Project Description

Before listing the objectives of this project, its beginnings will be briefly outlined. The authors, not being satisfied with the observed outcomes in these service courses, surveyed faculty in the mechanical and civil engineering departments with the object of obtaining suggestions for improving the courses. The faculty in these departments, in addition to their own internal discussions, then held discussions with their employer stakeholders, professional colleagues, and recent alumni. The conclusions coming from these processes were that:

- traditional "survey" courses do not meet student needs,
- these courses should concentrate on topics which relate to professional practice in the students' discipline, and
- experiential reinforcement of classroom instruction in a studio setting is highly desirable.

These were the processes whereby we came to propose the project described below. In this project we seek to establish a new and improved way to deliver the engineering service course. There is a national need to improve the effectiveness of service courses. The service courses directly impacted are those offered by electrical and computer engineering departments to students enrolled in other engineering or science curricula. Our initial focus will be a pilot study, proposed herein, to construct effective service courses in electrical systems to be offered to mechanical engineering majors. If this pilot effort is successful, we plan to request further support to export this course to other campuses and to develop material for a service course at Rose-Hulman for civil engineering majors.

a) Goals and objectives:

1. To produce educational materials for a service course that motivates students by presenting the content of electrical systems in the context of mechanical engineering.
2. To measure the outcomes of students in this course and compare them with the outcomes of students from a traditional service course.
3. To nationally disseminate the information and educational materials from 1 and 2.

b) <u>Detailed Project Plan</u>:

Introduction and overview

In recognition that knowledge of electrical systems and instrumentation is vital in many fields of engineering, electrical and computer engineering departments are asked to offer service courses in these areas. We propose to produce and disseminate educational materials that will help bring effective educational practices to these engineering service courses.

Motivating students and engaging their interest is the one element vital for the success of any course.[1] Unfortunately, this is also the same element that is often lacking in service courses. We propose to address this problem by developing educational materials for service courses that present topics in electrical systems from the viewpoint and in the context of the discipline being served. The study of electrical systems will be embedded into the students' chosen major discipline. Modern tools and techniques shall be employed for content delivery. We feel this combination, context and effective delivery, can be used to attract the interest of students while, at the same time, allowing them to integrate knowledge of electrical systems into their existing base of knowledge. Effective tools and appropriate pedagogy will be employed to ensure the courses are effective for a variety of student learning styles. Our focus throughout will be to develop materials that will effectively engage and motivate individual students. We will produce educational materials that enable instructors to clearly show students that these courses involve useful knowledge, that the material is accessible to them, and that an understanding of the tools, techniques, and content in these courses will enhance their professional careers.

Assessment and the measurement of outcomes form an integral part of this project. We shall determine whether and to what extent the practices employed here result in more desirable outcomes when compared to a traditional service course. Student outcomes will be observed and causal relationships between the educational tools employed and the observed outcomes will be carefully established. In this project, we will answer the question "Are students coming from this courses better prepared and motivated when compared to students who have taken a more traditional engineering service course and, if so, in what ways and why?"

A review board will be formed and will be comprised of nationally-recognized experts in engineering education and assessment. Members of this review board will work with the investigators to establish criteria for assessment and evaluation in order to provide information for the continuous improvement of the courses, to assure that best practices are employed, and to provide data on the efficacy of the models for the development of engineering service courses. The members of this review board are ***Bruce Carlson*** and ***Ken Conner*** of Rensselaer Institute of Technology, ***Gloria Rogers*** of Rose-Hulman Institute of Technology, and ***Karl Smith*** of the University of Wisconsin. Their biographical sketches can be found in the appendices.

This work will produce adaptable and readily accessible educational materials. Materials will be disseminated through published packages that will include web-based learning modules and hypertext documents. *McGraw-Hill* has indicated an interest in publishing the results of this project. These materials would likely include a textbook, a compact disk, and an instructor handbook. Journal articles as well as presentations and perhaps workshops at educational conferences will also help disseminate our work. Assessment and continuous improvement will be a permanent feature of these courses. Effective and easily implemented assessment tools will be disseminated to help users to continuously improve their implementations.

