AC 2009-1428: INTEGRATING INFORMATION LITERACY INTO A FIRST-YEAR MASS AND ENERGY BALANCES COURSE

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Integrating information literacy into a first year mass and energy balances course

As part of a curriculum-wide information literacy program in engineering, a second-semester first year course offers a substantive introduction to information literacy, building on first-semester writing intensive courses and a college-wide online quiz-tutorial to offer discipline-specific instruction in information literacy. This course lays the groundwork for additional information literacy instruction throughout the engineering core curriculum and in the capstone design clinic.

Information literacy topics are integrated with course material in mass and energy balances using the organizing vehicle of a semester-long project on Life-Cycle Assessment. The engineering librarian taught a class that was tailored to the course and the LCA projects; developed a course-specific web site to direct students to relevant library resources they would use in completing the project; and assisted student teams per request as they progressed with their projects. The course professor assigned reading on information literacy; conducted a class discussion on information literacy in the broader context of intentional learning and reflective judgment; developed a homework assignment designed to practice information retrieval and evaluation skills; reviewed these skills on a midterm exam; reinforced information literacy skills on assignments including problem sets and ethics case analyses; and incorporated information literacy throughout the LCA project and specifically through an LCA annotated bibliography assignment.

Assessment data from student work as well as course surveys and focus groups provide feedback on student learning and indicate areas for future innovation. We discuss course-level innovations in the context of the larger curriculum-integrated information literacy program in engineering.

Introduction

Over the last several years, advocates of information literacy education have supported the idea of curriculum-integrated instruction as an effective student learning strategy, and this strategy has begun to be employed within engineering education.[1,2] Curriculum integration necessarily requires buy-in and collaboration from faculty[3] as well as detailed attention to course-level integration. [4,5] Despite some support found in the ABET 2000 outcomes criteria,[6] there remain both political and logistical challenges in this effort, given the particularly packed nature of the engineering curriculum and a strong resistance to change within the profession.[7]

Building on this literature, and with the support of a college-wide curriculum-integrated approach to information literacy, we have established a sequenced information literacy curriculum for engineering. The college's formal information literacy program began in 2003/2004 with an initial focus on first-year, writing-intensive courses, followed by departmental adoption of discipline-specific, sequenced, curriculum-integrated information literacy programs. Prior to the initial discussions and planning for this program in 2002, there was not a college-wide formal program, although the library conducted many instruction sessions that promoted and taught information literacy concepts.

Here we focus on one course in order to illustrate both the approach we have taken in our liberal-arts context, and to provide some details on the faculty-librarian collaboration process. The course brings information literacy to the fore by linking it to every other course element, including engineering ethics, engineering calculations, a project on life-cycle assessment (LCA), and the development of reflective judgment and intentional learning.

Background

On our campus, efforts to enhance instruction in information literacy have been underway for several years. The effort began with a focus on first-year instruction and continued with a curriculum-integrated approach in which departments work with librarians to create sequenced, discipline-specific instruction across the curriculum. To date, fourteen departments on campus (nearly 40 percent) have developed information literacy standards for their curricula.[8]

Engineering's information literacy standards were developed in March 2007.[9] A first-semester first-year course in engineering (required of all majors with considerable non-major enrollment) incorporates library instruction and requires students to conduct research related to a design project. In parallel with this course, students normally take a writing intensive course that introduces them to library resources that are not specific to engineering, and students take an information literacy quiz-tutorial online.[10] The college is in the process of improving this aspect of the first-year information literacy program to ensure a larger number of students receive this preliminary learning opportunity in information literacy. This paper focuses on the second-semester first year course that builds on these preliminary skills and provides a basis for more advanced learning within the major. Later courses address other aspects of information literacy in the context of laboratories, design, and engineering analysis in a variety of areas. The capstone design course utilizes information literacy skills on a real-world design project for a corporate, governmental, or non-profit client.

