The Case School of Engineering, in partnership with the Weatherhead School of Management, launched a new Master of Engineering and Management (MEM) degree program in 2001. This unique program combines the engineering and management disciplines. The program was developed in consultation with 28 major companies nationwide, including leading biomedical companies. In addition, representatives from University schools and departments including engineering, management, medicine, and the Health Systems Management Center participated in the design. The input from the companies indicated that industry needs engineers with not only a solid foundation in engineering but also additional knowledge and skills in management and business.

After extensive competitive benchmarking with many of the leading programs in the country that were joint business and engineering programs, we decided to take a different approach. Virtually all other programs take advantage of existing business and engineering courses and double count them in such a way that the student earns two degrees (an M.S. in engineering and an M.B.A. in business, for example) in less time in the joint program than would be required if the student completed the programs one at a time. This means engineering courses are taught by engineering faculty, and business courses by business faculty. **Thus, in these other programs, it is left up to the student to integrate the subject matter between the two degrees.**

**Our new approach was to design, develop, and deliver an integrated learning experience wherever the input from our corporate partners suggested that was preferable.** This meant that a faculty team consisting of one engineering professor and one business professor would work together to design an integrated learning component (course) for the program, as evidenced by the drafting of a syllabus. All of the faculty involved in developing the program would review and comment on this syllabus until it was formally approved by the team. Then the two faculty designers would actually develop the course. This included creation or selection of case studies and exercises, field trips, exams, presentations, reading material, etc. Finally, these same two faculty colleagues would deliver the course to the students enrolling in the program. We felt this design, development, and delivery continuity would benefit such an ambitious undertaking. In this approach, it is clearly up to the faculty to design an integrated learning experience for the students, rather than left up to the students to integrate the different courses from the various disciplines.
The faculty participants in this process have tended to adopt one of two models for the instructional delivery. In the first model, they do a lot of coordination in the design and development, but split up the delivery such that one of them may teach one or a series of classes as a part of the course, but without the other’s attendance and participation. In the second model, it is common for both faculty members to attend virtually every class. One of them is the class leader for the day, but the other actively participates in the discussion and delivery as well. Students have expressed a clear preference for the second model, but without being critical of the first. Finally, elements of the curriculum that are essentially 100% engineering or 100% business were designed by one professor from the appropriate discipline and are taught by that one professor, since an integrated learning experience was unnecessary.

The program accepted its first group of students in the summer of 2001, and offered only one track entitled Technology Entrepreneurship. It was open to all engineering disciplines, and 30 of the 42 credits required were of the integrated type described above. In 2002 we introduced a concentration in Biomedical Entrepreneurship within the MEM program. The educational objective of both the Biomedical Entrepreneurship and the Technology Entrepreneurship track is to provide engineers with the business and management context required to enable them to drive innovation within their companies while serving in a technical capacity. The biomedical track builds on the manufacturing orientation of the original Technology Entrepreneurship track. Since manufacturing is a key element of biomedical industries, the Biomedical Entrepreneurship track adds highly valuable skills to BME graduates.

The program includes courses in engineering and management, as well as an experience component (e.g., an internship). Students may enter the program as undergraduates with senior status, typically in the summer between the junior and senior years, and the program does not interfere with completing the undergraduate degree requirements. By making use of summers for both course work and internships, the degree is completed in one additional year beyond the BS, for a total of five years. Students complete a total of 42 credit hours for the program, with 12 being completed in a summer term, and 15 each in a fall and spring semester. Admission to the Biomedical Entrepreneurship concentration is limited to students who have or will complete an undergraduate degree in Biomedical Engineering, or whose training includes significant biomedical engineering content. This requirement ensures that the graduates will have true depth in biomedical engineering as well as the content of the MEM degree.

Five courses are specific to the Biomedical Entrepreneurship concentration: Engineering Statistics for the Biosciences, Models of Health Care Systems, Regulation in the Biosciences, and two graduate level technical biomedical engineering electives in an area of specialization. Areas of elective specialization include Biomaterials/Tissue Engineering; Neural Engineering/Neural Prostheses, and Biomedical Imaging/Sensing.

The remaining courses are the core courses for the MEM degree, but are equally important for the Biomedical Entrepreneurship concentration: Professional Development; Project Management; Accounting, Finance and Engineering Economics; Materials and Manufacturing Processes; Product and Process Design, Development and Delivery; Information Technology and Systems; Engineering Entrepreneurship; and Understanding People and Change in Organizations. Of the 42 credit hours required to complete the biomedical track, 27 are of the
integrated variety. Some courses, such as Materials and Manufacturing Processes, were modified to include biomedical content for all of the students in the MEM program.