Proposed Course

Engagement from each individual student will be obtained by delivering the content of this course from the viewpoint of the student's major discipline. Too often this material is offered to the biological, chemical, civil, or mechanical engineer from the viewpoint of an electrical or computer engineer. This can result in barriers being constructed that act to prevent students from integrating knowledge of electrical systems into their existing knowledge base. From the student's viewpoint, these service courses often become a collection of unrelated techniques with little relevance to the work in their chosen discipline, often lightly covering a variety of electrical and computer engineering topics. Basic circuit theory is often followed by superficial coverage of topics such as AC power, instrumentation, digital circuits, control systems, machines, etc. It is rare that any topic is covered in depth unless particular instructors decide to bias the course towards their own interests with little considerations given to the students' major. The question repeatedly heard in these classes is "Why do we need to know this material?" The answer frequently heard in reply is: "In order to perform [substitute here some useful tool or technique], we must first become familiar with this knowledge." More often than not the promised useful tool or technique is then not used at all or else not explored in any depth. The resulting student frustration ends in most students lacking confidence and competence when working on projects that involve electrical systems and instrumentation and in many of the students having an active aversion to any work that involves electrical systems. The outcome is that material is presented, exams are taken, and grades are assigned, with those students who obtain a minimal knowledge of electrical vocabulary and the mechanics of solving problems passing the course while still being unable to approach tasks in their discipline involving a significant electrical component.

This type of course—a survey course where many topics are given superficial coverage—can result in bored and disengaged students who gain little useful knowledge. Instructors in these courses tell themselves that, with a sound knowledge of the basics, at least the biological or mechanical engineer can learn about a particular area of electrical systems or instrumentation in more detail when the need arises. This is no doubt true for the best students, but, then again, our best students can likely learn the necessary material in any case. The challenge and opportunity lies in motivating good to below average students. We need to engage them in the study of electrical engineering by showing them the relevance of electrical systems to their major course of study. We need to make this knowledge more accessible by making connections between it and their existing base of knowledge.

Students will be engaged by delivering electrical systems content in the context of the discipline being served. To take a service course to mechanical engineers as an example, discussions of measurement and instrumentation would be placed in the context of what tasks the working mechanical engineer will typically be called upon to accomplish. Discussions of instrumentation could be embedded in the context of engine design and emissions analysis. A discussion of industrial power distribution could be placed in the context of plant engineering.

We shall develop course materials in close cooperation with faculty and professionals in the discipline, and, where feasible, current practices will be used in these courses. The objective will be met when both the content and its context are meaningful to the students being served. We will invite industrial partners to our classes to give short discussions of their professional work. Together, these steps will make evident to each student that the topics studied and the tools and techniques employed are vitally important in their chosen discipline.

These goals necessarily imply significant faculty development in learning current practice in the discipline being served. We feel this cross-fertilization will lead to an enhanced awareness of practices in other disciplines on the part of the faculty designing these courses and will be an important benefit of this work. Faculty have little hope in reducing barriers between disciplines for our students if we ourselves spend almost no time in studying the activities in disciplines other than our own and often have little appreciation of current practices in them.

Embedding the content of these courses in the context of the students' chosen discipline is consistent with constructivist theories of knowledge which state that the assimilation of new knowledge is aided by connecting to an existing base of knowledge.[2,3] We need to bring these established educational ideas to the engineering service course. It is crucial that these students tie the knowledge gained in these service courses to that of their major discipline.

It is well known that reflection and metacognition are essential aspects of constructing knowledge and meaning. Long ago, John Dewey emphasized the importance of reflective thinking as an educational goal.[4] He argued that students should be asked to reflect, to perform self-assessments of their understanding. Donald Schön also points to the need for reflection and argues persuasively that the educational preparation engineering professionals presently receive often does not allow them to develop critical thinking skills.[5]

Active learning and writing will be techniques used to introduce reflection and deep thought on the part of the students. The collaborative and active learning techniques described by Johnson, Johnson, and Smith and Slavin will be use to improve the understanding of many students who are not effectively engaged with other techniques.[6,7]

