Introducing Freshmen to the Field of Industrial Engineering Through the Use of Collaborative Project Experiences

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Abstract

This paper describes a pilot module created by several members of the Industrial and Systems Engineering Department at Lehigh University in collaboration with industry partners as a component of the freshman engineering course (Engineering 95). The module is designed to help freshmen better understand the role and function of industrial engineers (IE) and information and systems engineers (I&SE). By putting the freshmen within the context of an IE project environment, they can more accurately understand and evaluate their interest in an industrial engineering career. This enables the student to make a more informed decision regarding which engineering discipline to follow after the freshman year.

The six-week module engages students in an industrial engineering project as the means of introducing them to: 1) experiential problem-solving; 2) the engineering method of design, construct, measure and test; 3) typical aspects of people, process and technology that are found within IE projects, and 4) the necessity for good leadership, communication, and teamwork. Class sessions include an introduction to agile enterprise systems, the design of a business plan, instruction in process mapping, concepts of engineering economy and ROI, and how to conduct a design review. Teamwork and communication of project results using multimedia techniques contribute to leadership skill development. The Enterprise Systems Center Collaboratory is used to bring industry partners into the classroom via remote electronic links to provide project feedback.

The paper also describes the relationship of the IE/I&SE module to the entire Engineering 95 course, the methods that make using the module transferable to other IE faculty members with various areas of specialization, and an early look at the effectiveness of the module in defining the IE role and conveying understanding to freshmen of the IE discipline.

The Challenge

The new dean of the P.C. Rossin College of Engineering and Applied Sciences at Lehigh University, Dr. Mohammed El-Aasser, challenged Lehigh's engineering faculty to develop an innovative course, the prototype identified as Engineering 95, designed to introduce freshmen to the various engineering disciplines. He believed that freshmen engineering students were often insufficiently prepared to make an informed decision on which engineering specialty to choose in their sophomore year. Previous introductory courses had been cast in more of a "meet and greet" style, with introductions to the various faculty members and lectures on the contents of each discipline's offerings. Dean El-Aasser's challenge to the faculty was to create modules that would involve the students in the kinds of activities that they would experience if they chose a particular discipline. By actually doing what a chemical, industrial, electrical, mechanical, or computer engineer or computer scientist does, the student would have a much better understanding of whether those activities were compatible with the student's skills and interests. Dean El-Aasser expected that this would lead to a higher retention rate within each of the various disciplines as students made more informed choices of majors.

There were a number of obstacles to creating this course. First, most freshmen do not possess many engineering skills when they enter college. Second, the module was to last only six weeks for each discipline, which significantly limited the amount of time available to teach the necessary skills. Third, there needed to be a completed product at the end of the six-week session to share with the students taking modules in the other engineering disciplines.

The chosen course design for the pilot consisted of modules from five of the disciplines in the engineering college – chemical engineering, computer science and engineering, materials science and engineering, mechanical engineering, and industrial engineering. Each module ran for six weeks. Students could choose their top choice and were randomly assigned a second choice. All students received their first choice. In all, 64 students participated.

Choosing a Methodology

The team of faculty and industry partners from the Industrial and Systems Engineering Department used the Greenfield Coalition Learning Hierarchy as the basis upon which to develop their module. This educational model, developed by the Greenfield Coalition at Focus: HOPE in Detroit as part of a National Science Foundation project, is predicated on the belief that students learn faster and become more effective problem solvers if they actively participate in their learning.[1] The model also seeks to place each learning activity in a learning context, giving it meaning in an overall structure.

The figure below shows the Greenfield Coalition's Learning Hierarchy.