The course, Mass and Energy Balances, is a second-semester first year course that follows on the previous design-based introduction to engineering. It is a core course, required of all engineering majors, with enrollments ranging from 20-40 students, depending on interest in engineering among that year's entering class. Larger enrollments typically result in splitting the class into two sections to support student learning. The course is modeled after a course in chemical engineering varyingly known as "stoichiometry," "introductory process engineering," or "mass and energy balances." The most popular textbook in this area for decades has been Felder and Rousseau's[11], and Felder's activity in the engineering education community has led to his course representing something of a model for many. In our offering of the course, students learn mass and energy balances while they are introduced to problem-solving strategies, problem-set presentation, intentional learning, ethics case analyses, and other skills. Elements on intentional learning and ethics, and the incorporation of a life-cycle assessment project, are different from typical offerings of this course. To make room for these elements, we removed the most discipline-specific material that would not interest many students in our interdisciplinary engineering science program. Learning objectives (adapted parts verbatim with permission from Felder[12]) are stated on the course syllabus as follows:

- **Basic engineering calculations and computation**. Convert quantities from one set of units to another quickly and accurately; define, calculate and estimate properties of process materials including fluid density, flow rate, and chemical composition (mass and mole fractions, concentrations).
- **Material and energy balance calculations.** Draw and label process flow charts from verbal process descriptions; carry out degree-of-freedom analyses; write and solve material and energy balance equations from single-unit and multiple-unit processes, processes with recycle and bypass, and reactive processes. Apply mass and energy balance principles to product life-cycle assessment (LCA).
- **Introductory Thermodynamics**. Perform pressure-volume-temperature calculations for ideal and non-ideal gases. Calculate internal energy and enthalpy changes for process fluids. Apply the first law to perform energy and combined material/energy balances.
- **Learning Community**. Work effectively in problem-solving communities and carry out meaningful and constructive performance assessments of self and peers.
- **Engineering ethics**. Use a variety of ethical frameworks to think critically about ethical problems in the profession.
- **Information Literacy.** Identify, access, and critically evaluate information. Use information effectively, ethically, and legally. Conduct searches for peer-reviewed journal articles and patents in appropriate databases. Properly and ethically attribute information sources.
- **Self-directed Learning.** Demonstrate a process of self-managing, self-monitoring, and self-modifying student learning through an iterative process of reflection and change.

The students apply mass and energy balances to a product life-cycle assessment (LCA), an approach to identifying and quantifying the environmental impacts of a product from withdrawal of raw materials through processing, sale, use, re-use, re-manufacturing, or recycling, to its final disposition.[13] This project holds many disparate pieces of the course together because it has components in ethics and information literacy as well as mass and energy balances. The

developmental theory of reflective judgment[14] -- the progression through successive sets of epistemological assumptions toward more critical thinking and decision-making under uncertainty -- is presented as a way to connect the self-directed learning and information literacy aspects of the course to engineering ethics as well as to the technical material in the course through a series of written reflections on learning.

Therefore even though the Felder course and our course are quite similar in primary content and utilize the same textbook, the application context of information literacy here is quite different from that described by Bullard and Felder.[15] While their assignments and instruction focused more specifically on the chemical engineering literature, sources of engineering data for process calculations, and the use of standard references such as engineering handbooks, the instruction in this course is geared more toward a broad introduction to sources in engineering and sustainability research.

Learning Strategies for Information Literacy in Mass and Energy Balances

Elements of the course related to information literacy include a class taught by the science and engineering librarian. This class is tailored to the course and the LCA project, and includes many elements of exemplary practice in library instruction described previously.[15, 16] Meeting in a computer classroom, students are introduced to library resources, including the catalog, interlibrary loan, and databases in the engineering and science literature. They discuss the pros and cons of searches on the open Internet, and learn the difference between publicly available and proprietary online information. They learn to develop search strategies and apply them to LCA-related research topics. The nature of the instruction is interactive and hands-on, with students working in the large group to brainstorm keywords together and identify elements of a successful search strategy, then using handouts individually to develop keywords for a new topic, and working at computers both individually and in teams to conduct their own searches relevant to their project topic. Reporting back out to the larger group, students learn from one another what was successful and challenging about their work. At this session, the librarian introduces a course-specific web resource with links to a variety of library resources related to the LCA, and continues to assist student teams in individual meetings as needed.

