AC 2007-1753: AN UNDERGRADUATE, ENTREPRENEURIAL DESIGN SEQUENCE: A DECADE OF DEVELOPMENT AND SUCCESS

Frederick Berry, Rose-Hulman Institute of Technology
Electrical and Computer Engineering Department

Dr. Frederick C. Berry received the BS, MS, and DE degrees from Louisiana Tech University in 1981, 1983, and 1988 respectfully. He taught in the Electrical Engineering Department at Louisiana Tech University from 1982-1995. Currently Dr. Berry is Professor and Head of the Electrical and Computer Engineering Department at Rose-Hulman Institute of Technology.

Patricia Carlson, Rose-Hulman Institute of Technology
Department of Humanitees and Social Sciences

Patricia A. Carlson is a transplanted middle westerner, having spent her childhood in Norfolk, Virginia. She came to Rose-Hulman early in her teaching career and has taught a wide variety of courses over the past three decades. Pat has held a number of American Society for Engineering Education summer fellowships that have taken her to NASA-Goddard, NASA-Langley, the Army Research Laboratory in Aberdeen, Maryland, and NASA's Classroom of the Future in Wheeling, WV. She was on loan to the Air Force Human Resources Laboratory from 1989 to 1995, managing a project to transition advanced instructional technologies to ten different middle schools located in five states. She is on the editorial board of three professional publications and has served as National Research Council Senior Fellow assigned to the Air Force Human Resources Laboratory. In her spare time, Pat enjoys reading and gardening.

William Eccles, Rose-Hulman Institute of Technology
Electrical and Computer Engineering Department

William J. Eccles has been teaching electrical engineering courses since 1954. He holds SBEE and SM degrees from the Massachusetts Institute of Technology and the PhD degree from Purdue University. He has been at Rose-Hulman Institute of Technology for fifteen years after retiring from the University of South Carolina. His primary activities have been in the senior design sequence and in circuits and systems. His three-volume text, Pragmatic Circuits, was published in 2006 by Morgan and Claypool.

Bruce Ferguson, Rose-Hulman Institute of Technology
Electrical and Computer Engineering Department

Bruce A. Ferguson received the B.S., M.S., and the Ph. D. degree in EE from Purdue University. He is currently an associate professor in the ECE department at Rose-Hulman Institute of Technology in Terre Haute, IN. His technical interests include communication systems and fiber optic systems. He has previously worked with space and ground communication systems and photonics. Dr. Ferguson is a member Eta Kappa Nu, IEEE, and ASEE.

Daniel Moore, Rose-Hulman Institute of Technology
Electrical and Computer Engineering Department

Dr. Dan Moore is the associate dean of the faculty and professor in the Electrical and Engineering Department at Rose-Hulman Institute of Technology. He received his PhD in Electrical Engineering from N. C. State University in 1989 in the area of compound semiconductors. He directed the departmental senior design program for several years and now oversees externally sponsored multidisciplinary graduate and undergraduate projects. His current research interests include engineering design methodologies, student learning styles and active/cooperative education. He was the 2001 – 2003 chair of the Educational Research Methods (ERM) division of

ASEE, is a senior member of IEEE, and an ABET evaluator

Mihaela Radu, Rose-Hulman Institute of Technology
Electrical and Computer Engineering Department

Dr. Mihaela Elena Radu received the Diploma Engineer (M.S.) degree in Electronics and Telecommunications Engineering from the Polytechnic Institute of Cluj-Napoca, Romania, in 1985, and a Ph.D. in Electrical Engineering from the Technical University of Cluj-Napoca, in 2000. Since 1991 she has been an Assistant Professor, then Associate Professor with The Technical University of Cluj-Napoca, Faculty of Electronics and Telecommunications. In 2003 she joined Rose-Hulman Institute of Technology, Terre Haute, Indiana, as a Visiting Associate Professor, tenured–tracked position since 2006. She had several international scholarship and trainings at The University of Limerick, Ireland, BQR Reliability Engineering, Israel, Technical University of Budapest, Hungary, and she was involved in numerous research and educational grants at the national and international level.

Terry Schumacher, Rose-Hulman Institute of Technology
Department of Engineering Management

Terry Schumacher is an Associate Professor of Engineering Management at the Rose-Hulman Institute of Technology. During the past 8 years he has taught Project Management, Marketing, Technology Forecasting, Strategy, Intercultural Communication and Organizational Behavior in the MS program. Prior to joining Rose-Hulman, Terry developed courseware at the Open University Business School. His industrial experience includes 3 years in a software research center in Munich and 7 years as policy analyst in the electric utility industry. Terry earned his Ph.D. in Systems Science from Portland State University in1992.