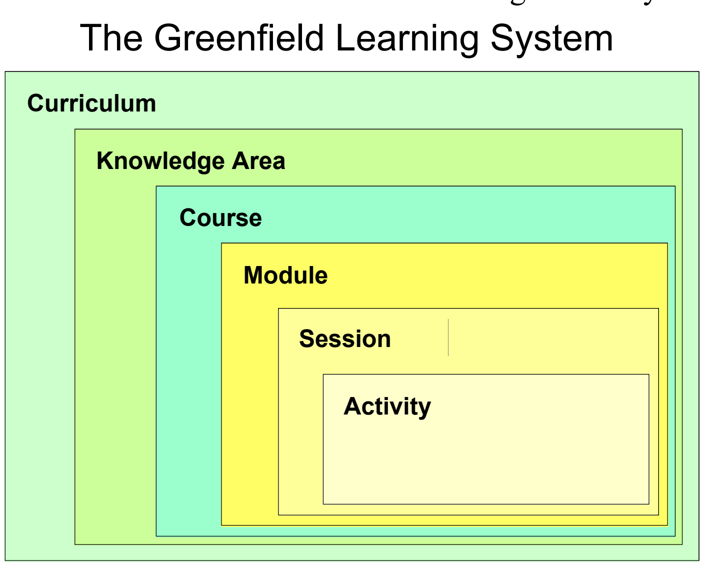

FIGURE 1. Greenfield Coalition Learning Hierarchy[2]

In this model, the learning activity represents the smallest component of the curriculum. Learning activities are grouped together to form sessions. One or more sessions may make up a single class period. These sessions, taken together, form the module that is one component of the Engineering 95 course. The structure of the IE/I&SE module appears below. Detailed descriptions of the various component activities appear in the section "Module Content".

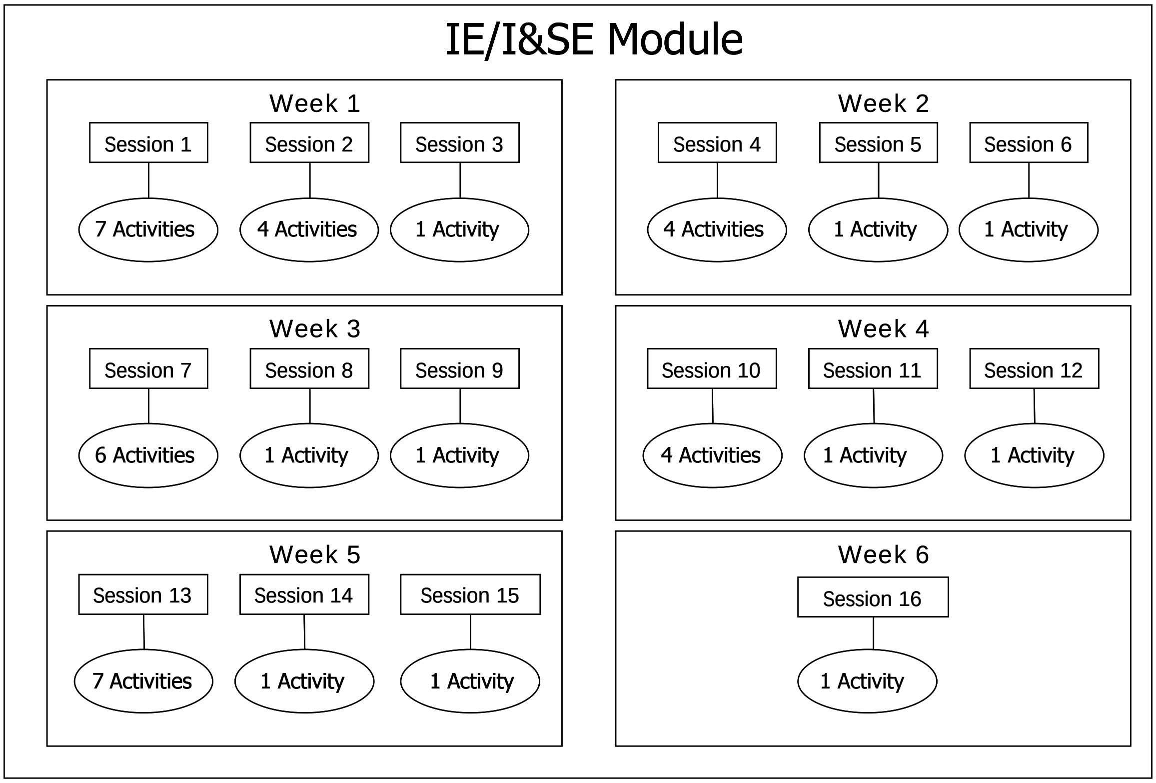

Figure 2. IE/I&SE Module Design

In the development of the learning activities, the team paid particular attention to the "conditions of learning" identified by Robert Gagne, particularly the nine instructional events and their corresponding cognitive processes.[3] These were incorporated into each activity to the extent possible. Earlier work with the Greenfield Coalition had demonstrated the value of attention to these processes.[4,5,6,7]

Another important component of module development from the Greenfield Coalition design process was placing the module within a learning context. This context requires defining the motivation, the objectives, and the prior knowledge of the participants. To that purpose, the team identified the following motivations for developing the module:

1. To communicate an understanding and introduction to what IE/I&SE engineers do in the "real world."
2. To provide information to facilitate the decision of choosing a discipline after the students' freshman year of engineering.

