published peer reviewed data on this system in an appropriate source. Copy the page containing either tabulated data or a figure representing the data in addition to copying the citation information as discussed in class previously. If possible compare your two results above with the published data in a brief paragraph.

Figure 4 - Another example for adding on a portion to an existing problem to now have an IL component.

Now that some examples have been shown on how to incorporate IL skills into engineering, it is time to see if these interventions have any positive impact on students' abilities to find and use information.

Post-Incorporation Assessment Data

The same survey from Figure 1 was given to ChE seniors again after they had experienced the thermodynamics course with the IL techniques. This survey was given the following fall after they had spent a summer away from the material, thus it should somewhat simulate what a graduating engineer might recall as they begin their first job as lifelong learners outside of our courses. There were 24 responses to the survey.

Table 2 - A summary of the percentage of responses for each category from the post-surveys given to senior chemical engineering students.

Category	Response
internet search engines	0.24
library books	0.11
people	0.06
online library reference materials	0.09
library search engine	0.09
journal search engine	0.23
magazines	0.00
journals	0.07
professional organizations	0.01
contact the original source	0.00
text books	0.01
commercial website	0.03
government website	0.06
bibliographic information	0.00

The quantitative results show that the students rated themselves at 7.33 for being able to find information for engineering problem solving, 7.58 for their ability to find information in the library, 7.25 for being able to judge the accuracy of information, and 7.58 for their ability to read technical papers. Note that these scores are nearly identical to the seniors from SIE, but higher than those of the chemical engineering sophomores. It could be that students become more confident as they approach senior status regardless of their training since the SIE students had rated themselves similarly with no or little training in IL skills and this should be examined in the future.

Surprisingly, only 63% of the ChE seniors recalled covering IL skills in the thermodynamics course the previous spring semester. However, the quality of student responses to the open ended questions seemed much better balanced towards peer reviewed materials compared to the SIE seniors. We are comparing the two senior level groups as a control and an experimental group because they have taken a common core of freshmen and humanities courses along with overlapping strongly in the sciences at the lower levels. Twenty-four percent of the ChE responses indicated a general search engine as a primary search tool, compared to 34% of the SIE responses. The biggest difference, though, was for journal search engines which made up 23% of the ChE responses, but only 3% of the SIE responses. Likewise, chemical engineers were much less likely to rely on a person for information or to use magazines than the SIE responses indicated.

The thermodynamics course is being offered again this spring semester and more IL incorporations are being planned. During the original offering, IL components appeared in 40-45% of the homework assignments. In this offering, they will appear in 90-100% of the assignments. A pre-survey will be done with this junior class and a post-survey will be done at the end of summer to see how the results from the previous ChE evaluations change when the same group of students is used for pre- and post-surveys.

Ongoing developments in the College of Engineering at the University of Arizona indicate that information literacy may become the main measurable component of lifelong learning skills for ABET purposes, but more groundwork is being laid for that possibility. The librarians recently prepared a short workshop with engineering faculty participation to build consensus about what lifelong learning is and how to assess it[14]. An ongoing development process in continuing to build consensus on these issues.

Future work will investigate the replicability of the pre- and post- evaluation results for a single class of chemical engineering students and also for a single class of systems and industrial engineering students. More assessment data was not available at the time of writing due to timing mismatches.

Conclusions

To be successful in practice, engineering students need to know how to gather and effectively use information for the purposes of making informed decisions and implementing assigned tasks. We have highlighted in this paper just a few techniques where information literacy skills can be incorporated into engineering courses. The pre- and post-assessments showed that the techniques seem to have exposed students to many new resources they remember after significant time away from their learning experiences. Finally, further work is needed to more rigorously assess whether the IL skills may be a strong foundation for lifelong learning skills for engineers.

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