AC 2008-1702: HOTS FOR INDEPENDENT READING AND RESEARCH IN APPLIED ENGINEERING (IRRAE)

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HOTS for Independent Reading & Research in Applied Engineering (IRRAE)

Joe has been an engineer for five years and gets most of his information from colleagues, the internet, and professional organizations. He is now getting a Masters degree and has been told he needs to use library resources. The library resources he has used in the past are books that his professor put on reserve for his class. He's not sure what he's supposed to do.

This scenario is common in Wisconsin and probably in many other places. Instructors and librarians at the University of Wisconsin-Madison have created an infrastructure to help engineering graduate students learn how to find and use information. The Master of Engineering in Professional Practice (MEPP) at UW-Madison includes information literacy [1] throughout the two year curriculum. Some students understand the need to go beyond Google early in the program, but most students are gradually won over to secondary (library) research through a reiterative process. After two years students ask how to access to the library after graduation. What happens during these two years to change the students?

"Independent Reading and Research in Applied Engineering" (IRRAE) is part of the two year Master of Engineering in Professional Practice (MEPP) offered by UW-Madison. MEPP stresses the skills needed by practicing engineers for technical leadership; it might be regarded as a technical alternative to an MBA. Therefore, **"higher order thinking skills" (HOTS**) for critical evaluation, problem solving, and communication are essential elements in the MEPP curriculum. For the purpose of this paper, HOTS are defined as the "higher" four levels of Bloom's taxonomy. [3]

Thanks to a unique collaboration between the UW-Madison College of Engineering, the UW Technical Communication program, and the Wendt Engineering Library, Independent Reading and Research in Applied Engineering has become a valued (if exhausting!) opportunity for engineers in MEPP to discover the value of effective and timely secondary research to solve practical engineering problems.

"Higher Order Thinking Skills" – HOTS – have been identified as the skills beyond technical knowledge and problem solving that lead to improved effectiveness in communication and in leadership. [9, 4, 10] This paper reports on the successful efforts of a course development and delivery team to apply the intellectual analysis provided by Bloom's taxonomy and the accreditation requirements of ABET to motivate and to evaluate work in an online graduate course for practicing engineers. An essential innovation has been to apply HOTS to the identification, evaluation, and application of secondary research resources made available through the Wendt Engineering Library. This course has been effective in motivating HOTS for library research.

The role of IRRAE in MEPP

MEPP, the first online degree program offered at UW-Madison, is a two-year course delivered through the web. It is a "blended" program, utilizing a number of distance education tools:

- synchronous webinars (using LiveMeeting) for teaching, discussion, and student presentations
- asynchronous forums, email, and online document management

- individualized tutoring, assistance, and instruction through email and phone

Overview of MEPP

MEPP is designed on the "cohort" model. Every Fall, a new cohort is admitted and spends a week on the UW-Madison campus in a first summer residency week; students receive orientation to the program and complete a networking course to facilitate their online work. Thereafter, students enroll concurrently in the same classes for two years. Appendix A outlines the two-year MEPP calendar.

Students meet with their library liaison in a library orientation during residency week. Library resources are integrated into the MEPP curriculum, especially the MEPP writing courses where the library liaisons participate in discussion forums and webinars.

At about the half-way point in the MEPP program, students take Independent Reading and research in Applied Engineering (IRRAE). This project-based course requires online research that contributes to the participant's professional and career growth. Although the projects must be practical, they must also fulfill strict academic requirements. Students are gradually won over to the idea of secondary (library) research.

The Challenges of an Online Research Course

A successful online project-based graduate course requiring secondary research skills for practicing engineers presents a number of challenges:

1. Establish the value of secondary research for practical engineering work.
2. Teach the variety, purposes, and uses of modern research tools.
3. Deliver the assistance and instruction needed for successful projects.
4. Require basic project management for the written research projects.
5. Provide an opportunity to share the results of the work.

Top Ten List

How Can Engineering Projects Benefit from Effective Secondary Research?
(by the authors of this paper)

10. Maybe no one else has ever done this.
9. Maybe the work has already been done successfully.
8. Maybe the work has already been done badly.
7. A project can be evaluated against the current "state-of-the-art."
6. Don't re-invent the wheel.
5. Build on other successful work.
4. Avoid the pitfalls of other UN-successful work
3. Engineers around the globe are conducting research.
2. The person at the next desk may be doing research.
1. Research can be an effective non-capital way to improve productivity, quality, and profit.

