Immersing Students in Reengineering to Make Industry Meaningful in College

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An innovative capstone project at Illinois Valley Community College immerses engineering design and electronics students in the technology and methodology they will encounter in the workplace.

The four-semester project gives the students first-hand experience with continuous quality improvement methodology, reengineering, and entrepreneurship. Freshmen engineering transfer students, enrolled in an engineering graphics course, and freshmen design and electronics students, enrolled in a beginning CAD course, are brought into the continuous quality improvement loop in their first semester; they analyze and recommend improvements on products previously designed by student teams. In their second semester, the CAD design and electronics students fine tune the product redesigns. Freshmen CAD students complete the set of working drawings.

The process is repeated every year. When the freshmen CAD students become sophomore design students, they create models, and, working with electronics students, create prototypes of the redesigned products.

In the fourth semester, the project culminates with the addition of business students and the formation of student teams or "companies," which manufacture, market and sell the products. In that fourth semester, the engineering design students are enrolled in Design Projects, which is a capstone for Associate in Applied Science degree programs in CAE/CAD. They assume the role of project managers to implement the production of products. The business students are enrolled in a course, which is a capstone in their A.A.S. degree programs. This one-semester, entrepreneurial, capstone project is called Making Industry Meaningful In College or MIMIC since it creates a simulated industrial environment for students to sharpen their technical skills as well as teamwork, critical thinking, problem solving and communication skills.

Over the course of the project, the technical students not only benefit from extensive experience with the technology in their fields, but as a result of their teamwork, they become more aware of technology outside of their fields

The four-semester program is a redesign of a one-semester multi-disciplinary project IVCC pioneered ten years ago. The original project required student teams to accomplish the entire process – from product decision and design to sales – in one semester. The limited time frame did not allow enough time for the students to design viable products. The expanded

program solves that problem. Equally important, this four-semester program models the industry process: engineers pass their original designs to designers who prototype and model; designers pass the designs to drafters who complete the working drawings.

While this program was designed for a four-semester, community college setting, it is adaptable to other timelines and other college settings. It is a replicable, cost-effective model.

The origin of the capstone project

Ten years ago, the engineering design instructor and a business instructor at Illinois Valley Community College developed an innovative plan to provide their students with workplace experiences. As a project in one of their courses, the instructors integrated their students into teams to develop, produce and sell a product. They named the project Making Industry Meaningful In College or MIMIC. A few years later the technical side of the teams expanded when electronics students were added to the project. The business side also expanded, and a MIMIC business course was developed as a capstone for students in Associate in Applied Science degree programs in marketing, accounting, management, computer systems and information systems.

The MIMIC project successfully addressed a problem the technical programs faced -- providing students with workplace experiences. IVCC is located in a rural and primarily agricultural district in north central Illinois with a limited industrial base. As a result, a limited number of engineering and technology jobs are available in the district, posing problems for students seeking internships and for the college seeking industry partnerships. Technical jobs, however, are readily available just outside of the college district; Chicago, Rockford and Peoria are all within 60 to 100 miles of the campus. By providing simulated world of work experience, MIMIC provided a solution to the technical programs' dilemma.

In the first ten years of the MIMIC project, the entire process was completed in one semester, including:

- Assigning students to multidisciplinary "companies,"
- Providing training in project management, teamwork, problem solving, critical thinking and communication skills,
- Choosing, designing, prototyping, manufacturing, marketing and selling products.

While the project successfully provided teamwork, problem solving and communication experiences, the limited time frame did not allow students to absorb the training, design viable products, and experience CQI methodology. Expanding the program for the engineering and electronics students solved those problems.

The one semester project also did not match the industry process as well as the expanded program. Originally, the same engineering students were required to create the original design, prototype and complete the working drawings during the one semester project. The expanded program replicates the industry process in which engineers pass their original

designs to designers who prototype and model, and designers pass the designs to drafters who complete the working drawings.