David Voltmer, Rose-Hulman Institute of Technology
Electrical and Computer Engineering Department

David R. Voltmer received degrees from Iowa State University (BSEE), University of Southern California (MSEE), and The Ohio State University (PhD EE). During nearly four decades of teaching, Dr. Voltmer has maintained a technical focus in electromagnetics, microwaves, and antennas. His more recent efforts are directed toward the design process and project courses. He has served in many offices of the ERM division of ASEE and in FIE. Dr. Voltmer is an ASEE Fellow and a Life Senior member of IEEE.

Mark Yoder, Rose-Hulman Institute of Technology
Electrical and Computer Engineering Department

Mark A. Yoder - Professor of Electrical and Computer Engineering at Rose- Hulman Institute of Technology in Terre Haute, Indiana. Co-authored the books DSP First: A Multimedia Approach and Signal Processing First with Jim McClellan and Ron Schafer which were published by Prentice Hall in 1998 and 2003. And he has also co-authored Engineering Our Digital Future with Geoffrey Orsak, et. al. published 2004 by Prentice Hall. Mark's biography isn't complete without some mention of his family. His wife Sarah has her Ph.D. in Electrical Engineering from Purdue University, and they have ten wonderful children ages 23, 23, 20, 18, 16, 14, 12, 10, 7, and 4. Three boys and seven girls.

Edward Wheeler, Rose-Hulman Institute of Technology
Electrical and Computer Engineering Department

Edward Wheeler is Associate Professor in Electrical and Computer Engineering at Rose-Hulman

Institute of Technology. He received a Ph.D. in electrical engineering from the University of Missouri-Rolla in 1996. His interests include electromagnetic compatibility, engineering education, and the electrical and optical properties of materials.

An Undergraduate, Entrepreneurial Design Sequence: A Decade of Development and Success

Abstract - A commitment by the ECE Department of Rose-Hulman to develop and offer an entrepreneurial design sequence as a curricular hallmark has been rewarded by satisfied clients and design-savvy graduates over the past decade. The highly-coordinated, four-course sequence features a wide range of topics including creativity, teamwork skills, design methodology, systems engineering, product design specifications, conceptual design, design reviews, intellectual property, project management, budgeting, scheduling, proposal writing, social impact considerations, prototype fabrication and testing, client briefings, and project reporting. Students apply these concepts as they propose, undertake, and complete projects for a variety of clients. The tenor of the sequence focuses on the underlying principle that engineering is a profession in which services for clients are rendered in an equitable, economical and ethical manner. This paper describes the learning objectives, evolution, current status, and assessment of the four-course sequence. This paper details the content, implementation, activities, teaching loads, assessment, and student reactions to the design sequence.

Index Terms – Creativity, Teamwork, Design, Project, Professional

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Introduction

". . . the proper study of mankind is the science of design . . .", Herbert A. Simon[1]

In the mid-90's, the Electrical and Computer Engineering Department of Rose-Hulman Institute of Technology completed a thorough curricular review with a special focus on the design component. Many (and sometimes contradictory) views of the design process were presented and discussed during the intense and lengthy process. The process was concluded by a deep departmental commitment to enhance and strengthen the design component of the curriculum. In reaching this decision, the department made the painful decision to replace three, senior-level technical electives—those courses that are fun to teach since they are taken by students who choose to be there—with a coordinated, four-course, design sequence.

During this curricular design process, a number of underlying principles emerged and provided the guidelines by which the ECE design sequence was developed.

- Engineering is a serving profession.
- Design is the basis of all engineering activities.
- Modern engineering design requires teamwork skills.
- Decision-making and communications are vital components of design.
- Learning the process of design is best accomplished by designing solutions to real problems.
- Useful design techniques and models must be provided to students.
- Students must be responsible for the success of their project.
- The design sequence must be well-coordinated.
- Faculty workloads within the design sequence must not be burdensome.
- High-quality design is challenging, but this creative process is highly rewarding and FUN.

Based upon these principles a four-course design sequence has evolved over the past decade; the process, its implementation, and its results are described in the remainder of this paper.

The Design Sequence v1.0

The professional nature of engineering is a value that must be deeply ingrained within the students. Accordingly, the original version of the design sequence spanned the sophomore, junior, and senior years. Personal responsibility and team work were the hallmarks of the design sequence. Students were confronted with situations that required them to practice the principles of design and to make decisions. The problems were devised to be increasingly challenging, required additional team skills, and demanded more creative thinking as the students progressed through the sequence. Each team had a faculty mentor who asked probing questions and raised important issues, but very purposely avoided the role of problem solver. The sequence concluded with each team developing and realizing a solution to a unique customer problem. Throughout the entire sequence, communications—internal to the team and external to the client and the faculty mentor—was required. Each term a written report and oral presentation concluded the project.