In preparation for the class taught by the librarian, students read an article on information literacy[17] that describes the struggles of students at a similar/rival college to perform information literacy tasks. Class discussion of the article motivates students to take information literacy seriously and cautions them against overconfidence. Having already visited issues related to reflective judgment, students are motivated to seek tools that assist them in developing critical thinking.

A homework assignment then allows students to practice information retrieval and evaluation skills. Students are asked to find the best sources to support their answers to the following questions (skills practiced noted in parentheses following each question):

a. Who developed the patent for the Clif shot litter leash? What earlier innovations did it build upon? (Requires a patent search.)

b. Find two peer reviewed original research articles published in the last year about how climate change will affect hurricane frequency in the Atlantic. (Practices database search strategies and proper citation format)
c. What is a ballast in a fluorescent light fixture? (Focuses on evaluation of sources; many definitions of ballast exist, but what sources are authoritative in this context?)
d. What is the National Science Foundation's budget for fiscal 2008? (Requires current knowledge that might be most appropriate for an Internet search, but conflicting reports require students to evaluate sources.)
e. Find a review of previous research on materials engineers' use of materials in space which are inspired by the natural world. (Practices database search strategies and citation, as well as distinguishing original research from review articles)
f. Name three cases of academic dissent from military funded research Feldman cites in his article in the *Annals of the New York Academy of Sciences*, 577: 231-241. (Requires students to physically enter the library and locate periodicals in the stacks.)

It is notable that this assignment does not focus students in one topical area, but reaches across possible areas of engineering interest. This is intentional in a first-year course in order to pique the interest of the variety of students who may be interested in engineering, but perhaps not fully excited about product life-cycle assessment or mass and energy balances.

After receiving feedback on the homework, an exam question reinforces information literacy skills with the following questions:

a. What was the second patent issued in the United States (after the Great Fire of 1836)? What was it for? To whom was it issued?
b. Find a peer-reviewed article published by [other engineering professor] in 2007. Whom do he and his co-authors acknowledge as having assisted with sample collection and field work?
c. In Anna Sears's 2003 study of graduate students published in the *Journal of Women and Minorities in Science and Engineering*, approximately what percentages of women and men named life balance as an important factor in career satisfaction?
d. What are Smith's holdings for the *Journal of Industrial Ecology*? (i.e. do we have the journal, and if so what years/issues?)

Further, on problem sets and in their ethics case analyses, students are expected to provide support for their arguments or for data they utilized. Information skills are applied throughout the course.

The largest assignment addressing information literacy is the LCA. First, students assemble an annotated bibliography on their topic. They are required to provide at least five peer reviewed sources and include books, patents, technical reports, and Websites as well. They then reflect on the sources, noting the types of information provided, its relative quality and reliability.

The rest of the LCA assignment builds on the initial literature search. Students continually evaluate data they retrieve and ultimately create a written report that places sources in a "works cited" format. Students learn the APA style of citation as part of this process.

Assessment

The information literacy component of the class was assessed using focus groups, student course work, and student evaluation data from written surveys conducted after the librarian's class session (attached as an appendix to the paper) and at the end of the course. Results from each of these assessment measures are discussed below.

Focus groups were conducted in the last third of the semester; all 24 enrolled students were invited, with nine ultimate participants split into two sessions for optimal size and scheduling. Three general guiding questions prompted students to discuss how they were learning in the class, with one question probing the topic of critical thinking, which related to both the material on reflective judgment and the information literacy component of the course, though these were not mentioned explicitly in the question. Results were thematically coded; here we report all responses that relate to information literacy.

