Undergraduate Integrated Engineering & Business Practice Curriculum in the College of Engineering

Robert M. Dunn, Ph.D., John M. Brauer

College of Engineering
University of Notre Dame

Abstract

The College of Engineering at the University of Notre Dame has completed the third year of teaching its undergraduate Integrated Engineering & Business Practice Curriculum. The curriculum was developed as a response to corporate and parental requests for a more comprehensive engineering education. The curriculum is taught in an elective two course sequence to all disciplines of undergraduate engineers. The objective of the curriculum is to enhance the effectiveness of the engineering graduates through an understanding of the dynamics of corporate processes.

The first course in the sequence, Fundamentals of Integrated Engineering & Business, introduces the students to corporate financial reporting including balance sheets, income and expense and cash flows. Human resources processes, management fundamentals, project management, stage-gate development processes, supply chain management and quality topics are also covered. The course incorporates at least four guest speakers to close out the major topics and a breakfast opportunity with a corporate executive.

Advanced Topics in Integrated Engineering & Business builds on the foundation created in the “Fundamentals” course to build an understanding of the interrelationships of corporate functions. The course also develops the student’s personal skills beneficial to career success. Topics studied include a team based internet competitive business simulation CAPSTONE Management Simulation, effective business presentations, building business cases, emotional intelligence competencies and intellectual property. The course concludes with student presentations on contemporary business topics of globalization, outsourcing, leadership, and successful business models. A field trip to a company site is also included in the advanced course.

The curriculum was developed with the assistance of an academic and industrial advisory committee. The elective courses have been popular with over 55% of the 2001, 2002 and 2003 engineering graduates taking the fundamentals course. The courses have been consistently rated
in the top 30% of the engineering courses when evaluated by the University’s Teacher Course Evaluations (TCEs).

I. Introduction

Corporations in the 1990s experienced dramatic changes including restructuring, downsizing, process reengineering, outsourcing, delayering, globalization, lean manufacturing and supply chain management. These changes in the workplace have resulted in the need for continuous improvement, speed, cross-functional teamwork, empowerment, boundarylessness, entrepreneurialism and increased emphasis on competitiveness. These shifts have all impacted the way that engineers work and the competencies needed by engineering graduates to be successful in corporate positions. This was noted in 2000 by George Harrison, President and CEO, Southern Nuclear Operating Company when he wrote “… for a student to be fully prepared for the workplace they must be exposed to more business related courses during their academic career”1.

Several engineering programs have recognized this paradigm shift and have begun to offer a graduate level degree taught jointly with their business schools. At the undergraduate education level, fewer programs have been developed. MIT is offering an undergraduate engineering school-wide elective course called Management in Engineering2. Topics covered include financial principles, management of innovation, technical strategy, engineering project planning and control, human factors, sales and legal issues, and career planning. The University of Illinois at Champaign is piloting an innovative program in Technology and Management which brings together undergraduate students from the college of engineering and commerce and business administration3. The students enter the selective two year program as juniors and are required to complete twenty two credit hours beyond the requirements for their major degrees. The University of Texas at Austin is offering undergraduate engineering students a two week short-course to familiarize them with business concepts4. This paper describes how the University of Notre Dame College of Engineering has been addressing this challenge since 2000 at the undergraduate level.

II. Curriculum Description

The Integrated Engineering and Business Curriculum is two three credit elective courses offered at the undergraduate level. The objective of the courses is to educate the students in the cross functional business processes needed to be effective in their careers as engineers and to enhance the skills useful in a successful engineering career. The courses are offered to juniors and seniors in all departments of the college. The first course in the curriculum is EG 421 Fundamentals of Integrated Engineering and Business is offered in the fall semester. EG 422 Advanced Concepts of Integrated Engineering and Business is offered in the spring. These two courses fit into a space in engineering education that is similar to but different than programs offered at other universities. Several universities are offering programs in Engineering Management which combing a reduced set engineering courses with typically 20-30% of required courses in business. The University of Missouri-Rolla has a highly developed program offering B.S., M.S. and Ph.D.s in Engineering Management. The undergraduate Integrated
Engineering & Business courses have a similar, but smaller scale, objective to the Engineering Management curriculums but differ by packaging the material into two 3 credit courses (5% of the degree credits). Industrial Engineering is a broad professional discipline concerned with the analysis and design of systems and procedures for organizing the basic resources of production – people, information, materials and equipment – to achieve specific objectives. The IE and Integrated Engineering & Business programs are similar in the teaching of business processes. They differ in that the Integrated Engineering & Business courses have the objective of producing a man or woman that has a strong understanding of business processes they’ll need to interact with in the practice of their specific engineering discipline.