The first students enrolled in the biomedical track of this program will graduate in May 2004, so we do not yet have final data on important outcomes such as placement (these should be available at the conference). However, the first set of graduates (who all completed the Technology Entrepreneurship track) provides a basis for feedback and assessment of the general concept of integrating business and engineering in this unique program. We have no reason to expect that the feedback from the biomedical track will differ sharply from the technology track. In addition, we have feedback from all the biomedical track components that have been completed by the first group of students in that track.

Our feedback process includes extensive course evaluations for every course and every instructor in the program. This process measures both the content as well as the student’s development in skills and abilities, such as communication and team building. The students in the program independently construct their own evaluation system and provide formal feedback on all academic and non-academic aspects of the program. An example of the non-academic aspects is career placement opportunities. Finally, we view market acceptance of our students as a critical measure of the success of our program. In the very difficult job market of 2003, we experienced a 90% placement rate, with the typical offer 15 to 20 per cent higher in salary than the student would have expected with only the B.S. degree. Five of the 27 graduates accepted leadership appointments with their respective companies, an unusually high rate.

In addition to the verbal summary presented above, we are able to share the data shown in Table 1. The first section of the table shows the course evaluations and instructor evaluations for the core courses for the program that are required for all students (Biomedical Entrepreneurship and Technology Entrepreneurship). These evaluations are for the most recent offerings of the courses during calendar year 2003. They are shown in the normal sequence in which they would be completed; 12 credit hours in the summer term (the first term in the program), followed by 15 credits in the fall (second) semester and 15 in the spring (last semester). Class sizes for these core courses ranged from 27 to 33 students. When the same course title is repeated between the fall and spring semester, it is because the course is a six credit, two semester sequence. To accomplish the learning objectives in these courses, it was determined that more time than a typical three credit course was required, but that the subject matter did not lend itself to six credits in one semester.

The evaluations are on a 5 point scale with 5 being the best rating and 1 being the worst. The ratings are generally acceptable, but there is clearly room for improvement. We have observed improvement when the same faculty team stays together and repeats the course two or three times. It is clearly a challenge to get this integrated learning experience delivered very well the first time, even when very well intentioned colleagues work very hard together to do so. Since the students in the program pay a high proportion of their own tuition, they are a demanding group. Several faculty members teaching in the program receive higher ratings when they are teaching courses in their own schools to their own students. To their credit, however, they have a lot of passion for this program, and most have stayed steadfastly with it.
The second portion of the table shows the evaluations for the uniquely biomedical components of the program. Two of the three required courses have been offered, with the last just starting as of this writing. The enrollments in these courses range from 8 to 22. While these courses were developed to support our program, other parts of the University became aware of them and asked that their students be allowed to take them, so they are serving the needs of multiple markets.

Finally, the last section of the table shares the placement results for all the biomedical engineers who have entered the program, even if they completed the technology entrepreneurship track with the first group of graduates.

In addition to the formal measures described above, we systematically gather feedback from our corporate partners in the program. Two samples include:

From Don Richards, Managing Partner of the Chemicals Industry Practice, Accenture:

“Consulting careers – similar to traditional engineering organizations – increasingly require broader business skills to be successful. The content of the MEM degree is exactly what the market is looking for; adding business and management disciplines to the heritage of outstanding technical and analytical education provided by engineering.”

In the short history of the degree program, Accenture has hired two full time consultants from the program, the second to start in May 2004.

From Helen Rapp, Manager of Engineering Support Operations for Lighting, General Electric Consumer Products:

“Our experience with Case MEM students has been outstanding. We have hired students into both intern and full-time roles. They bring a unique blend of technical excellence and business acumen that drives the types of changes we need to maintain our leadership position in the tough global market.”

In the short history of the program, GE has hired three interns and one permanent placement, the latter being an Edison Engineer in Home Electric Products, Inc.

Finally, we gather feedback from our alumni as well as to how well they think the program prepared them for their initial experiences in industry. Following are some examples of such feedback (remember that the graduates have been out only about six months).