Survey Data from Librarian's Session

All students who attended the class taught by the librarian rated their learning experience as excellent or good. When asked to state the muddiest points from the session, students mentioned the use of interlibrary loan and referencing software (which was mentioned briefly but was not the focus of the session, as separate sessions are held on that topic outside of the course).

When asked what they found most helpful, students mentioned learning about the databases and other resources available on campus, learning how to navigate the libraries website, particularly the one-click icon for finding full text, and learning how to use interlibrary loan. Students also mentioned the specific mechanics of search databases, patent databases, and search strategies.

One important item covered in the session that students did not mention on their evaluations was the need to evaluate information resources. They also did not mention the group activity students did for practicing search strategies on a given topic. The assessment tool will be revised to probe these areas specifically to determine whether there is a need to change the emphasis of instruction or the approach to the group activity, or whether these were not mentioned due to student prior knowledge or some other reason.

Our own impressions of the session, supported by the data discussed above, is that many students were not very aware of the variety of resources available at the institution, despite an orientation to the libraries given to first-years and instruction most students receive in the previous semester in writing intensive courses. Students seemed to benefit particularly from learning how to approach a search, develop good key words, etc.

We believe the presence of the faculty member in the class was important to communicate the seriousness of the endeavor and to enrich the class by emphasizing particular points or expanding on certain details relevant for upcoming course assignments.

Focus Group Data

Overall, information literacy and related concepts were mentioned by four of the nine focus group participants, and represented a small portion of a broad-ranging conversation about student learning and all course assignments. This allows us to consider student comments on the topic in their entirety.

In one focus group, information literacy came up toward the end of the conversation, as students were discussing what could be improved about the class (as opposed to as a direct response to the prompt about critical thinking). Students were very positive about the information literacy aspects of the class. Referencing the information literacy reading[17] and discussion about the need to evaluate sources, a student said

> One thing that I found useful was that day when she was like `So guys don't trust everything that's on the Internet' because it's… well of course don't do it but you do it all the time. And I don't think about it as much as I should. And so to have someone who tells you `no, really, think about it' is really helpful.

Another student followed up saying,

> One thing helpful about this class is that she encourages us to research a lot. And, as a first year and second semester it's kind of like you're still kind of figuring out how the library database goes and all that and online articles and finding reliable sources. So that's been kind of a learning experience that's been really helpful.

A third student agreed, commenting "Yeah, I definitely don't think I could have found the information I needed without the library briefing."

In the other focus group, one student commented in response to the question about critical thinking:

> So, I guess the very first class Professor Riley talked about, you know, how do we learn and how do we know what we know is true. So, I guess that's kind of like a reflective judgment from the course, so it teaches us to think and you know there is a lot of practical applications when you are doing research. If you google something how do you know if this source is right, so I think critical thinking also has a lot to do with judgment. And I guess in terms of critical thinking mostly our reflections, and a lot of ethics in the course I think tends to help us make judgments and decide what is good and what is bad in terms of sources.

Here information literacy is understood as an integral part of critical thinking, reflective judgment, ethics, and research.

Students did not specifically mention the information literacy assignments or test questions in the focus groups, so further probing is needed to determine their role in student learning. It is

interesting to note that students for the most part did not immediately link critical thinking with information literacy, but the topic did come up unsolicited in both focus groups, with some students making that link, albeit belatedly.

Data from Course Evaluation Surveys

Summative student course evaluation data included student self-assessment of their fulfillment of course learning objectives, including information literacy. Students ranked the fulfillment of learning objectives on a 1-5 Likert-type scale. Mean scores ranged from 3.63 to 4.41. Students ranked learning community (teamwork) and basic engineering calculations the highest (4.41), and information literacy came in a close third with a mean of 4.35. However, large standard deviations for the scores (0.65-1.05), typical of the standard 5-point evaluation scale, preclude drawing any definitive conclusions here. One student remarked unsolicited, "definitely learned how to do this in this class."