3. To help the students determine if they find industrial engineering interesting, fun and challenging.

The specific objectives were defined as:
1. To introduce students to industrial engineering and what industrial engineers do
2. To introduce students to experiential problem-solving
3. To provide students with experience in the engineering method of design, construct, measure and test
4. To introduce the student to the unique aspects of people, process, and technology within industrial engineering problems
5. To have the students enjoy themselves within the context of an industrial engineering experience, to wit: working as part of a team, solving interesting problems, and role-playing.

The assumptions regarding prior knowledge were that the students had a high school education, minimal "real world" problem solving experience, some basic assumptions about industrial engineering, and that they had peer conversations that may or may not have included accurate information about industrial engineering as a discipline.

Module Content

The actual module content focused on student involvement in the design of an enterprise system. Students were required to 1) conceptualize a new product or service and then design an operational plan and system to implement it; 2) use computer-aided design tools to create proposed process and information flows; 3) simulate and test the proposed system through a classroom walk-through, and 4) build an economic model to evaluate the case supporting the operations plan. The final operating plan would then be presented to experienced reviewers for evaluation and feedback.

Students were provided with examples of sample products or services. They were permitted to choose one of the examples or create their own. In all the groups, students created their own products or services. Having the students create their own products provides a way to keep the course fresh each semester. The student products and services that were developed included:
- Business to sell computers to students leveraging the university student software fees to eliminate the licensing cost of major software packages
- Business to build, install, buy back, and resell lofts for the student dorms based on CAD customizing techniques
- Business to take grocery orders electronically and efficiently deliver them to the dorms
- Business to electronically link nearby auto repair facilities to students, faculty, and staff on campus, using developed software to help coordinate transportation and scheduling at the service center
- Business to perform dorm cleaning using efficient scheduling algorithms with an option to provide digital pictures of areas on which to concentrate or avoid
- Business to provide low-cost hair cuts and tanning booths with digital pictures for example haircuts

The goals of the project were identified to the students as:

1. **Learn what functions and systems comprise a business enterprise.** This was accomplished through presentation of enterprise models and discussion of the functions needed in the students' proposed businesses.
2. **Learn how to apply graphical design tools to develop process and information flows.** This was accomplished through a session using Visio™ for process design. Groups were required to submit as homework a process flow for their business that had at least three levels of detail.
3. **Learn how to build an operational business plan along with economic analysis of the operating plan.** This was accomplished through classroom activities reviewing example operational business plans and a session with Excel. Groups were required to submit as homework an Excel model incorporating the economic analysis of their business.
4. **Learn how to test process designs by simulation techniques.** This was accomplished by a simulated walkthrough of the business processes. Students from other groups observed, asked questions, and provided feedback. Students participated in a classroom activity simulating a manufacturing assembly line. Monte Carlo simulation principles were employed to simulate the assembly line.
5. **Work in teams to analyze, design and deliver presentations.** Most of the activities were performed in groups or were the responsibility of the group. Students worked in entirely different groups for the two modules. A video was shown to promote good presentation skills. Students had opportunities to formally present their project in a practice and final presentation. Using the Enterprise Systems Center (ESC) Collaboratory equipment, a presentation was given to an off-campus industrial reviewer who provided feedback on their operational business plan, analyses, and presentation skills.
6. **Experience team leadership opportunities.** Team leadership responsibility was rotated throughout the project. Students read and critiqued an article on leadership skills. They drew examples of good and bad leadership from their past jobs, teams, and organizations.
7. **Have fun.**

Evaluation of the project was based on the following criteria:

1. Organization of work
2. Quality of presentation (delivery) – both slides and oral
3. Use of required technical tools (Visio and Excel)
4. Demonstration of creativity and innovation
5. Quality of work
6. Value proposition to customer

Session Design

As shown in Figure 2 above, the module consisted of thirty-nine activities grouped into sixteen sessions. These sessions covered six weeks. The first five weeks consisted of three class meetings, one of three hours duration, one of 75-minute duration, and one of one hour duration. The sixth week was one three-hour session during which final presentations were made from each of the five modules of the Engineering 95 course. Session content by week was organized as follows.