- The sophomore year course, Engineering Practice, focused upon development of teamwork skills and the corresponding communications (agendas, minutes, and memos) necessary for good team work. The course content was based in engineering economics for which a variety of increasingly challenging projects were assigned to the teams. The course culminated with a multi-week, open-ended, final project for which a written report and oral presentation were required. All faculty members of the department mentored one team.
- The junior year course, Principles of Design, required each team to respond to a unique set of client requirements (often provided by a faculty member) so that they designed and fabricated a prototype solution. Student teams were expected to organize their efforts to complete the work in one ten-week term. A written report and an oral presentation concluded the project. All members of the department mentored one team.
- The senior year courses, Engineering Design I & II, required each team to respond to the needs of an external client (usually a company or a governmental or non-profit agency) by identifying the client's needs, defining system requirements, proposing alternate solutions, choosing the "best" solution, and designing, constructing and delivering a prototype solution. Each team was required to maintain regular, professional communications with their client. The twenty-five week project culminated in a written report and an oral presentation at the ECE Senior Project Symposium. Several faculty members mentored three or four teams each.

Lessons Learned and Design Sequence Modifications

Continuous monitoring and assessment of the design sequence for several years following its introduction was very revealing. The findings are summarized in the following list:

- The sophomore course was extremely unpopular with the students as they found engineering economics totally irrelevant to their view of engineering.
- The junior course was a modest success with the students, but the faculty felt a heavy burden of devising challenging, yet achievable problems with good learning-teaching experiences.
- The senior course clients were very enthusiastic about the creativity of the student designs and the quality of their work.
- The senior course was a bit burdensome for faculty teaching loads.
- Close coordination of the courses helped avoid repetition and smooth transitions between courses while providing increasingly challenging experiences to students.

A review of these findings made it painfully clear that changes in the sophomore course were needed. The very poor student evaluations of the sophomore course were addressed by implementing a major change in both content and delivery. Though the subject of engineering economy introduced students to important material, as sophomores they were more concerned with technical details such as differential equations and node-voltage techniques. They were unable to see the relevance of this subject to their engineering career. To enliven the course and to focus more upon design, engineering economics was replaced by introductory system design principles. These principles were applied to the very real problems associated with autonomous robotic competition[2]. The competition between teams was added to further engage students in the process. In its original form the course was set in a typical classroom lecture environment with an associated laboratory for team meetings; the revised format was wholly laboratory based with brief, daily introductory remarks on the principles of engineering design and practice and with limited outside homework assignments. In addition, the course was moved to the beginning of the junior year to take advantage of increased student maturity.

The burdensome nature of the teaching load associated with the junior course was due in part to the process of proposing new, "workable" problems and in part due to the heavy load of grading the many documents required from the students. In addition to this pressure, several other factors were coming to bear upon the junior level course as well. It became apparent that entrepreneurial and project management skills were becoming increasingly important in engineering. Changing community needs resulted in an increasing number of requests from non-profit and charitable organizations for product development. With these factors in mind, the junior level course was revised to reflect a more service learning nature[3]. The course focused on client-driven, entrepreneurial product development to meet the needs of community based clients. Accordingly, students discover client needs, define product specifications, search for relevant intellectual property, prepare budgetary and scheduling plans, consider social impact of the product; in short they prepare a complete proposal for the development of a product to meet the client's needs. The heavy grading load for the many written components of the proposals was greatly reduced by the introduction of Calibrated Peer Review (CPR)[4,5] in which the students evaluate each others work and in the process are able to better judge their written work. This has resulted in a significant reduction in the faculty workload of the original course, yet with significant improvement in student writing skills. Subject matter experts in entrepreneurial and project management skills provide guest lecturer coverage as needed.

Based upon the enthusiastic client response, the senior, project design course was working. In order to reduce the faculty workload to a sustainable level, the student teams were assigned increased independence and responsibility for the success of their design. The faculty mentor serves as a manager in a consulting company with several student teams working directly with their client. The faculty member does not get involved except for soliciting the projects, for design reviews, and for situations when problems arise between team members or between the team and the client.

With these modifications, the design sequence topics and activities progress from introductory design principles through proposal writing to the design and delivery of prototype systems. Close coordination of the course is more critical than in the original design sequence, but has been rather easy to achieve.