The project today

Today, Reengineering Makes Industry Meaningful In College embeds CQI methodology throughout the two-year engineering design and electronics curricula and culminates in the capstone MIMIC project. In the engineering and electronics programs, CQI is defined as an approach to management and industry that begins with a commitment to continuous improvement of processes, services and products and employs the scientific method. Instruction in CQI principles is reinforced through hands-on experience using student-designed products. Those products are subjected to the scientific method in a loop that includes analysis, redesign, prototyping, production, and continues with analysis of the redesigned product, further redesign, and so on.

Semester one: Students in the beginning CAD course, Computer Aided Drafting I, which is required of both engineering design and electronics students, are introduced to CQI principles. The students break down and analyze products built by student teams in previous semesters and make recommendations for improvement on those products. Based on those recommendations, students enrolled in Engineering Graphics I, prepare preliminary drawings of redesigns. Engineering Graphics I is a course designed for transfer to a four-year engineering program.

Semester two: Students in the second CAD course, either Computer Aided Drafting II or Electronics Drafting, continue to study the CQI loop. They complete the set of working drawings on the redesigned products.

Semester three: Students in the third CAD course, Computer Aided Design, continue to study CQI principles. They prepare models to be printed to a rapid prototyping machine and produce prototypes of the redesigned products.

Semester four, the capstone MIMIC project: Students in Design Projects, Linear Electronics, and a business course designed for the MIMIC project are assigned to multi-disciplinary teams to manufacture, market and sell the products that were prototyped the previous semester. This entrepreneurial component provides the student teams, called "companies," with a simulated industrial setting. The engineering design students in the Design Projects course act as project managers for their "companies."

This two-year reengineering program was phased in to allow as much participation as possible and to provide reengineered products for the student companies in the first year the program was in place. Product analysis, redesign and prototyping was completed in one semester, providing reengineered products for the student companies formed in the spring 2005 semester. The full, four-semester program will be in place for the 2005-2006 academic year.

Products created by student companies in previous years

Over the last ten years, student teams had one semester to select, design, prototype, produce and sell their products. The teams decided what they would produce, subject to approval by the MIMIC instructors. Once the student teams decided on a product, they submitted a proposal. The engineering and electronics instructors evaluated the feasibility, design intent, functions, specifications and capability for manufacturing and assembly on campus. The business instructor evaluated marketability and cost factors. Approval from all three instructors was required before the teams could proceed with prototyping and then production. Typical products included security devices, desktop water fountains, electronic games, lamps, clocks and lighted picture frames.

Figure 1. Desktop water fountain

The desktop water fountain, Figure 1 at left, and lamp, Figure 2 at right, are student-designed products manufactured and sold in previous years. The exterior of the fountain is constructed of plastic pots. The lamp features stars that glow after the light is turned off.

Figure 2. Star lamp

The number of products designed and sold each year has ranged from five to eight with each team creating a product. The number of teams has been determined by the number of students enrolled in the participating classes. The project is offered once a year, in the spring semester.

The flashing drink holder, Figure 3, is an example of a recently designed product. Marketed under the name Kan Kuzzie, this drink holder incorporates fiber optics with a tri-color LED and a printed circuit board. The top, bottom and battery holder were produced in a Rapid Prototyping Machine.

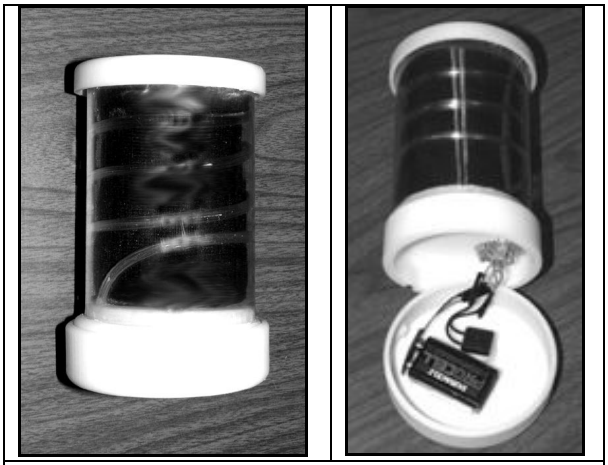

Figure 3. Flashing drink holder, exterior and interior views

Student products being reengineered

Products previously manufactured and sold by student teams are now being reengineered, not only to incorporate newer technology but also to improve the original design, functions, components, cost and ease of production.