Sessions 1 – 3 (Week 1)

- Meet instructors and review goals. This includes a brief overview of the evolution of the industrial engineering discipline as well as a consideration of some of the typical things IE's and I&SE's do. Many of these examples are drawn from actual project activities in the ESC. The student will understand how the project will demonstrate IE roles.
- Review elements of an enterprise system, examples of actual operational systems analysis, and the concept of the enterprise value chain. The student will be able to describe a business enterprise and the basic elements of a business plan.
- Form teams of two or three students.
- Instructors present possible business/process ideas for evaluation. A sample project is introduced and analyzed.
- Teams select project idea to evaluate.

In these sessions, students brainstormed to determine at least three ideas to pursue. Faculty and industry mentors provided feedback about the ideas and the students refined them. The final project selection was based on the constraints of time and information availability.

Sessions 4-6 (Week 2)

- The students are introduced to the concepts of knowledge management process design and process mapping and then learn how to use a graphical process analysis and design tool (Visio) in PC-equipped lab.

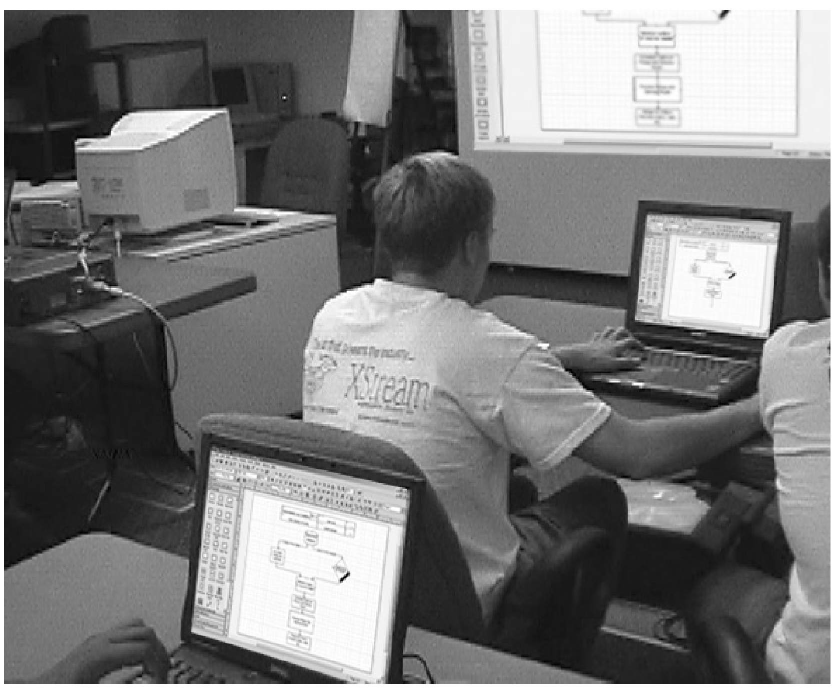
Figure 3. Students Learning Visio™ in ESC Collaboratory

- Discuss team leadership dynamics.
- Each team working separately develops business idea and detailed design of operational processes. The teamwork process through the project teaches team problem-solving and encourages the student to practice leadership skills.

Sessions 7-9 (Week 3)

- Students learn techniques of economic business case development (economic cost analysis, time value of money, initial principles of Monte Carlo analysis). Students participate in the Monte Carlo simulation of an assembly line to determine production capabilities.