The Design Sequence v2.0

The revised design sequence in both the EE and CE curricula is comprised of 16 credits (about 8% of program) of four, closely-coordinated courses spread over five terms of the junior and senior years. The required skills and project complexity increase steadily throughout the course sequence from elementary design principles with highly structured problems through team responsibilities and planning to nearly independent operations and prototype delivery. Team sizes are strictly limited to three or four so that each team member experiences a wide variety of team roles and so that management problems associated with larger teams are avoided. The role and responsibilities of an engineering professional are embedded throughout the entire sequence. CPR is employed to enhance students' critical reading skills and to improve student writing skills without excessive teaching loads imposed on the faculty. Electrical and Computer engineering students are equally mixed within the two programs and on most teams during the first two courses; in the last two courses, the mix is also related to the technical areas of the project. The courses of the sequence are related as shown in Figure 1. More details of each of the courses in their current form follow with complete course descriptions attached as Appendices A through D.

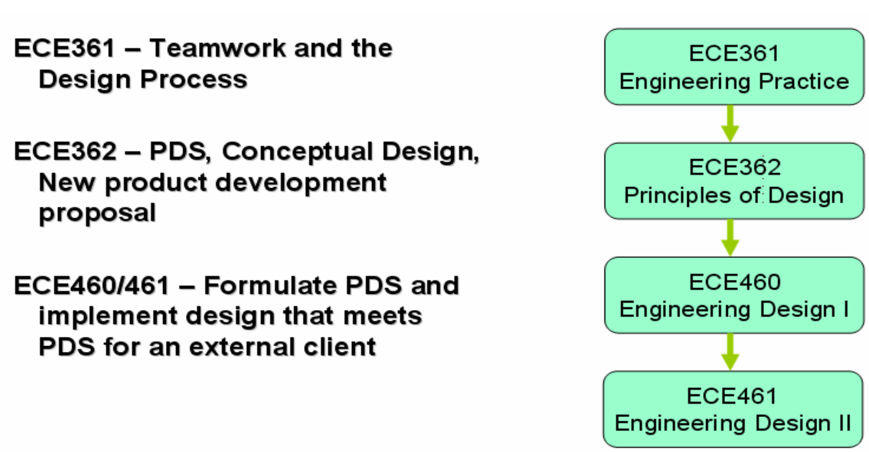

Figure 1 – The ECE Design Sequence

ECE361 – Engineering Practice – 2 credits –junior year.

Faculty members assign students to teams of three or four to balance skills, experiences, interests and hobbies. Each team has available a LEGO® Mindstorms®[6] from which to design, program, and construct an autonomous robot that meets performance requirements defined by the faculty. The technical concepts required are kept to a minimum so that students can identify the underlying principles and focus on the design process, not technical prowess. The topical coverage of the course is summarized below.

- Team skills and responsibilities
- Team communications – agendas, minutes, memos
- Design principles – requirements, decisions, documentation
- Creativity and brainstorming
- Conceptual design/detail design
- Decision-making
- Design review
- Testing and verification
- Documentation and presentations
- Professional development plans by each student
- Competition (scored, but un-graded)

Since this course marks the introduction of ECE students to the formal design process and the associated team skills, the processes and deliverables are carefully chosen by the instructors. Teams are provided only the most introductory design principles and skills. A set of requirements, or Product Design Specifications (PDS), and a timeline for completion of deliverables by all the teams is prepared by the instructors. Instructional topics are covered as needed throughout the course. CPR is introduced as computer-based tool for enhancing critical reading skills and to improve technical writing skills in preparing required documentation.

The problem assigned to the teams is the basis for inter-team competition during the last week of the term. It engages the students and provokes great rivalry, but the score is not used as a grading component. The competition is strictly for glory, pride and ego-building.

Professional development credit is considered a vital element of the course sequence. It begins in this course where each student is required to submit for approval a professional development plan for the last two years of their undergraduate career. The department encourages that each student join a professional society (the IEEE is recommended) and requires that they attend at least nine departmentally approved professional development seminars. Each student maintains a professional development log similar to that used by many state certification boards for maintenance of PE licensure. These logs are submitted at the completion of last course in the sequence as demonstration of completion of professional development graduation requirements.

ECE362 – Principles of Design – 4 credits – junior year

Prospective clients are invited to class during the first week to describe to the students their needs and to engage in detailed discussions. These clients (usually non-profit or charitable organizations) are solicited in advance by the faculty. The Indiana School for the Blind and Visually Impaired[7] has been the major client for the past several years. Students select the most interesting of the client needs; from this "sorting" process, the teams are self-selected. Each team works throughout the duration of the course in carrying a client's need through the preparation of a proposal requesting funds for the development of a product that meets these needs. The topical coverage is summarized below.