The positioning of the Integrated Engineering & Business courses is a complementary one with Engineering Economics. Knowledge of Engineering Economics allows engineers to understand and utilize the economic justification and viability of financial commitments made by organizations. The Integrated Engineering and Business programs expand the student’s understanding of business processes and skills in further subjects useful to engineers.

A. EG 421 Fundamentals of Integrated Engineering and Business

The first course in the curriculum is designed to be a stand-alone course to provide the students an understanding of the processes used by the business functions that engineers are involved with in their careers. The topics covered were selected by examining a fundamental model of corporations shown in figure 1.

<table>
<thead>
<tr>
<th>Suppliers</th>
<th>Market Planning</th>
<th>Customers</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>★ Product Development Processes</td>
<td></td>
</tr>
<tr>
<td></td>
<td>★ Supply Chain Processes</td>
<td></td>
</tr>
<tr>
<td></td>
<td>★ Customer Relations Processes</td>
<td></td>
</tr>
<tr>
<td>Suppliers</td>
<td>★ Finance</td>
<td>Customers</td>
</tr>
<tr>
<td>Suppliers</td>
<td>★ Human Resources</td>
<td></td>
</tr>
<tr>
<td>Suppliers</td>
<td>★ IT</td>
<td>Real Estate</td>
</tr>
</tbody>
</table>

Figure 1
Key Corporate Processes
The key processes that were selected as important for engineers to understand are the Financial Processes, Human Resources/Management, Product Development Processes and Supply Chain Processes. These subjects were also found to be desirable business topics in a survey of alumni conducted by The Ohio State University.

1. Financial Processes

The learning outcomes of the financial process modules are for the students to be able to assess and evaluate a company’s annual report and judge its financial health. The module begins with a review of Ram Charan’s *What the CEO Wants You to Know: How Your Company Really Works*. Subjects covered include Balance Sheets, Income and Expense Reporting and Cash Flow statements. The interaction of the Balance Sheets and I&E is also covered to show the relationships of the three financial reports. Evaluation of corporate financial health using solvency and liquidity ratios are covered. Student activities in this section include team-based in-class presentations of selected corporate annual reports, financial ratio analyses of a selected typical company and an optional exercise to develop the financial reports of a hypothetical football season bratwurst stand. The financial processes section is concluded with a discussion of personal finances by guest speakers from Merrill Lynch.

2. Human Resource Processes/Management

The learning outcomes of the HR/Management section are to be able to recognize and describe the human resource processes of staffing; attracting, training and retaining skills; measuring and rewarding employee performance. Students are also able to distinguish the basic roles of management, the manager as a coach, the manager as a leader, the manager as a mentor, and assess and identify the different six styles of management.

The key regulatory HR issues and five human resource processes of staffing, compensation, performance evaluations, and training are presented. Students are introduced to the importance of emotional intelligence in the workplace utilizing the case study “What Makes a Leader”. The objective of the management module is to help the students understand the basic responsibilities and key roles of managers. Beyond the basic roles of managers, the characteristics of leading edge delegators, mentors, coaches and leaders are covered. Students also learn the 6 different management styles and have the opportunity to take a Management Style Assessment to see what their own dominate management style will be when they enter management. Management principles are reinforced with a homework exercise using the case study “Tipping Point Leadership”, a study of the management style of Police Chief William Bratton. The HR/Management section is concluded with a management guest speaker from IBM.

3. Product Development Processes

The learning objectives of the Product Development Processes are to be able to identify and evaluate the elements of the five steps of a project management and to describe the seven elements of a well executed stage-gate product development processes. Students are introduced...
to the characteristics of a project, the key roles in a project and the five stages of project management; initiate, plan, start, monitor, close. This segment of the course is enhanced with video excerpts from the PBS special entitled “21st Century Jet – The building of the 777”\textsuperscript{9}. Students are required to identify the five stages of project management from the case study “The Boeing 767: From Concept to Production”\textsuperscript{10}. Building on foundation of project management, the seven elements of PRTM product development process are covered. Project management elements of decision making, project team organization, development activity structure, and development tools are reviewed. Cross-project management elements of the product strategy process, technology management and pipeline management are also covered. Student homework in this section is to review the product development structure used in the case study “BMW’s 3-Series: Managing Platform Design and Development Costs”\textsuperscript{11}.