Writing will be used to introduce critical thinking and reflection.[8] We need to build models in which students exercise their capacity for reflective thought and are asked to evaluate their work and understanding. The habits developed when writing—thinking comprehensively, expecting to rework the initial results, and knowing there is no one "correct answer"—are indispensable in educating what Schön calls the reflective practitioner. These steps are included in most descriptions of the design process, and it would seem particularly useful that writing be thoroughly integrated into engineering education since some of the most central elements of the design process are shared by writing.[9] Both processes have a preliminary creative stage—often termed brainstorming in design and prewriting in writing. The initial solutions in both processes are most often changed via a recursive procedure, and, through gradual improvement, some acceptable final solution is reached. Implicit in both processes is the crucial idea that there is often more than one acceptable solution and that often a unique "correct" solution does not exist

Another outcome of this course is for the students to learn to include topics from electrical systems in their discipline-specific writing. The students in these classes need to first understand how electrical systems are discussed and thought about in their discipline. That is, they will learn how such topics are addressed in their discourse communities.[10,11] The values of each discipline are embedded in the communications of that discipline. A discourse community is a community bound together by its language, by its terminology, and by its standards of investigation. The language of each discipline must be learned by students who wish to become members of that discourse community. They can hope to achieve inclusion only through reading and writing within that community and by framing investigations in the manner that their community deems meaningful.

Course Description

We propose to produce educational materials for a course in electrical systems for mechanical engineers. The course content has been obtained by consulting with faculty and working professionals in mechanical engineering. Relevance will be demonstrated to students through hands-on work with electrical systems in the context of mechanical engineering.

A studio format will be employed to allow a blend of lecture, demonstration, and student experiential work. Rose-Hulman has experience with the delivery of classes in the studio format in our studio physics classrooms. Pioneering work in the use of the studio format in science, mathematics and engineering education has been conducted at Rensselaer Polytechnic Institute. Work at RPI to allow the effective use of the studio format has involved significant NSF support, including an IR grant in 1996.[12] In the spring of this year, one of the authors (EW), traveled to RPI in order to meet with Rensselaer ECE professors Bruce Carlson and Ken Connor to ensure that our work is informed by the experience they have gained in employing the studio format in engineering courses.

The studio format will permit the design of a rich, multileveled environment for students to learn technical content and to gain experience in important skills such as teaming and effective communication. This format will enable students with a variety of learning styles and range of abilities to succeed in these courses.

The tentative title for the course is "Electrical Aspects of Mechanical Engineering"; its design starts with the following stated course goals and objectives.

Electrical Aspects of Mechanical Engineering

Goal: This course will have the goal of enabling all students to enter the mechanical engineering profession with sufficient confidence, knowledge, and practical skills to contribute to projects in mechanical engineering that involve electrical systems and instrumentation.

Objectives: After successfully completing this course all students should be able to:

- Understand single-phase and three-phase wiring diagrams, identify standard wiring symbols, and appreciate the importance of grounding.
- Understand transformers and their role in power distribution, and to quantify their impact on the cost of electrical power.
- Identify the most common types of cables and transformers by insulation and rating, and to satisfactorily size conductors and transformers in terms of ampacity and voltage regulation.
- Correctly determine the size of a capacitor bank needed to provide a specified level of power factor correction and to be able to quantify its impact on billing.
- Understand the principles of operation in energy conversion when applied to devices such as relays, solenoids, electromagnets, etc.
- Understand the operation and application of different types of AC and DC motors.
- Appreciate the different problems associated with speed control of various types of AC & DC motors.
- Correctly size motors for specified applications, and to be able to predict the speed and power loading of a particular combination of motor & load.
- Identify the most common types of signal transducers used by instrumentation in mechanical engineering installations e.g. strain gauges, pressure gauges, thermisters, etc.
- Solve simple problems associated with instrumentation, such as: bandwidth limitations, noise, impedance matching, etc.
- Develop an appreciation of safe working practices when exposed to AC and DC voltages above 100V.
- Connect, check and troubleshoot power, machine, and instrumentation circuits.

- Identify special measuring techniques which have to be applied to power circuits, machines, and instrumentation.
- Predict, by simulation and calculation, the performance of electrical circuits and instrumentation and then compare these to observed performance.
- Demonstrate an ability to include electrical systems into their discipline-specific writing.
- Demonstrate an ability to use electrical systems and instrumentation in discipline specific design work.