- System engineering principles
- Client needs
- Market analysis
- IP, patents, and competition
- Product design specifications (PDS)
- High Level Design Documents (HLDD)

- Work Breakdown Structure (WBS) and Scheduling
- Budget requirements
- Project management
- Risks and contingencies
- Social impact
- Proposal and presentation

Close coordination enables this course to build upon the team skills and design processes learned in the first course of the design sequence. However, now the student teams must generate the PDS; they must investigate the IP relevant to the product; they must establish schedules and budgets; they must consider the social impact of their proposed product. At the conclusion of the course, a written report and an oral presentation is made to the faculty and the clients. Yes, the client's voice is a factor in the grade earned by the team.

A writing assignment is associated with each of the course topics; at the end of the term, each team combines and edits these components to form a proposal for development of a product to meet the client's needs. Feedback for the first draft of all documentation is provided by computer-assigned classmates through the use of CPR. Without CPR, it would not be possible to sustain the teaching loads required by grading the many writing assignments. Moreover, the students' critical reading skills are enhanced by the process. Assessment data verifies the positive contributions of CPR to the course.

Student teams are encouraged to submit their proposal for review by external funding organizations such as the National Collegiate Inventors and Innovators Alliance (NCIIA)[8] for funding consideration. Those teams that are successful in attracting funding can use this external validation and funding as the basis for their project during the senior year courses.

ECE460 & 461 – Engineering Design I & II – 10 credits – distributed over 25 weeks of senior year

The sequence is concluded by the "senior project" courses, in essence a capstone design course. Student teams (assigned by faculty based upon student interest, grade point average, and technical preferences) operate nearly independently as they work with an external client to identify needs, establish requirements (PDS), organize and schedule the work, and design, test, and deliver a prototype to the client. Alternatively, student teams can use their proposed project from the previous course if they have received funding from an external source. The course environment is intended to mimic an industrial setting with the usual resources of laboratory and office facilities, laboratory equipment, computer network connections, long distance telephone and FAX services, copying privileges, and a purchasing coordinator through the ECE department.

The topical coverage for the "senior project" course is summarized below.

- PDS definition
- Design reviews
- Interim reports
- Non-Disclosure Agreements
- Peer Evaluations
- Client visits
- Professional Behavior and Responsibility

The operational model for these two courses is that student teams function as project teams within a consulting company that has been awarded a contract for their client's project. The faculty mentor serves as their manager. Consequently, the contact with the client, the project decisions, and responsibility for completing the project and delivering agreed upon products rests with the students. Aside from the solicitation of projects, preliminary organizational details, design reviews, and end-of-term evaluations, there is little contact between the faculty mentor and the client. In the rare cases where there are significant technical or communications problems, the faculty mentor becomes involved as would the manager in a consulting company. The faculty mentor becomes truly a manager, keeping the educational and project administrative tasks in line and resolving the larger issues, but seldom becoming involved with the technical issues of the project. This method of operation has two significant benefits.

Firstly, the student teams, not the faculty mentor, are responsible for the success of their project; they are given the freedom to fail. Secondly, the faculty workload for the project course is significantly reduced. One faculty member can oversee as many as a dozen projects for about half a teaching load.

Several additional details are noteworthy. The projects are solicited from external clients so as to minimize any vested interests of the faculty mentors. Project solicitation is conducted by several ECE faculty members using alumni, industry, and consulting contacts as well as previous clients. Each year about 25 projects are solicited with 20 or more used. The students have a choice and several projects are "rejected" by the students each year. Project solicitation by the faculty takes on the order of 40 hours or less.

There are no project fees assessed to the clients, but they are advised to review all student team recommendations by qualified professionals. Clients are expected to provide reimbursement for items purchased to complete the project, but all prototype hardware and software are considered property of the client. Any special software or capital equipment required for the project is expected to be supplied by the client.

The project's technical work is usually, though not always, of high technical quality. Students' do not always have the maturity to do the best job. They do not always have experience in the technical areas needed. But, as an educational exercise they must learn to function in these situations. That is the role and purpose of this design practicum.

Each year a senior project symposium is held in late April in which all teams make an oral presentation of their project results. This accompanies the written project report submitted to the client. Clients are invited to attend. An entire day is taken with all ECE sophomores and juniors urged to attend.

Was it worth the effort?

This question can be answered from several different perspectives—students, faculty, and clients. Of course, each group has different measures of success so the responses must be put into context.