Engagement Theory

"Engagement theory" has been important to MEPP course design since early in the development of the program. Greg Kearsley was an early course consultant; in "Engagement Theory: A

framework for technology-based teaching and learning," [6] Kearsley and Shneiderman summarized the basis for engagement as "Relate-Create-Donate."

1. ***Relate*** – "Emphasizes team efforts that involve communication, planning, management and social skills." Although IRRAE is "Independent," it flourishes within the context of the MEPP student cohort and benefits from peer review and group expertise in an engineering community of practice.

2. ***Create*** – "Students have to define the project (project domain) and focus their efforts on application of ideas to a specific context." The work for IRRAE is the creation and completion of a useful applied engineering project.

3. ***Donate*** – "Stresses the value of making a useful contribution while learning. Ideally, each project has an outside 'customer'." IRRAE projects are expected to be job related; reporting on the use and relative success of the project "on the job" is required.

"Engagement theory" effectively draws IRRAE participants into their projects and ensures an "applied" result within a rigorous "academic" program.

Course Scheduling/Project Management

Time is short, and participants in IRRAE are warned to control the scope of their projects. To provide a more practical schedule, initial IRRAE work is integrated with the preceding Communicating Technical Information course. See Appendix B: Integrated Schedule for Work in IRRAE.

The milestones in the course reflect the overall management of research projects; deliverables include a formal proposal with a reading plan, a literature review, a draft, and a final project document. A technical oral presentation is also required.

Projects must fulfill three major requirements: 1) they must create and link a reasonable scope to the time and resources available; 2) they must show practical and of demonstrable value for career and intellectual growth; 3) they must demonstrate significant and relevant research using the tools provided by Wendt Engineering Library, professional societies, and expert resources. Projects emphasize secondary research but may also have a primary research component if appropriate.

The Use of Bloom's Taxonomy

An innovation in this online research course is the specific application of Bloom's taxonomy and the hierarchy of cognitive accomplishments to the course.

Bloom's taxonomy has been used for describing learning outcomes as well as in grading. "The essential structure of the Taxonomy was a cumulative hierarchy: hierarchy because the classes of objectives were arranged in order of increasing complexity and cumulative because each class of behaviors was presumed to include all the behaviors of the less complex classes." [8] The six levels of Bloom's taxonomy and their performance descriptors are summarized in Table 1.

Table 1. Bloom's Taxonomy and associated descriptors.

(LEVEL 1 is the starting level or lowest foundation level of the hierarchy)

LEVEL 1: Knowledge - define, memorize, repeat, record, list, recall, name, relate, collect, label, specify, cite, enumerate, tell, recount

LEVEL 2: Comprehension - restate, summarize, discuss, describe, recognize, explain, express, identify, locate, report, retell, review, translate

LEVEL 3: Application - exhibit, solve, interview, simulate, apply, employ, use, demonstrate, dramatize, practice, illustrate, operate, calculate, show, experiment

LEVEL 4: Analysis - interpret, classify, analyze, arrange, differentiate, group, compare, organize, contrast, examine, scrutinize, survey, categorize, dissect, probe, inventory, investigate, question, discover, text, inquire, distinguish, detect, diagram, inspect

LEVEL 5: Synthesis - compose, setup, plan, prepare, propose, imagine, produce, hypothesize, invent, incorporate, develop, generalize, design, originate, formulate, predict, arrange, contrive, assemble, concoct, construct, systematize, create

LEVEL 6: Evaluation - judge, assess, decide, measure, appraise, estimate, evaluate, infer, rate, deduce, compare, score, value, predict, revise, choose, conclude, recommend, select, determine, criticize

(LEVEL 6 is the highest level of Bloom's hierarchy of cognitive difficulty.)

Climbing to "Level 6"

Table 2 summarizes the desired outcomes for each assignment based on Bloom's Taxonomy as articulated by the IRRAE instructors. The use of Bloom's taxonomy makes the discussions of "ideas" and "content" more precise both for explaining assignments initially and then for evaluating completed work. Bloom's taxonomy is used in both the assignment descriptions and in the grading forms; the ways in which Bloom's taxonomy will be used are clearly outlined for IRRAE participants. For example, grading forms checklisting the expected "cognitive levels" and other elements of the assignment are available for students to help them in the completion of their work.

The common experience has been that students do well with facts and summary; the major challenge is getting to an effective level of evaluation (building on the other HOTS). For example, in a Proposal, students must try to predict the value or benefits of a new proposed process; it is not enough to say that it will be "better" or "an improvement." In the Literature Review, it is not enough to do a "laundry list"; resources must also be evaluated as to their applicability, quality, and credibility. Finally, for a completed project, some effort must be made in analyzing the benefits and significance of the accomplishment. The best IRRAE work (receiving the best grades) involves all Bloom's stages and shows explicit attention to the "evaluation" level for all the assignments of the research projects.