More products are reengineered than needed for the student companies, allowing the instructors to select the best of the redesigned products for manufacture and sale.

As the strobe light (Figures 4 and 5 below) illustrates, the reengineering is improving the quality of the products. More importantly, students are immersed in the continuous quality improvement process throughout their technical programs.

Figure 4. Strobe light, original design, side and top views

The strobe light on the left (Figure 4) is the original product that was designed, produced and sold by a student team several years ago. The light on the right (Figure 5) is the reengineered product, redesigned for manufacturing and sale in spring 2005.

The original product, well designed for its time, predates the students' access to a rapid prototyping machine and mold making capability. For aesthetic purposes, the students taped over the glue that held the plastic box together. Newer technology and reengineering allowed the students to create the more commercially viable and professional product on the right.

Figure 5. Strobe light, reengineered design, side and top views

The new design is also more effective. The original design concentrated light in one direction, upward from the box. The new design distributes light more evenly throughout a room because the upper section is made of clear plastic.

In the electronic features, the RC time constant in the new design was altered to affect the time charge rates, which affects the flash rates. The new design includes a straight xenon tube, replacing a u-shaped one in the original design, and the circuit board was repositioned to accommodate the other design changes.

Integration of business students in the capstone MIMIC project

The business students who participate in MIMIC are enrolled in a capstone course, Integrated Business Operations, required in their Associate in Applied Science degree programs. They are from a variety of career fields, including marketing, accounting, management, computer systems and information systems, which allows the makeup of the "companies" to be representative of an industry. Integrating students from various disciplines not only fulfills the technical needs of the student teams but also provides valuable interaction and communication opportunities. Acting on the advice of the advisory committees for their career programs and utilizing a list of essential workplace skills[1] endorsed by the area Tech Prep consortium, the instructors who organize the project make the development of teamwork and communication skills a major focus. In their technical courses, the engineering and electronics students do work in teams and communicate with other technical students. In their companies, however, the students experience how people in other disciplines think and work, and they are encouraged and trained to adapt and communicate more effectively with people outside of their disciplines. Ten years of experience with the original MIMIC project continued to reinforce the need for such training and practice.

Organization and scheduling of the capstone MIMIC project

For the MIMIC project, when products are manufactured and sold, the students' courses are scheduled at a common time to allow for company meetings and training sessions as needed. Those courses are:

- Design Projects, a capstone course which enables students to use their skills to design products for production and supervise production as project managers.
- Linear Electronics, a course which focuses on analysis of electronic component design, application, and construction with and methods of interfacing linear integrated circuits.
- Integrated Business Operations, a capstone course which offers credit for the business side of the student companies.

Before the semester begins, the instructors evaluate the redesigned products, not only for the quality of the redesign, but also for the cost, ease of production and marketability. With more products redesigned than needed for the student companies, some redesigned products are not selected for production.

The semester begins with the three instructors assigning students into their companies and assigning each company to a product. Enrollment determines the number of companies and how many students from each discipline are in each; typically a company includes two engineering design students, two electronics students, and a mix of students from the various business fields. Where possible, when a student in one of the companies has worked on a redesign of a selected product, that product is assigned to the student's company.

Companies meet immediately for orientation and for training. Instructors from other disciplines are brought into the company meetings or into the individual courses, as

consultants would be in a business or industry setting, to teach workplace skills such as teamwork, goal setting, problem solving, critical thinking and communication skills. While certain training sessions are routinely provided, others are added based on the needs of the students and student companies that semester.

Communication channels, including e-mail and WebBoard, are established to allow students to conduct their company business realistically; students must prepare agendas, take and disseminate notes of meetings, for example.

During the weekly meetings that follow, companies decide on a product name and corporate name and training in various workplace skills continues. While the engineering design students act as project managers, students assume responsibility for a portion of the project based on their discipline: marketing students survey potential buyers to gauge product and pricing preferences and research any competition, accounting students start on production budgets, business students plan the fair where the products will be sold. Students also assume responsibility for facilitating company meetings on a rotation basis.