How did the students respond? Student evaluations are conducted every term in all courses at Rose-Hulman. Several sets of data from these surveys provide insight into the student perspective of ECE361 and ECE362, the first two courses in the sequence. Student responses ranged from 1 (Disagree strongly) to 5 (Agree strongly). The questions are summarized below:

- Question 1. This course developed or enhanced my ability to solve problems.
- Question 2. This course has caused me to think more about the subject matter.
- Question 3. I feel adequately prepared to take further courses in this area.
- Question 4. Overall, my learning experience has been:
- Question 5. This course had outside relevance:
- Question 6. Overall, how would you rate this course?

Limited data is available for ECE361, Engineering Practice. Most notably, the course had the dubious distinction of the lowest rated course (1.5 to 2.2 on a scale of 5 regardless of the instructor) in the institution with regard to Question 6 (the overall rating of the course.) Immediately following the course modifications and in the succeeding years, the student evaluations have been above the institute average ranging from 3.0 to 4.5 on a scale of 5.

More detailed data collected from questions regarding the course content for ECE 362, Principles of Design, are summarized in Figure 1 below. The data of Figure 1 show the mean values of student responses before and after the modification of ECE362 over a four year period of time; the course modification took place between years 2 and 3.

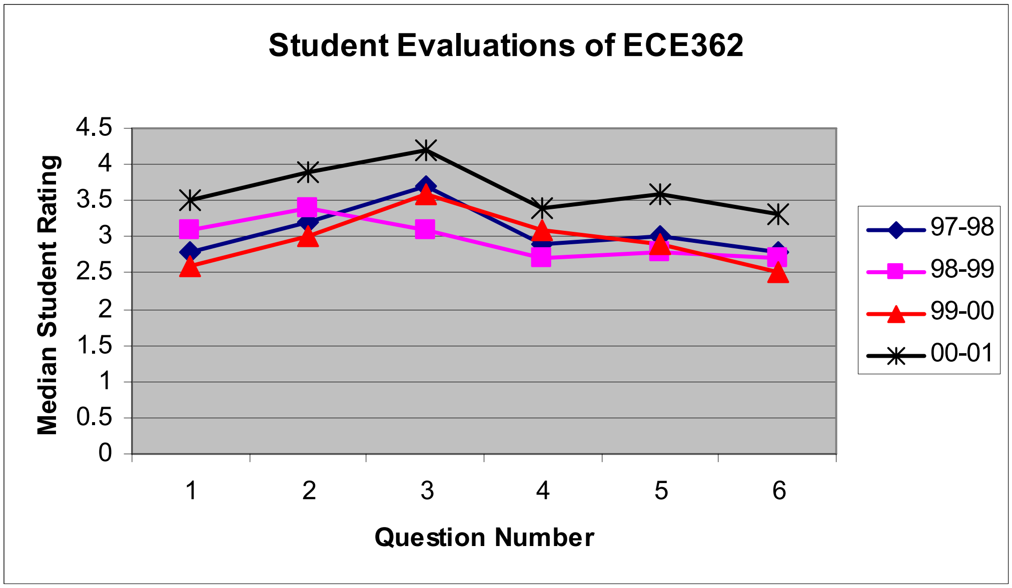

Figure 2 – Student Evaluations of ECE 362 Course Content

The data associated with the diamonds and the squares represent the original version of the course; the data associated with the triangles and the crosses represent the modified version of the course. The first year of the modified course shows little or no improvement. However, the second year offering of the modified course (with the logistic bugs of the first offering smoothed out) shows a significant improvement (nearly +0.5) for all questions. Students feel that the modified course is providing an improved learning experience. This level of student reaction to the modified course has continued in the succeeding years.

Senior exit interviews provide an additional perspective in which student evaluation data are collected. In these interviews students are asked to provide self-assessment of their abilities or skills on a 1-5 scale for the several areas that are emphasized in the design sequence. These data are collected annually; the data are shown for the original sequence and for the modified sequence. These data are shown in Table 1. The rightmost column indicates the percentage improvement of the revised sequence compared to the original sequence from the student perspective. Though only modest increases of 10-20% are indicated by this data, it is gratifying to see that students recognize that their skill level has improved.

