

## Collaborating with Industry to Improve the Role of Business in Engineering

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### Abstract

There are currently many pressures on the traditional four-year degree program and many educators and professional societies, including ASME, are starting to examine the viability of the four-year degree. In the US today many, if not most, new jobs are in small to medium businesses. The engineers in these companies must not only be technically proficient but they must also possess the business sense to ensure the company's success. In addition, growing outsourcing of routine engineering overseas makes it imperative that our graduates be able to develop, coordinate and lead projects globally. It is apparent that we cannot cover all of the topics that are needed in the traditional four-year undergraduate degree. A compromise that covers the fundamentals and some of the advanced topics and **integrates business concepts in the curriculum** appears to be the best approach for the undergraduate degree. In depth technical knowledge within a discipline (or disciplines) should be achieved at the graduate level.

Michigan Tech's Enterprise Program is intended to provide its students with the opportunity to develop knowledge and skills in their technical field of choice while exposing them to the business and societal issues faced by industry. Faculty mentors and industry partners share in this educational process by helping guide the students through this active learning experience. The Enterprise has been structured as a Minor at the University and consists of 20 semester hours. It consists of a minimum of 6 credits of project work, 2 credits of teaming/business problem solving, 2 credits of communications courses, 5 credits of business courses and 5 elective credits from a variety of technical and business topics. Students join an Enterprise at the beginning of their sophomore year and continue through their senior year. This curricula path is learner driven from the standpoint of the student's selection of the Enterprise's themes that range from topics such as "Watershed Assessment and Planning" to "Wireless Communications. Assessment results will be presented for the educational objectives and the learning outcomes, and comparisons will be made with the traditional educational paths.

### Background

Entrepreneurial education is gaining increased attention within the engineering education community in recent years resulting in the development of several new courses or options within existing programs. A large part of this focus on entrepreneurship is a recognition that most of the routine engineering is now, or will soon be, outsourced to countries such as India and China who are or will soon be graduating ten times the number of engineers as the US. In this climate, the relatively few US engineering graduates must learn to be more creative and innovative and must be able to operate in a business setting.

For example, at Brown University, students apply to participate in a two semester course sequence, typically in their senior year, designed to introduce them to entrepreneurship through solving real-world problems<sup>1</sup>. Interested students must undergo a rigorous selection procedure, including completion of a written application and a formal interview. Student teams in this program are comprised of engineering as well as non-engineering disciplines.

At Olin College, they have a vision of "Superb Engineering" that is founded on immersion in Arts, Humanities, Creativity, Innovation, Entrepreneurship, Philanthropy and Ethics<sup>2</sup>. With this vision, graduates are able to work naturally within both engineering and business environments. Beginning in their first year, Olin college students complete a course in Business Basics (accounting, ethics, quantitative analysis, finance, operations, economics, strategy, and organizational behavior). They complete a "mini- capstone" design project in their sophomore year, and are encouraged to obtain internships with local companies during the academic year as well as during the summer. They can then select the entrepreneurial path of their choosing to complete their degree requirements. However, it should be recognized that what works at Olin College in an entrepreneurial program may not work at a public university with a large engineering program such as MTU's.

Stanford University established the Stanford Technology Ventures Program (STVP) in 1995 within its School of Engineering<sup>3</sup>. The STVP has a goal of accelerating high-tech entrepreneurship

education through teaching, research, and outreach. The STVP teaches courses in entrepreneurship, supports graduate students conducting research into high-tech ventures, conducts an internship program, and administers a speaker series that brings 25 entrepreneurial leaders to campus each year. STVP also oversees a cross-campus entrepreneurship network among students and educators. In 2001, STVP received a grant from the Kauffman Center for Entrepreneurial Leadership to develop instructional resources to be delivered online.

In a study of the environmental conditions that lead to invention among engineers, researchers at the Wentworth Institute of Technology found that one of the key practices is to engage the students early in their careers<sup>4</sup>. Faculty from engineering and educational psychology teamed to study creativity and found that the standard structure of an engineering curriculum might actually be *driving creativity out* of our students. By the time they are seniors, most of our students have learned that their designs must comply to certain rigid standards, making it difficult for them to be creative and innovative. These researchers recommended that students begin their creative endeavors as early as their sophomore year and that working on interdisciplinary teams is a key factor to invention success.

Providing entrepreneurial skills to undergraduate college students will help them become tomorrow's employers and active contributors to the emerging knowledge economy. As noted in the National Academy of Engineering's "The Engineer of 2020," business and management skills will hold a more critical place in the engineer's role with the "growing interdependence between technology and the economic and social foundations of modern society". As such, there will be an "increasing number of opportunities for engineers to exercise their potential as leaders, not only in business, but also in the non-profit and government sectors"<sup>5</sup>.