The student teams research and purchase materials and determine the final selling price. A minimum of one week is devoted to producing the products with the students in all of the disciplines required to participate. The number of units to be produced is set by the instructors. Marketing students design packaging, and prepare the written instructions for assembly and/or operation of the products by working with students in a technical writing class.

Business students are in charge of scheduling, planning, picking a theme, promoting and setting up an end-of-semester MIMIC Fair where the products are sold. All of the students assist in the sale of their company's product at that on-campus event. The final work on the project is completed by accounting students who prepare a cost analysis of the sales at the fair, which culminates in a recommendation on the commercial viability of each product.

The MIMIC project wraps up with a celebration dinner for all participants with awards and certificates presented to the students.

The timeline for the current/most recent MIMIC project and the student guidebook, which spells out individual student and team responsibilities, are available on the MIMIC web site at www.ivcc.edu/mimic

Communication exercises in the capstone MIMIC project

A number of communication exercises are integrated into the MIMIC project. In addition to the small group communication skills required for the student companies to function successfully, the students complete other types of communication exercises that would be required of them on the job. All of the students give oral presentations in a 120-seat, multi-screen, electronic lecture hall. In addition to the student teams, the audience includes members of the faculty and administration.

The presentations are scheduled throughout the semester with students from each discipline explaining their portions of the project. Engineering students, for example, defend the product designs early in the semester; and accounting students defend their recommendations on the future potential of the products at the end of the semester.

In Figure 6, engineering design students illustrate and defend their design in an electronic lecture hall. While the student in the center is speaking, the student standing at the left is operating the computer and the panel that controls the multiple screens. The students receive training in giving professional presentations and in using presentation equipment and software as part of the MIMIC project.

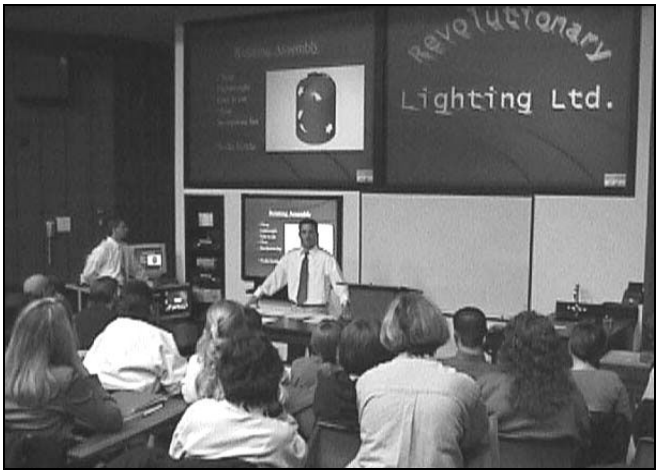

Figure 6. Engineering students defend their design in an electronic lecture hall.

The types of written materials produced by the students are determined by their discipline. Engineering students detail the product designs in formal, technical reports. Marketing students create sales slogans, advertising materials and product descriptions. Business students prepare notes of company meetings and send invitations and thank you messages to faculty who serve as consultants.

The students also encounter different thinking and communication styles as they interact in their companies, and, with the assistance of training in group dynamics and communication, they interact more productively. Feedback from students indicates the need for that training:

- An electronics student: "We can't get the money out of the accountants to buy parts."
- An accounting student: "The engineering and electronics students won't give me any numbers."
- A business student: "The electronics and CAD students had their minds already made up about what they're going to do. They wouldn't listen to us."
- An engineering student: "Those business students are hard to work with. Marketing students said we'd never be able to sell it. Two days later our instructor found something like it selling for 40 bucks. The accountants said our idea was no good – too complicated. We worked okay with the electronics guys."
- An electronics student: "I kind of understand the CAD students, but I don't know what those business students are thinking with. Instead of worrying about whether we can do it or if it will work, they just think about price and the schedule."

Clearly, the issues these students identified and had to address are typical of the workplace.