Table 2: IRRAE Milestones and Descriptors Derived from Bloom's Taxonomy.

	Bloom's Cognitive Level					
	Knowledge	Comprehension	Application	Analysis	Synthesis	Evaluation
01 IRRAE Project Proposal	Include facts about a problem to be solved	Discuss and describe the problem	Demonstrate or illustrate the expected use of the proposed solution.	Categorize and review possible implications of the proposed solution.	Plan a unified approach to solution (timeline, budget, personnel).	Assess likely level of success; predict value of proposed solution.

02 IRRAE Literature Review	Use research to discover the facts of the state-of-the-art.	Discuss related research, show relationships, and review the relative completeness of the information.	Apply the research to the problem; indicate what is useful and what is not.	Interpret and arrange your discussion to effectively deal with the topic.	Combine different ideas and research information to provide a clear and coherent summary	Draw conclusions as to what parts of the problems have or have not been solved. Recommend next steps.
03 IRRAE Project Document (Draft) **AND** **04 IRRAE Project Document (Final)**	Establish an effective factual basis for project (good research completed).	Discuss and relate the research, explain connections between elements of research and the problem.	Apply facts and research to the identified problem; show effective problem solving for the project.	Identify and relate components of the problems and elements of the research; establish relevance.	Assemble, organize, and present elements of the problem and details of research to demonstrate a coherent and complete solution.	Assess significance of your work, likely impact, recommend next steps, note any prospective problems or future issues

The approach clearly identifies the objective of the assignment and how each level will be used in grading.

ABET a-k: External Criteria for Engineering Professionalism

The authors also discovered that sometimes the students did not understand the value of the independent study course in the context of their MEPP experience. Since most MEPP students are working adults, the authors surmise that the engineering experience often doesn't include report research and writing. The authors found that referring the students to the ABET a-k criteria helped set the stage for that discussion. No single IRRAE assignment satisfies all these criteria, but students are made aware of ABET's requirements for the educational and performance accomplishments of professional engineers. ABET helps provide a checklist for the current state of an engineer's professionalism and may help identify areas for improvement or for life-long learning . [2, 5, 7]

Table 3. Program Outcomes and Assessment as defined by the Accrediting Board for Engineering and Technology (ABET). Engineering programs must be ABET certified; this establishes the credibility of a program. ABET visits engineering programs on a regular basis; general guidelines for what students should learn are defined by "Criterion 3: a – k." The ABET website provides more specific information and requirements. This a – k listing is from: http://abet.org

ABET Criterion 3: Program Outcomes and Assessment from http://abet.org
Engineering programs must demonstrate that their students attain:
(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 multi-disciplinary teams
(e) an ability to identify, formulate, and solve engineering problems
(f) an understanding of professional and ethical responsibility
(g) an ability to communicate effectively
(h) the broad education necessary to understand the impact of engineering solutions in a global, 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.

ABET criteria a through k invite interpretation. This has been a source of concern for some educators, but it has invited the IRRAE instructors to assess and articulate the research aims of the course and their applications to graduate work in engineering leadership. [2] Facility in research methodologies contribute to success in engineering professionalism: knowledge of basics, design of experiments, design of systems, problem analysis and solution, impact of engineering work. It is also easy to see that research skills contribute to the professionalism of "life-long learning" and that the research tools increasingly available for secondary research are "necessary for engineering practice."

The involvement of the Wendt Engineering Library in IRRAE

IRRAE is an opportunity to bring everyone (librarians, students and instructors) to a higher order thinking. Real world projects sometimes challenge the academic ivy tower and traditional library resources. For example: last summer a student wanted to write about company information security when Skype is used as a communication tool. Finding information on a very recent subject can be a problem in secondary research, but this is a common need in the work place.

Librarians, students, and instructors provide support in an online "library" discussion forum. Often students will correctly solve a problem for another student before the librarian even sees the question. Many students have individual correspondence and phone consultations with the librarians. Some students are ready for IRRAE, HOTS, and information gathering, evaluation and synthesis; they only need to be directed to resources they may not know about and be shown how to collect citations into a bibliographic management system, i.e. *RefWorks*. Other students struggle with why they even need information resources, and then struggle filtering through articles and using them.