Information literacy came up in two other places on the end-of-term assessment survey, in answers to open-response questions. First, the students were asked what they learned that surprised them. The most popular answer was "ethics" (19 of 24 mentions). However, four students mentioned "reflective judgment," "critical thinking" or "effective researching" – making this the second-most popular category (because information literacy was presented as an aspect of reflective judgment, they are considered together here). Two students mentioned a class field trip, and one student mentioned the contribution of the course to the decision to become an engineer.

The second place information literacy emerged was in listing three things they liked about the class. Here it emerged twice. Other topics were named more frequently, notably ethics and the LCA assignment, particularly in the context of its focus on sustainability. Information literacy did not come up in the discussion of things to change or in any other negative context, while some of the more frequently mentioned topics did.

Data from student coursework

On the homework assignment, only 7 of 24 students were able to answer all questions completely and correctly. Common problems (gleaned from the assignments themselves and class discussions in which the class went over the assignment) included the following:

- Failing to dig into the patent for citations to previous work
- Failure to cite completely in APA format (missing volume numbers, dates, pages, patent number, etc.), cutting and pasting messy web links without proper web citation from proprietary databases, encyclopedias, and patent cites.
- Difficulty distinguishing between peer reviewed work and news articles about research.
- Citing websites whose authority is not known or discussed. Using a language dictionary for a technical definition.
- Relying on a single source when multiple sources would help.
- Citing secondary sources, when a primary source would be better.
- Citing the proposed budget rather than the funded budget for the NSF.

- Difficulty finding a review article – both a search strategy failure and a lack of understanding of what review articles are.
- Failure to attempt to go to the library to locate a print journal.
- Difficulty interpreting results from the college library catalog.
- Failure to ask or read signs about where periodicals are located within the library.

Test data show significantly improved performance, despite a badly chosen question regarding the second patent, due to the professor's ignorance of the history of patent numbering. The professor accepted answers that either gave the patent that was numbered 2 in the numbering system developed after the fire (even though the patent application occurred well before the fire), or the patent submitted second after the date of the fire (exceedingly difficult to identify, though several tried). Even where students gave incorrect answers due to the confusion in the question, all students did demonstrate an ability to use patent databases, which the question intended to test.

The second question regarding a peer reviewed article by another professor in the department revealed interesting results. While the vast majority of students correctly identified the paper in question, some used a database, but others used such sources as the professor's curriculum vitae or personal website. A few students cited a different paper from the same year that was a research report submitted to a collaborating institute, not peer reviewed.

In the third question, a few students failed to go to the library to retrieve the article in question, citing time constraints. Among those who successfully retrieved the article, not all students reported the correct statistics. Again, that's not what the problem was intending to test, but it is an aspect of information literacy that may need attention in subsequent courses in the curriculum.

In the fourth question, student results were more divided, with several reporting only online holdings. This is a fairly common error due to the intricacies of the library catalog at our institution that require one to look in more than one location to determine the full holdings for a given journal title. This topic was covered, but clearly students were still struggling with this aspect of research at our institution.

Student problem sets reinforced information literacy principles in that students were expected to properly cite sources of data, including their textbook. By holding students accountable for this in grading homework, citing data sources very quickly became their habit.

The annotated bibliography assignment, and the LCA assignment overall, reveals the iterative nature of student learning. After the first annotated bibliography, students were graded on a check/check-plus basis and received written feedback on their work. Typical problems were not including all types of sources requested, problems with citation format, and difficulty in annotating a work with an eye to their particular research question. Perhaps because the LCAs represent group work, the quality was generally higher than on the individual assignments. In their final drafts, students received scores ranging from 8 to 10 out of 10 in the category of "research quality" which measured the variety, quality, and appropriateness of sources as well as proper citation. Students generally lost points for missing citations, especially when reporting data values used in calculations. Students met at least the letter of the requirements for variety

(spelled out as at least one patent, peer-reviewed article, web site, etc.), but some projects continued to rely heavily on web sources, or sources that could be retrieved without a physical trip to the library.