Technology in the project

Throughout the two years of reengineering, the technical students have extensive experience with technology they will encounter in the workplace including: AutoCAD, Solid Works, Auto CAD Inventor, 3D Studio Max, Catalyst, Multi Sim, Dimension Rapid Prototyping Machine, and CNC machines and programs.

The capstone MIMIC project exposes the students to technology outside of their fields. All of the students on a team participate in decisions on such matters as purchasing of components, pricing, marketing and manufacturing, which requires them to understand the entire process. The technical students become familiar with Excel, Page Maker and Photo Shop. The business students become familiar with engineering and electronics technology.

Engineering students produce components for their products (Figure 7) using a Dimension Rapid Prototyping machine (Figure 8). The teamwork in the MIMIC project exposes business students to that technology.

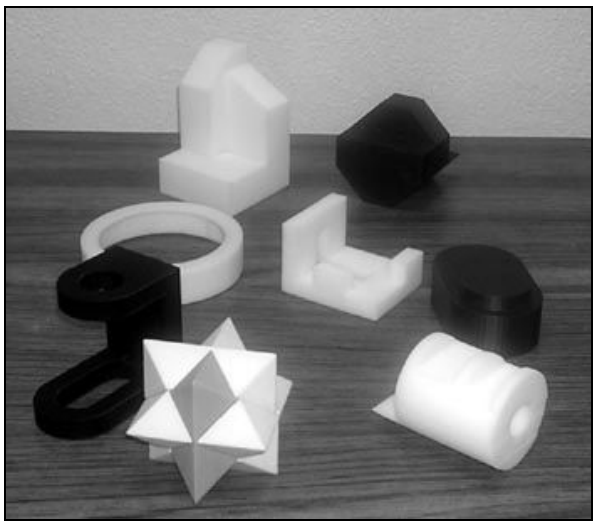

Figure 7. Components produced in a rapid prototyping machine.

Figure 8. Dimension Rapid Prototyping Machine

The communication needs of MIMIC require the students to learn and employ communication technology. Outside of company meetings, the students communicate through email and Web Board. The required oral presentations provide the MIMIC students with training and experience using presentation software and equipment. Their formal presentations are in a multi-screen electronic lecture hall using Power Point, a PC projector, a document camera and an electronic white board (see Figure 6 above).

Other learning in the MIMIC project

In addition to exposing students to communication styles and technologies outside of their disciplines, MIMIC provides students with opportunities to learn about the entire process of manufacturing and project and time management. All team members participate in producing and selling the product. They also participate in decision making at every stage, including the purchasing of components and pricing. That broad participation helps them to understand how their role fits into the entire process. It also makes them more aware of scheduling and time problems and of their need to meet deadlines. The team environment makes students aware of their responsibilities in a way that their individual classroom assignments do not. In their exit interviews, students routinely advise future MIMIC participants not to relax even if they are on schedule.

Evaluation and assessment of the project

Since the one-semester MIMIC project was expanded to a four-semester reengineering program beginning in fall 2004, a full assessment of the program will not be possible until the first group of freshmen have completed their technical programs. In the interim, an examination of the products redesigned in the fall of 2004 (see strobe light in Figures 4 and 5) is a clear indication that product quality and viability has improved even in one semester. As the program continues, students in the reengineering program and the MIMIC project are being evaluated from a number of perspectives.

In the semesters before the capstone MIMIC project:

- Instructors evaluate student analyses of products and recommendations for redesign,
- Instructors evaluate redesigns and working drawings,
- Instructors evaluate the final drawing package.
- Instructors evaluate models and prototypes.

During the MIMIC project:

- Instructors evaluate teamwork and communication skills.
- Instructors evaluate marketing surveys, promotional plans and materials, accounting reports and financial plans.
- Consulting instructors assist in evaluations or oral reports, written reports, e-mail and memos.
- Potential buyers evaluate products.

At the conclusion of and following the MIMIC project:

- Students provide feedback on their teams, on the training provided by the consulting instructors and on the entrepreneurial project.
- Technical students provide feedback about the four-semester program.
- Business and industry leaders provide feedback on the products, program and graduates.

