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Utilizing a Capstone Project as a Catalyst for Reengineering, Recruitment, and Retention

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. With the support of a National Science Foundation grant, the project is the catalyst for embedding continuous quality improvement (CQI) and reengineering throughout the students’ four-semester programs and is a recruiting and retention tool.

Engineering and electronics students are brought into the CQI loop in their first semester course. Over the course of three semesters, the students design products, build prototypes, recommend improvements, redesign the products, and build new prototypes. In the fourth semester, the students participate in the capstone project, entitled Making Industry Meaningful In College (MIMIC), which teams engineering design and electronics students with students in business into “companies” to produce and sell the products. The classes that incorporate MIMIC are scheduled at a common time for the “companies” to meet and to receive training in such areas as group dynamics.

The hands-on, learning-centered nature of the MIMIC project is utilized in recruiting. High school students are brought to campus to participate in project-related activities and experience the technology available to the college teams, for example, rapid prototyping. High school instructors identify students/graduates as potential leadership track students. Those students are encouraged to enroll in a college strategies course, free of charge, and then are paid to offer peer support to other technical students.

Freshmen in engineering and electronics for whom English is a second language are being assessed on language skills required for them to succeed in their technical programs. ESL students who need help will receive assistance through the Academic Enrichment Center and peer support through the leadership track.

The innovative MIMIC project not only serves as an effective recruiting and retention tool, it allows students to implement and sharpen their technical skills and to improve their teamwork, critical thinking and communication skills in a simulated industrial setting. It is a cost-effective, replicable 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, since it creates a simulated industrial environment. 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 more closely replicates the industry process in which the engineers who design a product will not stay with that product throughout the entire process but instead pass their designs on to others who prototype, model and reengineer.

The project today

Today, Making Industry Meaningful In College is used as a catalyst to embed CQI methodology throughout the two-year engineering design and electronics curricula. 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.

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 begin by breaking down and analyzing products built by student teams in previous semesters
and making recommendations for improvement on those products. In their second and third semester courses, students continue to study CQI principles, and they continue to design, prototype, redesign and prototype products. In the third semester, the engineering design students also receive training in project management.

In semester four, engineering design, electronics and business students are assigned to multidisciplinary teams to manufacture, market and sell the products that have been reengineered in previous semesters. This capstone entrepreneurial component provides the student teams, called "companies," with a simulated industrial setting.

**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.

![The desktop water fountain, Figure 1 at left, is a student-designed product manufactured and sold a few years ago. The exterior of the fountain is constructed of plastic pots.](image1)

![The flashing drink holder, Figure 2, 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.](image2)

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.
**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 3 and 4 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.

The strobe light on the left (Figure 3) is the original product that was designed, produced and sold by a student team several years ago. The light on the right (Figure 4) is the reengineered product.

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.

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 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.
- Digital Microprocessor, a course which focuses on logic gates and design procedures, TTL circuits and CMOS technology
- 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. The student teams work with the manufacturing instructor and students, as needed, to produce their products. While it would be preferable to include manufacturing students in the MIMIC companies, enrollment and scheduling problems currently prevent the manufacturing students from participating fully in the project.

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 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 5, 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.

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 6) using a Dimension Rapid Prototyping machine (Figure 7). The teamwork in the MIMIC project exposes business students to that technology.

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 5 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.

Recruitment and Retention Efforts

The hands-on, learning-centered nature of the MIMIC project is being utilized in recruiting students to enroll in engineering design and electronics programs. This year, technical teachers and small groups of students from area high schools are being brought to campus to observe and participate in project-related activities. Next year, modules related to MIMIC and reengineering will be video streamed to area high schools.

To enhance recruitment and retention, a leadership track has been created for technical students. This year, engineering design and electronics instructors at IVCC have identified promising technical students and encouraged them to enroll in a college strategies course, free of charge. The students who successfully completed that course in the fall of 2005 are being paid a stipend in spring 2006 to provide peer support to other technical students. For next year, high school instructors will identify students or recent graduates as potential leadership track students. Prior to their admission at IVCC, those students will be contacted about participating in the leadership track.

Reading skills of the technical students are also being targeted in an effort to improve the students’ success in their courses. At IVCC, initial placement in writing and math courses is determined by scores on assessment tests required of all incoming freshmen. While most incoming freshmen also take a reading assessment test, no reading courses are required for completion of degree programs. Assessment scores that indicate weaknesses or serious deficiencies in reading result in a recommendation but not a requirement to take a developmental reading course.

Under auspices of the N.S.F. grant, the intention was to begin addressing reading skills by focusing on non-native speakers of English, especially Hispanic students who are a small but growing population at the college. In technical programs, ESL students face special challenges, not only with reading of complex technical materials, but also with the oral communications skills needed in teamwork situations. The ESL students needing help with reading would be referred to the appropriate support services on campus for immediate assistance. The college offers a full range of services through the Center for Academic
Enrichment including individual tutoring, and English as a Second Language instruction is offered in a multi-level format. Through the Center, the college has also offered conversational English instruction in a small group format. Peer support was also to be offered through the leadership track.