The product development process is a relevant process for all engineering disciplines except the civil engineers. During the product development lectures, the civil engineers were offered guest speaker lectures in Construction Management, Design/Build construction processes and labor regulations on construction projects.

The project management and product development segment is closed out with either guest speakers from GE Medical Systems or a certified project manager from Siemens.

4. Supply Chain Processes & Quality

The learning objectives of the supply chain module are to describe and assess the Supply Chain Processes including planning processes, procurement, operations, distribution and the interactive management challenges of the Supply Chain. This section is introduced with a review of the basic SCOR operations cell including production planning, procurement, operations, distribution and financials. This foundation is used introduce the concept of an integrated supply chain, the interrelationships and the four elements that flow in an integrated supply chain; information, money, materials and services. The case study used in the Supply Chain module is “The Power of Virtual Integration; Dell’s Supply Chain”\textsuperscript{12}.

The quality module is introduced with a history of the quality movement including the teachings of W. Edwards Deming, J.M. Juran, Philip Crosby, Activity Based Costing, ISO 9000 and the Malcolm Baldrige Quality Award. The modern movement in Six Sigma is introduced and the following quality classes are used to cover the toolkits used in the 5 stages of the Define/Measure/Analyze/Improve and Control (DMAIC) phases of Six Sigma process improvement processes. The Supply Chain/Quality section of the course is concluded with a GE master black belt guest speaker.

The students are required to write a report on the guest speakers for the course with the most important part being the observation of the characteristics of the speakers that made them successful in their careers. The students are also required in small groups to attend a breakfast with a visiting corporate executive selected from the College of Engineering’s Industrial Advisory Council.
Good manners are good business. Each class is concluded with a discussion of “words to the wise” about business social etiquette. Topics covered include proper introductions, handshaking, exchanging business cards, meal etiquette, proper business attire, the art of small talk, thank you notes, cultural awareness, ethics, and influencing.

B. EG 422 Integrated Engineering and Business Advanced Concepts

The advanced course builds on the EG 421 with the objective of providing the students with an understanding of the interrelationships of the corporate functions and the development of the student’s personal skills. These objectives are accomplished with the following modules:

1. CAPSTONE Business Simulation

In this exercise students are assigned to teams and compete with other teams using an internet based business simulation, CAPSTONE Management Simulation. The simulated company that the teams manage is a $100M sensor business with products in 5 different markets. This module includes presentation of the stages of effective teams and is graded as a team effort. The teams are required to make marketing, development, pricing, manufacturing, forecasting, human resource, financing and quality decision. Each cycle of the simulation is equivalent to a year of operations and full annual reports are generated for each competing company. Each customer market has different product selection criteria based on price, age of product, reliability and product performance. Students compete for revenues, market share and profits. The simulation is introduced early in the semester with two practice rounds followed by an eight week competitive series. Using this simulation, the students learn the interaction of all corporate functions and the trade-offs necessary for a company to gain market share and make profits. A stockholders meeting presentation by the team is conducted at the end of the 8 simulated years of competition. The CAPSTONE business simulation is used in hundreds of business curriculums also being used in undergraduate engineering education at University of Colorado-Boulder, Arizona Western College, and Milwaukee School of Engineering.

2. Effective Business Presentations

Effective business presentations are learned in a project based exercise taught by the members of the class. Sections of the book The Articulate Executive are assigned to the students for in-class presentations. Students learn the importance of good business presentations, understanding your audience, strong beginnings, organizational structures, powerful messages, strong finishes, listening walls, the power of silence, body language, how to read prepared text, the use of visual aids and the art of questions and answers.

3. Business Plans

The twelve sections of a sound business plan are covered next in the module. Subjects covered include mission statements, goals, value and vision statements, industrial analyses, critical success factors, SWOT analysis, market definition and segmentation, competition, company descriptions and corporate financials. The student exercise for this section is the preparation of a “reverse engineered business plan”. The exercise requires the students to construct the business
plan of a publicly traded company using all available information. The learning objective of this section is to give the engineers an understanding scope of business plans that are prepared for most major product development activities.