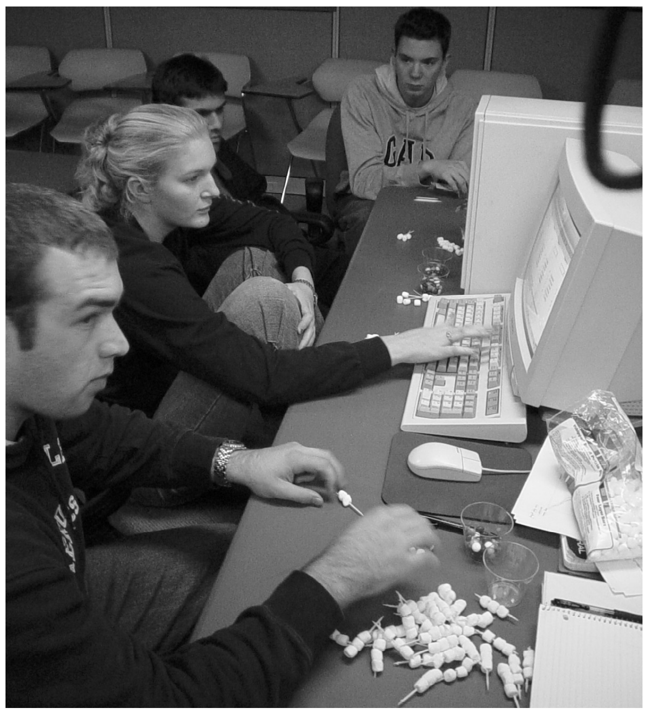

Figure 4. Students Using Monte Carlo Simulation

- Each team develops cost analysis of their proposed business processes and develops business case for their design. This includes using Monte Carlo to define best and worst case estimates of key variables (set at 5 and 95 percentile points). For example, the loft building company set estimates of the number of students who would buy and sell back their lofts each year.
- Exam

Feedback from the first offering of the module indicated that students did not understand what simulation was or how to apply it to their projects. In the second offering the Monte Carlo assembly activity requiring physical hand assembly was added. The feedback from the second group of students was significantly better than the first in terms of understanding simulation.

Sessions 10-12 (Week 4)

- Each team conducts a simulated classroom walk-through of their business processes including a team-developed PowerPoint™ presentation, and receives feedback from class and outside industry experts via teleconference. The facilities of the Enterprise System Center's Learning Collaboratory are used to bring the industry expert into the classroom via remote feed to real-time interaction with the team members.

Figure 5. Student Presentations with Collaboratory Link to Industry Reviewer (center of photo)

- Teams develop and conduct dry run of final presentation to experienced reviewers.

The inclusion of the outside reviewer carried a great deal of weight with the students. The reviewers provided constructive criticism that the students used to enhance their final presentation. The remote, real-time interaction gave team members a chance to experience presenting to an audience that was not directly in front of them.

Sessions 13-15 (Week 5)

- Each team presents its final design to the class and reviewers and receives feedback. These presentation opportunities teach good communication skills.
- Each student provides assessment of team leadership experience.
- Each group submits final report.

The operational business plan becomes the work product of the group. It brings together all the pieces that the group has completed over the past five weeks.

Session 16 (Week 6)

- Final presentation to students in other engineering modules.

This gives students the opportunity to present to a large group and sharpen their skills. Prior to this they have had the chance to present and receive feedback from students in their module.

Module Evaluation

A total of 22 students took the two industrial engineering modules in the Fall Semester. Upon evaluation, more than 80% of the students felt that they had had a significant engineering experience that had allowed them to do many of the things that industrial engineers do. The majority said that they had had fun in the process, making it more likely that they will favorably consider an industrial engineering major. The full results of the evaluation appear below. 1 is low and 5 is high.

	1	**2**	**3**	**4**	**5**
Have a significant engineering experience: To innovate and create a product or service design, utilize IE technology-oriented techniques, and communicate the resulting business model			4	11	7
Learn what functions and systems comprise a business enterprise			3	15	4
Learn how to apply graphical design tools to develop process and information flows			2	9	11
Learn how to build an operational business plan along with economic analysis of the operating plan		1	4	13	4
Learn how to test process designs by simulation (walkthrough) techniques		2	8	10	2
Work in teams to analyze, design and deliver presentations			2	13	7
Experience team leadership opportunities	1	2	5	12	2
Have fun!		4	4	12	2

Other Course Modules

The four other modules that comprised Engineering 95 were provided by the chemical, materials, mechanical, and computer science engineering disciplines. The materials science students tested existing golf balls and designed their own golf ball. The chemical engineering students undertook a fluid dynamics design project. The mechanical engineering students designed, rapid prototyped, and raced cars. The computer science students undertook the redesign of different graphical user interfaces (GUI) of commercially available computer programs. Overall evaluation results from Engineering 95 show that the course was well-received. The students particularly enjoyed the opportunity to work in teams and the exposure they were given to the nature of each of the engineering disciplines. The pilot is being repeated in the Spring semester of 2003 and the current planning is to require the course for the entire entering freshman class in Fall of 2003.