An initial problem in providing support or tracking technical students at a community college is identifying those students because of the large number of students who enroll part-time; therefore, enrollment in introductory courses becomes the most reliable method for identifying freshmen. Computer Aided Drafting I: Auto CAD was selected because the course is a required, introductory course for both engineering design and electronics students. In fall 2005, however, no students for whom English is a second language enrolled in CAD I. But, reading assessments on incoming freshmen who are native speakers of English did reveal reading problems. Based on a reading test administered before the start of the fall semester, more than half of the CAD I students who took the test should have enrolled in a developmental reading course. As Figure 8 reveals, less than one-fourth of those who were recommended into a reading course actually enrolled, and only half of those who enrolled successfully completed the course.

![Figure 8. Reading Test Results and Developmental Course Enrollments.](image)

<table>
<thead>
<tr>
<th>Students tested</th>
<th>Recommended into developmental reading course</th>
<th>Enrolled in recommended reading course</th>
<th>Successfully completed reading course</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number</td>
<td>Number</td>
<td>% of those tested</td>
<td>Number</td>
</tr>
<tr>
<td>32*</td>
<td>18</td>
<td>56%</td>
<td>4</td>
</tr>
</tbody>
</table>

*Reading assessment results were available on 32 students or 82 percent of the 39 engineering design and electronics students who enrolled in an introductory CAD course in fall 2005.*

The reading information collected thus far indicates a need for continued research:
1. All incoming technical students should be assessed for reading skills.
2. Reading levels of textbooks in technical courses should be determined and compared to the reading skill levels of technical students.
3. Technical students should be tracked to determine if a relationship exists between reading skill and/or successful completion of developmental reading courses and successful completion of technical courses and programs.

The lack of students for whom English is a second language this year also signals a need to focus more recruiting efforts on the growing population of Hispanic students in the college district.
**Evaluation and assessment of the project**

Since the one-semester MIMIC project just expanded to a four-semester reengineering program, a full assessment of the program will not be possible until the first group of freshmen have completed their technical programs. The recruitment and retention efforts, including high school outreach, creation of the leadership track, and reading assessments and assistance, are being evaluated through feedback from the students and by tracking student enrollments and completions. In the interim, an examination of the redesigned products (see strobe light in Figures 3 and 4) is a clear indication that product quality and viability has improved even in one semester.

Since its inception, the MIMIC project and student participants have been evaluated from a number of perspectives:

- Instructors have evaluated product proposals, designs, prototypes and products.
- Instructors have evaluated teamwork and communication skills.
- Instructors have evaluated marketing surveys, promotional plans and materials, accounting reports and financial plans.
- Consulting instructors have assisted in evaluations or oral reports, written reports, e-mail and memos.
- Potential buyers have evaluated products.
- Students have provided feedback on their teams, on the training provided by the consulting instructors and on the entrepreneurial project.
- Business and industry leaders have provided feedback on the program and graduates.

In exit interviews conducted at the end of the MIMIC project, students have routinely 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.”

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.”

This year, with reengineering becoming a focus, instructors are evaluating the product recommendations, redesigns and prototypes. An advisory committee of business and industry leaders has been formed for the entire project, providing a formal structure for feedback. Advisory committee members will participate in the evaluation of products as well as in evaluation of the entire program. In addition:

- Students in internships and graduates will provide feedback about the four-semester program. Feedback from leadership track students will be reviewed separately.
Enrollments will be reviewed to assess recruitment efforts.

Performance of leadership track and ESL students will be reviewed to assess retention efforts.

**Funding for the capstone MIMIC project**

The funding for the one-semester MIMIC project is minimal. 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.

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.

Since its inception, the MIMIC project has been sponsored by the college's Tech Prep team, and the funding has come from a mini-grant provided through Carl D. Perkins federal legislation. Product sales, from previous years, covered some additional expenses for supplies and end-of-project recognition for the students. A grant from the National Science Foundation is currently providing funds for some of the MIMIC project including product supplies, a stipend for the manufacturing instructor and some stipends to IVCC instructors for providing training in teamwork and other workplace skills. The N.S.F. grant is also currently providing funding for some of the recruitment and retention efforts, including the leadership track and some high school outreach. But MIMIC began and has been offered for ten years with a budget of $3,000 or less each year.

**Adaptability of the reengineering program and capstone MIMIC project**

Making Industry Meaningful In College is a capstone project 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. This year, IVCC phased the program in to provide reengineered products for the student companies; the design and reengineering components were completed in the first semester, and the entrepreneurial components were completed in the second semester. This experience illustrates that the program can be successful in two semesters.

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 MIMIC are offered at Lehigh University, Michigan Technological University and Rowan University. The Engineering Clinics at Rowan are offered in the sophomore year. The Integrated Product Development program at Lehigh and The Enterprise Program at MTU 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

Making 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 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. Because the capstone project is a hands-on, simulated world of work experience, it serves as a catalyst for recruitment and retention, including high school outreach efforts and development of a leadership track for promising students. Embedding reengineering throughout the technical programs results in 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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