Course design includes providing a studio classroom with modern instrumentation clusters and software packages. Instrumentation clusters include oscilloscopes, counters, multimeters, waveshape generators, and power supplies. Software will include *Maple*, *Matlab*, *Electronics Workbench*, and *LabView* as well as word-processing and spreadsheet applications.

Care has been given toward the implementation of this course. These plans and the lessons learned during implementation will be available to others seeking to implement the curricular reforms in this project. Briefly then, in year 1, we shall focus on curricular changes. The studio format will not be introduced until year 2. In year 1, we shall focus on developing classroom materials, laboratory exercises, and Web-based resources. We will work to establish our consistent theme of embedding electrical systems into the discipline being served, which in this pilot study is mechanical engineering. Also in year 1 materials will be developed that introduce active learning and writing into the classroom. In year 2, we will build on this preparatory work when the studio classroom is constructed and we shall develop educational materials appropriate to that format.

This implementation plan positively impacts the project's educational research merits and its implementation at Rose-Hulman (also its implementation elsewhere). Through restricting changes in the first year to only curricular changes, another control group will be created for assessment purposes. This may allow us to separate the effects due to curricular changes from those due to the studio format. At minimum we should be able to separate the effects due to curricular changes alone from those due to curricular changes together with the studio format. The implementation itself will be made more effective and practical by allowing change to be more gradually introduced into these courses. Curricular modifications will be initiated and partially established without the simultaneous integration of the studio format into the courses.

We shall employ, whenever appropriate, the work of others in these courses. Below are two examples.

The work of Connors at Rensselaer on the cantalevered beam will be used as a vehicle to investigate a ubiquitous building block in the study of structures. We shall embed discussions of instrumentation, second order systems, and electromagnetics into its study. Thus, we will be able to begin with the study of a system that can model many components of a mechanical structure.

We will use the work of Rizzoni at Ohio State University by embedding a discussion of electric circuits, instrumentation, and measurement into discussion of automobile design and operation.

We shall utilize the work of Raja, Halpin, Sankar, and Halpin to employ case studies in this course.[13] Their work at Auburn University involves showing the connections that exist between SMET education and real-world issues in engineering, science, and technology. They are developing multimedia materials to be used in synchronous and asynchronous learning.

The work of Fisher and others at Michigan State University in linking service courses to students' major engineering design experience will also be utilized in this course.[14]

We will employ the Web to help achieve three aims:

1. Depth of learning: A multileveled environment—including system simulations, classroom supplements, and hypertext documents—will be built to engage today's students.

2. Student accountability: Web-based tools will be constructed to assure that homework and out-of-class activities are performed.

3. Assessment of student learning: Web-based tools will be employed efficiently gather information on student learning outcomes.

The WWW will be employed to implement Just-in-Time Teaching (JiTT)—developed at IUPUI and the US Air Force Academy with NSF support (DUE 9752365)—to encourage students to come to class prepared. With JiTT, students answer preparatory questions a short time before their next class meeting. In addition to encouraging student preparedness, we shall use JiTT to add depth to student understanding after class via addition examples and extensions of concepts discussed in class. We shall have access to lessons learned in using JiTT from those working to employ it at Indiana University under a current NSF project (DUE 9981111).

The studio format will allow the effective use of Erik Mazur's ConcepTests and Peer Instruction techniques.[15] Our aim in using these Web-based learning tools is to instill rigor into the class so that desirable outcomes are achieved, but to layer the rigor in a supportive environment.

Conclusion

This project directly addresses three of the four common themes identified for DUE programs:

1. Diversity

   -diversity is enhanced by employing educational strategies that are effective for a variety of learning styles.

   -diversity is enhanced through the construction of a multilayered, supportive learning environment.

2. Faculty Development

   -faculty development is encouraged by asking ECE professors to learn about other disciplines, to listen to workers in other disciplines, and by asking them to present electrical systems in the context of other disciplines.