Table 1 – Design Skill Levels Self-assessment during Senior ECE Exit Interviews

Skills	Original Sequence	Modified Sequence	Percentage Increase
Written Communications	3.7	4.0	8.1%
Oral Communications	3.5	4.0	14.3%
Teamwork	4.0	4.5	12.5%
Hands-on Engineering Experience	3.4	4.1	20.6%
Engineering Design Knowledge	3.3	4.0	21.2%
Project Management	3.4	4.1	20.6%
Engineering Ethics and Professionalism	3.6	4.1	13.9%

But was it worth the effort for the faculty? The faculty never doubted the value of the design sequence as evidenced by their willingness to reduce the number of senior electives in the curriculum to make room for the design sequence. However, the faculty did have strong reservations regarding the burdensome teaching loads of the original sequence where every faculty member shared in the teaching of the first two courses. While this required only a few hours each week with a single team, it was not used in computing teaching loads. In the revised sequence, only two or three faculty are teaching any of the courses with up to eight teams for which they receive teaching credit. But more importantly, the grading requirements of the design sequence are greatly reduced by virtue of the use of CPR in the first two courses and by increased student responsibilities in the latter two courses. Students provide the critiques of many of their colleagues' first drafts of written documentation; this frees the faculty to focus on the design process and to help teams hone their later drafts. No formal data has been collected, but anecdotal data indicates strong faculty support for the revised design sequence—both from an educational point of view and from a workload point of view.

Though faculty support for the course is strong and widespread throughout the ECE department, not all faculty members are willing or qualified to teach the design courses. The teaching of "soft skills" associated with design courses makes many faculty members uncomfortable; they prefer the mathematically-based, technical courses of their discipline area. Without the "champions" of the design sequence who provide enthusiastic support and frequently teach the design courses, the sequence would not be successful. Sustained offering of this sequence requires an acknowledgement of this teaching preference; indeed, the hiring policies of the department must keep a critical mass of design area faculty members as is required for the technical areas.

No formal assessment data has been collected from the clients. They are busy people and are reluctant to submit formal, written assessment. Informally, the clients' responses given to the senior project faculty mentors have been uniformly positive. In particular, they note that the student project teams produce creative designs, complete the projects with technical competence and in a timely manner, and exhibit professional maturity. Though only anecdotal, these responses are extremely favorable.

The Future

The decade of development and modification of a strong design component has achieved many of the original goals. As expected, significant faculty time was required to achieve this accomplishment. The current design course sequence develops and sharpens our students' design skills and requires a modest, yet sustainable, workload by the faculty. Moreover, close and careful coordination of the courses in the design sequence enables the students to move seamlessly from one course to the next. In addition to the skills of design of the original sequence, students gain valuable service learning and entrepreneurial experience. The limited formal assessment data does not dampen our enthusiasm for our current design sequence. We have confidence in our student design skills with their completion of this sequence. With the success of the design sequence, we intend to maintain the primacy of design in the ECE curricula.

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Appendix A: ECE361 Syllabus

ECE 361 Engineering Practice 1R-3L-2C F,W Pre: ECE 200. Creativity, project design specifications, team roles, effective conduct of team meetings, written and oral communication skills, professionalism, project management, and completion of team project(s).

Instructor(s)
All ECE Faculty

Required/Elective
Required

Class/Laboratory Schedule
Two 105-minute lectures per week.

Prerequisites
ECE 200 – Circuits and Systems

Textbook(s)
None

Course Objectives
After successfully completing this course the student should be able to:

- Identify blocks to creativity and apply that knowledge to overcome stumbling blocks,
- Conduct and participate in team meetings and prepare agendas, minutes, and memos,
- Make team decisions to solve open-ended problems,
- Organize and manage a project toward successful milestone completions,
- Present their work both orally and in writing,
- Demonstrate an understanding of ethical behavior in the profession of engineering and practice this behavior throughout the course, and
- Prepare and carry out a personal Professional Development Plan.

Course Topics

- Team skills and communications
- Lego robotics techniques
- Design Process
- Creativity
- Basic Project Management
- Professionalism

Appendix B: ECE362 Syllabus

ECE 362 Principles of Design; 2R-6L-4C; W, S; Pre: RH 330, ECE 362; A formal design course that emphasizes the design process. Project management, project reporting and decision-making are learned by student teams as they carry a project through several stages of a formal design process.

Instructor(s)
Berry and Voltmer

Required/Elective
Required

Class/Laboratory Schedule
Four 50-minute lectures per week.

Prerequisites
ECE361 - Engineering Practice, RH330 – Technical Communication

Textbook(s)
- Design for Electrical and Computer Engineers Theory, Concepts, and Practice Custom Publishing McGraw Hill
- Course Web Page http://www.rose-hulman.edu/~berry/ECE362_S2005_2006.htm

Course Objectives
After successful completion of this course, students will:
1. work in multidisciplinary teams,
2. carry a design project through a sequence of several stages:
   a) EITHER starting from an initial design brief, a student team will work with a client to develop a product design specification. Then the team will develop conceptual design alternatives and select a conceptual design,
   b) OR starting from a product design specification, a student team will develop conceptual design alternatives and select a conceptual design. Then the team will carry out a detail-design leading to a prototype,
3. prepare and deliver appropriate written and oral reports,
4. make use of professional publications and other appropriate information resources,
5. follow appropriate standards of professional practice.