Discussion

Students clearly showed improvement in information literacy skills over the course of the semester. Instruction from the librarian, reinforced by the course professor in class and by assigned reading, and the incorporation of information literacy into homework, test material, and the semester-long project likely all contributed to student learning. Student performance improved over the semester, and students rated the fulfillment of the information literacy objective highly.

Given the small amount of attention given to information literacy in the curriculum prior to this integration, it is perhaps not surprising that giving time and attention to the topic would result in student learning. By providing the details of the course integration here, we hope to demystify for faculty what is involved in a faculty-librarian partnership for information literacy.

By taking a curriculum-integrated approach, information literacy can be incorporated into courses at the level of the learning objective. Once this occurs, it becomes important to visit the topic repeatedly and give students opportunity for iteration and improvement. In this case, student work included reading, homework, test question, and project. Evaluation of sources was connected conceptually to critical thinking and reflective judgment, which related to both lifelong learning and engineering ethics. In this way the course was given some cohesion, and information literacy was not treated as an "add-on."

One of the challenges of integrating information literacy in a liberal arts college context is a history of presumption that students already possessed information literacy skills prior to their arrival on campus. There is a reluctance to instruct students in something that is seen as a skill set outside of the discipline. Engineering, because of its professional orientation, is perhaps more amenable to incorporating the teaching of skills in the classroom. Still, faculty commitment remains a challenge, especially for the depth of integration discussed here.

Moving forward, a new faculty member is taking on the responsibilities for this course, and new relationships must be forged to maintain this level of integration and develop further integration in other parts of the curriculum. In a sense, this work is never completed, but faculty and librarians are in a process of continuous improvement to keep information literacy in focus and ensure student learning is effective.

Conclusion

This paper detailed the course-level integration and faculty-librarian partnership implemented in a second-semester first year course, in the context of a curriculum-integrated approach to information literacy. Assessment data highlighted the importance of librarian instruction and faculty reinforcement through reading, class discussion, and iterative coursework. Introducing

information literacy as part of a unit on reflective judgment and intentional learning and connecting these topics to both technical course content and engineering ethics further supported student learning.

This model, and indeed the curriculum-integrated approach to information literacy more generally, is resource intensive. Time is required of both faculty and librarians to prepare, conduct, and evaluate classroom interactions and assignments. However, student assignments in this case were integrated with existing assignments (tests, projects, etc.) to the extent possible, and the additional homework required less time to grade than other homework (written or problem sets). It appears that investing resources in this way does result in improving students' awareness of the importance of information literacy and their abilities to access, evaluate, and use information effectively.

The model of course-level integrations using librarian-run class sessions, faculty class sessions, readings, and assignments can be adapted in a variety of settings. This experience has been leveraged at Smith College through a faculty lunchtime panel convened by the Information Literacy Team, showcasing several examples of faculty and librarians working together to support student learning of information literacy concepts. Several faculty who attended the panel requested the sample assignments from this class and intend to implement them in their own teaching. It is this level of interaction that creates opportunities for faculty to join in and become passionate about information literacy instruction. Scaling up within our institutional context or at other institutions is primarily a matter of faculty buy-in. Incentives for faculty participation (simple recognition may be enough in many cases) and offering sample assignments that save faculty time may encourage faculty participation.

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MUDDIEST or FUZZIEST POINT

Course: _____ Date: _____

IF YOU WOULD LIKE A PERSONAL REPLY TO YOUR QUESTIONS PLEASE INDICATE YOUR NAME AND EMAIL ADDRESS BELOW (OPTIONAL)

NAME_____

EMAIL ADDRESS_____

Muddiest Point(s) That You Encountered

Please note the topic(s) covered in this instruction session that you <u>particularly</u> do not understand, are confused about, or you feel needs more explanation.

What is one helpful highlight you remember from this class?

Overall how would you rate this class?

_____Excellent _____Good _____Fair _____Poor

THANK YOU!