Use of the Collaboratory as a Course Development Resource

Setting the class in the ESC Collaboratory environment during its development allowed for rapid cycling in the review of the module with feedback used to incorporate enhancements as the course progressed. Additional enhancements could then be added to the second offering. In effect, through the Collaboratory method, the course could be created using a rapid prototyping methodology.

Use of the ESC Collaboratory facilities also provided several opportunities for course enhancements. Industry reviewers provided external input in real-time by means of a video link. Students gained experience interacting with experts who were not physically present. The real-time nature of the reviews also required the students to respond quickly. During the Visio™ tutorial, the use of the Collaboratory facilitated rapid tutoring to get students up to speed quickly on the software tool. This was essential given the compact nature of the six-week schedule.

Module Flexibility

Because of the flexibility of the design of the IE/I&SE module, other IE faculty members with other areas of specialization can be called upon to provide learning activities and/or sessions for future offerings of the course. The new learning activity can be substituted for one of the present activities to keep the course fresh and up-to-date. This also provides the opportunity for the Engineering 95 student to interact with a wider variety of IE/I&SE faculty members, giving a broader introduction to the department. In this way, the student can get a better idea of what the department has to offer. In addition, the entire module has been developed to be available on CD-ROM so that other faculty can review the module and identify areas where they can participate. This also permits other faculty to teach the more general areas of the course, again allowing for a greater rotation of personnel in front of the potential industrial engineering student.

Conclusion

The challenge presented by Lehigh's engineering dean to develop a more effective method of communicating the differences in engineering disciplines to incoming freshmen provided the opportunity for industrial engineering faculty and industry partners to create an innovative teaching experience. The resulting module utilizes the Greenfield Coalition learning hierarchy to create a flexible framework to demonstrate to the freshman engineer the components of industrial engineering work. The essential component of that module is the ability of the student to "try out" what industrial engineers do in the context of an enterprise project environment. Use of the ESC Collaboratory provided the flexibility to rapidly try out various alternatives during course development.

Initial results from the pilot semester indicate that the module is an effective teaching tool and that it successfully communicates the characteristics of the industrial engineer's work to the student. Further data collection once the pilot is rolled out to the entire freshmen engineering class and over a four-year period will be needed before it is clear whether this process results in better engineering choices by freshmen and better retention of students in their majors. Nevertheless the course seems to be a valuable addition to the freshman curriculum and headed in the right direction.

[1]Falkenburg, D., "The Greenfield Coalition: Partnership for Change in Manufacturing Engineering and Technology Education," *Proceedings of the International Conference on Engineering Education,* Oslo, Norway, August 6-10, 2001.
[2] Falkenburg.
[3] Gagne, R., Briggs, L., Wager, W. (1992). Principles of Instructional Design (4th Ed.). Fort Worth, TX: HBJ College Publishers.
[4] Falkenburg.

[5] Khasnabis, S., Ellis, R.D., Schuch-Miller, D., Liu, S.L., Santhanamurthy, R., Plonka, F., Falkenburg, D., "Web-Enhanced Tools for an Engineering Economics Course," *Proceeding of the 32nd ASEE/IEEE Frontiers in Education Conference,* Boston, MA, November 6-9, 2002.
[6]Ahmed, M.S., Baskin, N.L., Tonkay, G.L., Wittchen, A.G., Zimmers, Jr., E.W. "Web-Based Learning Activities in Manufacturing Systems," *Proceedings of the 2002 American Society for Engineering Education Annual Conference & Exposition,* Montreal, Quebec, Canada, June 16-19,2002.
[7]Falkenburg, D., "E-Learning in the Greenfield Coalition," *Proceedings of the International Conference on Engineering Education,* Oslo, Norway, August 6-10, 2001.

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