In the past, exit interviews with students revealed their initial reluctance and reservations about the MIMIC project, their struggles during the project, and their eventual appreciation of its value. As one electronics student said: "At the time, I hated doing it. That was the best class I had."

In the past, business and industry leaders have also been overwhelmingly supportive of the one-semester MIMIC project because it prepares students for the workplace by giving them hands-on experience dealing with real problems. As one industry supervisor wrote: "Our company requires one to two years training to become proficient at project management. Dan (CAD student) came to us well prepared." A manufacturing manager said: "It's great. These students run into the same problems we have."

Funding for the capstone MIMIC project

The only funding required for the four-semester program is for the one-semester MIMIC project. In Spring 2005, that budget was approximately $3,000:

- $1,200 for the three instructors ($400 stipend each)
- $1,000 for product supplies.
- Under $1,000 paid to other IVCC instructors for providing training in teamwork and other workplace skills.

Since its inception, the MIMIC project has been sponsored by the college's Tech Prep team, and the funding is from a mini-grant provided through Carl D. Perkins federal legislation. Product sales, from previous years, cover some additional expenses for supplies and end-of-project recognition for the students.

For product supplies, each student company is allocated a budget determined by the number of companies formed that semester. Instructors, acting as consultants, are paid $75 or $50 for a one-session exercise depending on whether the exercise is new or a repeat.

Adaptability of the reengineering program and capstone MIMIC project

Reengineering Makes Industry Meaningful In College was designed for four-semester technical programs at a community college, but the concept is adaptable to a varying number of semesters in a variety of college settings. IVCCs experience with phasing in the program in one year proves that the program can be completed in two semesters. The reengineering components can be scheduled in the first semester and entrepreneurial components in the second. The reengineering components in semester one can include product analysis, recommendations and redesign; prototyping can be in either semester.

The program can be adapted to various college settings and levels, including university programs, by adjusting the complexity of the products to match student backgrounds and instructor/course/program expectations. Programs that incorporate aspects of Reengineering Makes Industry Meaningful In College are offered at Lehigh University, Michigan Technological University and Rowan University. The Engineering Clinics at Rowan[2] are

offered in the sophomore year. The Integrated Product Development program at Lehigh[3] and The Enterprise Program at MTU[4] are capstone projects in their four-year programs. The Lehigh teams of students in engineering, industrial design and business produce prototypes and business plans in collaboration with industry partners. At MTU, The Enterprise Program option allows engineering students to work with industry partners in student-run companies or "enterprises" that exist beyond a semester. As Lehigh and MTU illustrate, industry partners can be integrated into the program.

Conclusion

Reengineering Makes Industry Meaningful in College provides engineering and electronics students with workplace experiences by immersing them in industry technology and methodology throughout their two-year programs. The first three semesters provide hands-on experience with CQI methodology through reengineering of previously designed student products. The fourth or capstone semester provides entrepreneurial, teamwork and communication experience by teaming the technical students with business students into “companies” to produce, market and sell the redesigned products.

The capstone, entrepreneurial project is replicable and cost-effective. The addition of the reengineering component in preceding semesters creates an innovative model that can be adapted to a varying number of semesters and integrated into a variety of technical programs and college settings.

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3. Integrated Product Development. Lehigh University, Bethlehem, PA. http://www.lehigh.edu/ipd/programs
4. The Enterprise Program. Michigan Technological University, Houghton, MI. http://www.enterprise.mtu.edu

DORENE PEREZ, the Program Director/Instructor of CAD/CAE at IVCC, was one of the MIMIC program originators. A co-leader of the Tech Prep team, she has been recognized for her pioneering in the development of online courses. She is participating in a National Science Foundation funded revision of the CAD program at Moraine Valley Community College. Before teaching, she served five years as a CAD manager in industry.

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ROSE MARIE LYNCH, a communications instructor, is co-leader of the college’s Tech Prep team and co-director of the Center for Excellence in Teaching, Learning and Assessment. She provides communication

training to the MIMIC students. In 1999, she was named Illinois Professor of the Year by the Carnegie Foundation. She holds a Ph.D. in English from Ball State University.