Students start IRRAE with a draft research proposal already written. Library liaisons review each student project and send individualized tips on choosing appropriate resources and keywords. For example this email was sent to a student:
"Here is a screenshot of the Google scholar search we demonstrated in class last week. The thesis located in the search includes an extensive bibliography with articles that may be of interest to you. Additional keywords ideas such as compaction testing, pavement design, in-place stiffness, CBR value and geotechnical engineering may help narrow your search results."

A library skills webinar is given in the 2nd week. The webinars allow for screen sharing so that students can see demonstrations of their topics being searched and are able to verbally ask questions.

Selected students are asked to present information and library skills to the other students. For example, a student who has a business topic will show how to find business information. A person who has identified a great journal article will show others how to use *Web of Science* and *Google Scholar* to find related articles. Another student will show how to search *Compendex* and have articles delivered electronically through the library service. The students who help teach the webinar are using higher order thinking. They are also selling the idea of information literacy to other students in the class.

What are some challenges in IRRAE? A common problem is the overload of information gathered. "Yes. You can have ANY article delivered to you electronically" isn't necessarily good news to the student who doesn't know how to select the very best articles for delivery. Another problem is the timely delivery of books. The course is short and students need to quickly identify and request books for delivery.

The signs of success

As graduation nears MEPP students ask about their access to library databases. Many of them want continued access to research. Every year MEPP alumni request a library research webinar where alumni are given options for limited library access as alumni members, shown free internet sites (e.g. Google Scholar) and fee-based solutions (e.g.Wisconsin TechSearch).

Graduates are asked to rate the importance of each course to the MEPP curriculum. IRRAE students have rated the course an average of 4.5 on a scale of 1 through 5 with 5 being the highest.

Every MEPP course receives an official evaluation from the students. The 2007 IRRAE evaluations relating to research are very high.

- Improved my research skills considerably (50% agree, 50% strongly agree)
- Use of Bloom's taxonomy helped me understand course expectations for quality of work (72% agree, 17% strongly agree)

Sample comment: "I did like the research part of the course. A ton of information is out there and having all the tools to look at it is great."

The clearest sign of success is an information problem that was well chosen, researched, analyzed and evaluated. Student oral presentations at the end of the summer provide the final impetus for synthesis of information. Stunning bibliographies and "thank yous" to the library motivate the liaison librarian to attend presentations. The presentations are a view into real world problems and solutions for everyone in attendance. The final demonstration of HOTS is enjoyed by instructors, students and librarians over a hot lunch.

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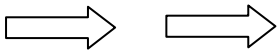
Appendix A. The Two-year MEPP Program.

Year 1 - Summer	Year 1 – Fall	Year 1 – Spring	Year 2 – Summer	Year 2 – Residency	Year 2 – Fall	Year 2 – Spring
1 week summer residency **Network Skills** 1 credit	**Engineering Economic Analysis and Management** 3 credits **Technical Project Management** 3 credits	**Engineering Problem Solving with Computers** 3 credits **Communica -ting Technical Information** 3 credits	**Independent Reading and Research in Applied Engineering** 1 credit	***Summer Residency*** ***Following the summer course – IRRAE presentations to faculty and year one students***	**Engineering Applications of Statistics** 3 credits **International Engineering Strategies and Operations** 3 credits	**Quality Engineering and Quality Management** 3 credits **Engineering and Business Data Communica -tions and the Virtual Office** 3 credits

(For more information about MEPP, visit: http://mepp.engr.wisc.edu/)

Appendix B. Integrated Schedule for Work in IRRAE.

Spring Semester	Summer - 8 week session	2nd Residency

Communicating Technical Information 3 credits ***START***  **Weeks 1- 12: Technical Communication Work.** **Weeks 13 – 14: IRRAE kickoff; preliminaries on research; proposal process; draft research Proposals due week 15.**	**Independent Reading and Research in Applied Engineering** 1 credit  ***FINISH*** ***IRRAE Milestones:*** **IRRAE Proposal** **Literature Review** **Draft of Final Project Document** **Final project document.**	***1-week Summer Residency*** **Technical Oral Presentations.** ***SHARING*** **Presentations by IRRAE participants using PowerPoint to summarize IRRAE project accomplishments.**
In week 13 and 14 of the 15-week Communicating Technical Information course, the IRRAE instructors cooperate to "launch" the IRRAE projects. Research overview and introductions are provided by the Wendt Library liaison. A First Draft of the IRRAE Research Proposal is due as the final assignment of the technical communication course. A Final improved and corrected version of the proposal is then submitted for the first assignment of the summer IRRAE course. Other "milestone assignments" are due every two weeks in the summer course. Finally, after the projects are completed, IRRAE participants share their work with MEPP faculty and with the incoming MEPP class through technical oral presentations.		