3. Integration of Technology

   -current practices in technology will be integrated into these courses

   -Web-based learning tools will be used in content delivery

Our goal in this project is a simple one. It is to develop educational materials that serve as a model for electrical and computer engineering departments wishing to offer service courses to mechanical engineers that engage students by serving their needs and interests and that continually improve through effective assessment. Desirable outcomes are achieved by placing rigorous content and high expectations into a contextually rich, supportive active learning environment that employs best practices in education.

c) Experience and Capability of the Principal Investigators

Edward Wheeler is a young engineering educator with several years of industrial experience and whose interests include engineering education reform. As a faculty member, he has been recognized for distinguished teaching. While he was still a graduate student, his department chair and engineering school dean nominated him for a teaching award from ASEE recognizing excellence in teaching as a graduate student.

His publications include ones on the effective use of communication and writing in engineering education, and he participates in conferences and workshops devoted to the improvement of engineering education. His students regularly present papers in student research contests and conferences.

Cliff Grigg has seventeen years teaching experience and sixteen years industrial experience. He has taught a variety of courses including electrical circuit analysis, control systems, power systems, and energy conversion. He has been heavily involved in teaching service courses for the past twelve years.

His interests include the effective use of communication and writing in engineering education, and he actively participates in the Technical Communication courses presented at Rose-Hulman. He received the "Teacher of the Year Award" in 1995.

d) Evaluation Plan

There will be multi-leveled assessment and improvement strategies integrated into these courses. Assessment will begin during the 2000-2001 academic year when students who are enrolled in traditional versions of these courses will be used as a comparison group for the project. These students will be assessed on the same metrics as the students in the revised courses to develop a basis for comparison. These data will provide benchmarks for the evaluation of the effectiveness of the funded project. Then, during year 1 of the funded project (the 2001-2002 academic year), we shall begin introducing curricular changes. The studio format will be introduced in year 2 of the project. The assessments shall be both formative and summative and employ clearly stated and measurable course objectives to probe performance in course content, attitudes toward course subject matter, level of satisfaction with the course, effectiveness of the pedagogy in relation to learning styles, and the ability of students to transfer knowledge to their major discipline. In particular, we will probe their success and preparedness in their senior design projects. Since these projects often involve electrical systems, we should expect the students to be better prepared if the course described herein really achieves its aims. Along with gathering data related to their senior design work, we intend to initiate longitudinal studies with employers regarding graduates attitudes and abilities.

Assessment must gather meaningful data while, at the same time, not be intrusive by detracting from the learning environment. This work will employ the RosE-Portfolio, an electronic portfolio system developed during the past four years at Rose-Hulman Institute of Technology. We will develop a class portfolio that can be used to efficiently document student work for each course objective and provide easily accessible assessment data. The RosE-Portfolio emphasizes the importance of student reflection by requiring students to write a reflective statement about the relevance of their submission to the course objective. This reflective exercise reinforces the importance of writing and reflection that is embedded in the course.

Multiple assessment methods will be used with focus on student and faculty self-assessments of their achievement of these objectives, student and faculty course assessment related to course objectives, and departmental and institutional course assessment. With the assistance of the Rose-Hulman Office of Assessment, we will collect both quantitative and qualitative assessment data. Results on exams will be compared for differences in knowledge gains and differences by learning styles and pedagogy employed. Assessment professionals will work closely with course developers to embed assessment in ways that are non-intrusive and yet provide meaningful formative and summative assessment data. These strategies will be included in the final product for dissemination.

Gathering accurate, easily accessible and meaningful data on our students and their learning is an integral part of courses' design. Assessment is particularly important in this project since, as described above, an important part of the development of these courses involves an outside assessment of a review board consisting of persons with recognized expertise engineering education and assessment. Each year of this project, this review board will assess the effectiveness of the courses and provide information for improvement.

e) Dissemination of Results

Adaptable and readily accessible educational materials will be produced in this work. Materials will be disseminated through published packages that include web-based learning modules, hypertext documents, and assessment tools. *McGraw-Hill Incorporated* has indicated an interest in publishing the results of this project. This material will likely include a textbook, a compact disk, and an instructor handbook.

Journal articles reporting this work shall be published in the *ASEE Prism*, the *ASEE Journal of Engineering Education*, and the *IEEE Transactions in Education*. Educational conference presentations to help disseminate this work will include ones at the *ASEE/IEEE Frontiers in Education Conference* and the *ASEE Annual Conference*.