4. Emotional Intelligence Competencies

Career success in the business environment is dependent on the maturity of an individual’s emotional intelligence. The section starts with the students performing a HayGroup “Emotional Competence Inventory – University Edition”\textsuperscript{15} to assess their personal emotional intelligence competency profile. Students are then assigned one of the emotional intelligence competencies to research and present in class. The presentations focus on the definition of the competency, an example of the competency practiced well and explanation of how to increase your skill levels in the competency.

5. Intellectual Property for Engineers

A patent lawyer visits the class to instruct the students on intellectual property and how it is protected. The purpose of this class is to have the students understand the value of intellectual property, how it is used and protected in business.

6. Corporate Field Trip

A field trip is arranged for the class to visit a business to observe the topics discussed in the two courses. For the past two years we have been hosted by GE Medical Systems in Waukesha, WI.

7. Current Topic Business Presentations

The course concludes with the students presenting a business presentation in class. The subjects are selected by the students with the requirement that the subject must be relevant to contemporary business issues? Typical subjects include the leadership examples of Jack Welch, Lou Gerstner, Rudy Guiliani and Colin Powell, the market models of WalMart and Southwest Airlines, negotiating and influencing, the Tynelol Credo story, The European Union, the emergence of China and India in Global Businesses, what went wrong at Enron, the wisdom of teams, the Segway story, Bose JIT II, Bill Gates and Microsoft, and the theory of constraints.

III. Student Response and Feedback

Student response to the Integrated Engineering and Business curriculum has been strong. For the three years that the curriculum has been offered, over 55% of the graduating engineering students have taken the elective Fundamentals course. Student participation in the Advanced course has also been strong with 40% of the 2004 engineering graduates taking the course. Feedback about the courses is gathered using several mechanisms. The University of Notre Dame uses a student evaluation questionnaire called Teacher Course Evaluations (TCEs) to evaluate course instruction. One key course comparison question in the survey is the “overall perception of teaching” question. The fundamentals course has been rated in the top 30% of the...
College of Engineering’s courses 6 out of the 7 times that it has been evaluated by the students. The Advanced course has been evaluated 5 times and has been rated in the top 30% each time.

At the conclusion of the advanced course, students are asked to take a course survey that evaluates the value of each module taught in both of the courses of the curriculum. The three modules that the students felt would help them the most in their careers were the financial section of the fundamentals course and the CAPSIM and business presentations of the advanced course. Employer’s feedback has been favorable. One company that has had a sufficient number of graduates to observe the course results, and is familiar with the course content, has been encouraging its Notre Dame summer interns to take the courses. Structured post graduation feedback is a challenge because of the difficulty in maintaining contact with a sufficient number of students to create statistically significant results. Numerous graduates have taken the trouble to provide feedback from their jobs. These comments, as you would expect, have been supportive and encouraging.

IV. Integrated Engineering and Business Advisory Councils

The curriculum has been guided with the advice of two advisory councils, an academic advisory committee and an industrial advisory committee. The academic advisory committee was used in the first year of the curriculum development had the objective of providing sound educational fundamentals in the curriculum and to also keep all the departments of the college informed about the development of the curriculum. The industrial advisory council is a subset of the College of Engineering’s Industrial Advisory Council. The six members of the committee include 3 Chairman and CEO’s, 2 Presidents and 2 Senior Vice Presidents of major corporations. The advisory council meets annually to review the activities and results of the curriculum.

Bibliography
2 URL: [http://owc.mit.edu/OcwWeb/Mechanical-Engineering/2.96](http://owc.mit.edu/OcwWeb/Mechanical-Engineering/2.96) Management in Engineering, Fall 2002
Robert M. Dunn, Ph.D.
Bob is the Director of the Integrated Engineering & Business Practices Program. He graduated from Notre Dame with a BS in Engineering Science, The Pennsylvania State University with a MS in Engineering Mechanics and received a Ph.D. in Aeronautical and Aerospace Engineering from the University of Illinois. He worked for the IBM Corporation for 33 years where his career involved the management of complex organizations and business relations around the world. He was in management positions for over 25 years and held executive positions for over 13 years.

John M. Brauer
John is the associate director of the Integrated Engineering & Business Practices Program. He has a Bachelor’s and Master’s degree in chemical engineering from the University of Buffalo. He has 34 years of industrial experience, the last 29 of which were spend at IBM in a variety of management positions. John has working experience in process development, product development, manufacturing, quality, facilities management and environmental health and safety.