Course Topics
- What Is Intellectual Property
- What Is an Annotated Bibliography
- Market Analysis
  1. Augmented Projects are existing products that are *added-to or supplemented*, to extend their functionality.
  2. Bi-associated Projects are projects that *combine two different* products and create a new product from the combination.
- PRODUCT DESIGN SPECIFICATION
  1. Performance specifications address a need.
  2. Environmental specification addresses the surroundings and conditions of operation.
- Project Technical Description
  1. Description: It is important to start the description with a very concise description in order to put the features and benefits in context.
  2. Visual Element: A picture, a sketch, screen shot, or a diagram that shows either the components of the product or how the product fits in its environment is usually helpful for the reader.
  3. Key Benefits: State the key benefits of the product early. The use of bullet points is ideal. Then conclude stating the key benefits again in a paragraph form.

- Project Technical Description
    1. Does the project technical description tell the reader what the product does in the opening paragraph or sentence?
    2. Does the project technical description use concise and precise sentences along with concrete words to explain the product?
    3. Does the project technical description use visual elements to help explain the product?
    4. Does the project technical description present the key benefits of the product early in the description?
    5. Does the project technical description present an analysis of any competitors?
    6. Does the project technical description include an explanation of how the parts fit and function together?
    7. Does the project technical description conclude with the key benefits of the product in paragraph form near the end of the description?
    8. Does the project technical description convince you this project can be done?
- Social Impact Statement

Appendix C: ECE460 Syllabus

ECE 460 Engineering Design I; 2R-6L-4C; F,W: The third in a sequence of formal design courses that emphasizes completion of a client-driven project using the design process. Student teams carry a project from inception to completion to satisfy the need of a client. Integral laboratory.

Instructor(s)
All ECE Faculty

Required/Elective
Required

Class/Laboratory Schedule
One 50-minute lecture and twelve hours per week of team project work.

Prerequisites
ECE 362, senior standing and completion of at least seven of the EE or CPE core courses.

Textbook(s)
None

Course Objectives
In this course, students shall:

- Extend their knowledge of an engineering design methodology.
- Become aware of the characteristics of successful product development through application.
- Encounter the needs of an external client.
- Work closely with an external client on an engineering project.
- Complete conceptual and detailed designs for a client-driven project.
- Work in multidiscipline teams.
- Analyze and synthesize information, and make and justify decisions.
- Prepare written and oral reports, oral design reviews, memos, and journals.
- Become aware of how the workplace functions.
- Use ethics in decision-making, following IEEE's code of ethics.

Course Topics

- Goals of year-long course, schedule, examples of past work
- Introduction to available projects, team and project assignment
- Product design specifications, preparation of timelines
- Review of design principles, conceptual design
- Report writing, preparation of interim report

Lab Topics

- Completion of client-driven project.

Appendix D: ECE461 Syllabus

ECE 461 Engineering Design II; 2R-6L-4C; W,S: Continuation of the design project from EC460. Offered over two terms; no credit will be granted for the first term alone. Six credits will be granted after completion of the second term. Integral laboratory.

Instructor(s)
All ECE Faculty

Required/Elective
Required

Class/Laboratory Schedule
One 50-minute lecture and twelve hours per week (six hours in second quarter) of team project work.

Prerequisites
ECE 460

Textbook(s)
None

Course Objectives
In this course, students shall:

- Extend their knowledge of an engineering design methodology.
- Become aware of the characteristics of successful product development through application.
- Encounter the needs of an external client.
- Work closely with an external client on an engineering project.
- Complete conceptual and detailed designs for a client-driven project.
- Work in multidiscipline teams.
- Analyze and synthesize information, and make and justify decisions.
- Prepare written and oral reports, oral design reviews, memos, and journals.
- Become aware of how the workplace functions.
- Use ethics in decision-making, following IEEE's code of ethics.
- Complete departmental Professional Development requirement by end of course.

Course Topics

- Review of work and progress in previous course
- Scheduling for remainder of year
- Teamwork, professional behavior
- Review of design principles, testability
- Critical design reviews. demonstrations to “management”
- Developing and making presentations
- Ethics and law
- Working with the media

Lab Topics

- Completion of client-driven project.