From Jennifer Knauf, Sales Engineer at The Lincoln Electric Company:

“The MEM curriculum added business skills to my fundamental engineering knowledge. These added skills allowed me to secure a position in a company interested not only in my technical skill set, but also my ability to save them money through the methods and techniques I learned in the program. The MEM program has put me in a position to excel in the business-centered engineering field.”
Table 1: Numerical Summary

Core Courses in the Biomedical Entrepreneurship Program

<table>
<thead>
<tr>
<th>Semester</th>
<th>Number</th>
<th>Credits</th>
<th>Title</th>
<th>Course Evaluation(s)</th>
<th>Instructor Evaluation(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Summer (1)</td>
<td>IIME 400</td>
<td>3</td>
<td>Professional Development</td>
<td>3.8</td>
<td>3.8</td>
</tr>
<tr>
<td>Summer (1)</td>
<td>IIME 405</td>
<td>3</td>
<td>Project Management</td>
<td>3.8, 4.1</td>
<td>4.0, 4.4</td>
</tr>
<tr>
<td>Summer (1)</td>
<td>IIME 410</td>
<td>3</td>
<td>Accounting, Finance and Engineering Economics*</td>
<td>2.4, 4.5</td>
<td>2.2, 4.8</td>
</tr>
<tr>
<td>Summer (1)</td>
<td>IIME 415</td>
<td>3</td>
<td>Materials and Manufacturing Processes*</td>
<td>4.1, 3.9</td>
<td>4.5, 3.4</td>
</tr>
<tr>
<td>Fall (2)</td>
<td>IIME 420</td>
<td>3</td>
<td>Information Technology and Systems</td>
<td>2.9</td>
<td>3</td>
</tr>
<tr>
<td>Fall (2)</td>
<td>IIME 430A</td>
<td>3</td>
<td>Product and Process Design, Development, Delivery</td>
<td>4.1</td>
<td>4.1</td>
</tr>
<tr>
<td>Fall (2)</td>
<td>IIME 450A</td>
<td>3</td>
<td>Engineering Entrepreneurship*</td>
<td>3.8, 3.5</td>
<td>3.9, 3.5</td>
</tr>
<tr>
<td>Spring (3)</td>
<td>IIME 425</td>
<td>3</td>
<td>Understanding People and Change in Organizations**</td>
<td>4.6</td>
<td>4.8</td>
</tr>
<tr>
<td>Spring (3)</td>
<td>IIME 430B</td>
<td>3</td>
<td>Product and Process Design, Development, Delivery**</td>
<td>3.6</td>
<td>3.7</td>
</tr>
<tr>
<td>Spring (3)</td>
<td>IIME 450B</td>
<td>3</td>
<td>Engineering Entrepreneurship**</td>
<td>3.9</td>
<td>4.5</td>
</tr>
</tbody>
</table>

Required Courses for the Biomedical Entrepreneurship Track

<table>
<thead>
<tr>
<th>Semester</th>
<th>Number</th>
<th>Credits</th>
<th>Title</th>
<th>Course Evaluation(s)</th>
<th>Instructor Evaluation(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fall (2)</td>
<td>IIME 445</td>
<td>3</td>
<td>Engineering Statistics for the Biosciences*</td>
<td>4.3</td>
<td>4.7</td>
</tr>
<tr>
<td>Spring (3)</td>
<td>IIME 446</td>
<td>1.5</td>
<td>Models of Health Care Systems*</td>
<td>3.7</td>
<td>4.7</td>
</tr>
<tr>
<td>Spring (3)</td>
<td>IIME 447</td>
<td>1.5</td>
<td>Regulatory Affairs for the Biosciences***</td>
<td>Not available</td>
<td>Not available</td>
</tr>
</tbody>
</table>

* New instructor
** First time offered
*** Has not yet been offered

Placement Information

Technology Entrepreneurship Graduates (4) with BME Degree (2003)

- Eaton Corporation Leadership Appointment (Non-BME Position; this graduate had double major in EE)
- Guidant Technologies
- Steris Corporation
- Moved to facilitate spouse's career; still seeking employment

Biomedical Entrepreneurship Graduates (6 Students; Expected May 2004)

- AMS Consulting (Not exclusively BME position)
- Other five students are still actively recruiting

From Fulter Hong, Edison Engineer, Home Electric Products, Inc., GE Consumer Products:

“The key to MEM is the impact of networking with industries, sharpening your communication skills and the guidance on career development from distinguished faculty and administration.”

From Anupam Sharma, Business Analyst, Accenture Securities:

“The business principles taught during the course of the MEM program have been invaluable resources in analyzing problems and delivering innovative solutions to clients.”

Finally, from Nepolina Chhetri, Implementation Engineer, Polyolefins R & D, The Dow Chemical Company:
“I have been in training to run a R & D pilot plant and I can already see these skills providing me a competitive advantage to exceed expectations.”

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