One of the Hallmarks of 21st Century Engineering Education will be active, discovery-based learning that is driven by the customer for our educational products, the student. This educational approach has become a reality at Michigan Tech over the past several years through the implementation of the Enterprise program. The program was initiated with a successful proposal submitted by the Colleges of Engineering and Science & Arts and the School of Business and Economics in response to the National Science Foundation Action Agenda for Systemic Engineering Education Reform. The goal of the Enterprise program development was to create a new engineering curriculum which incorporates active learning and integrates the engineering education experience while addressing industry's need for engineers with strong technical, communication, interpersonal, and business skills.

### **The Michigan Tech Enterprise Program**

An April 2003 article in ASEE's Prism magazine<sup>6</sup>, noted that "Engineering students who graduate from Michigan Tech's Enterprise Program have a choice. They can take a job working for someone else or they can start their own companies." The Michigan Tech Enterprise Program ([www.enterprise.mtu.edu](http://www.enterprise.mtu.edu)) is an extensive multi-disciplinary, active, discovery-based learning environment that includes a multi-year design experience for engineering students. Within this option the university has established a number of engineering/business entities, called Enterprises, and students choose to join an enterprise "company" and work with other students and faculty to make it a successful venture. Each Enterprise, for the most part, operates much like a real company in the private sector. The employees (students) write business plans, solve real-world problems, perform testing and analyses, make recommendations, build prototypes, manufacture parts, stay within budgets, and manage multiple projects. The objectives of the Enterprise Program are to:

- create an environment which facilitates the transition from the undergraduate program to the professional work force,
- provide opportunities for students and faculty to develop leadership and entrepreneurial skills in a learning setting that closely resembles an industrial or professional environment,
- give the students ownership of a portion of their academic program that connects strongly to their career goals,
- develop the skills and desire for life-long learning,
- understand what makes an enterprise or business successful,
- give the students a taste of the rewards and accountability associated with creating new products and working with paying clients, and
- utilize the students' fundamental background in science and engineering in the context of solving a problem when non-technical issues, such as cost or societal impacts, are of equal importance.

The genesis of the Enterprise Program at MTU was a direct result of industrial assessment of engineering degree programs across the nation and our belief that all students should have the

opportunity to graduate with the confidence that they have the skills and abilities to start their own company. Survey after survey of university, college and departmental industrial advisory boards identified the same shortfalls in today's engineering education. Technical competence is seldom an issue with industry and it is typically considered a 'given' for ABET accredited engineering programs. However, several other personal and professional attributes are consistently identified as critical to the success of an engineer, but generally lacking in new engineering graduates including:

- strong skills in communication and persuasion
- ability to lead, persuade, and work effectively as a member of a team
- sound understanding of non-technical forces that affect engineering decisions
- ability to coordinate and lead projects globally
- demonstrated management skills and a strong business sense

Many of these skills and expertise are not easily taught within a traditional classroom setting. In fact most, if not all, of these abilities are best developed through practice. The engineering programs at MTU liberated some of the credits typically assigned technical/approved electives and created a new and different experience designed to educate and prepare graduating engineers for more productive and successful careers.

### **Enterprise Curricular Structure**

The Enterprise curriculum is two-pronged and consists of 1) participation in the operation of a business (project work) and 2) completion of concentrated course material (instructional modules) designed to provide key information, processes and skills required for effective management of a viable business. Ideally, students enroll in the Enterprise Program for 6 continuous semesters (excluding co-op absences). Of the 20 semester credits required of the Enterprise Minor, 6-7 credits result from working on real-world projects, i.e. operating the company. Each enterprise is required to address and complete at least one major project/product per year, although multiple projects are encouraged when appropriate and available. Consequently, each student participates in a minimum of three different projects during their tenure in the enterprise. Their tasks and responsibilities are many and varied, since over the three-year period they contribute to the projects in different ways due to changing levels of technical expertise, maturity, and seniority. The majority of projects address real-world engineering and business problems identified and sponsored by industry clients.

The remaining 13-14 credits in the Enterprise minor path stem from the student involvement in structured mini-courses or professional development modules, some of which are required and others elective. Each module is equivalent to 1 semester credit or 14 contact hours of instruction and is very concentrated in its subject matter, providing students with only the most critical information and instruction to enable them to employ their new-found knowledge directly in the operation of the enterprise. The philosophy behind this approach is that students will better master the subject matter through its immediate application and that further development and understanding of the material will come through both student interest and company (Enterprise) needs. In addition to required modules in Teaming and Communications, students can choose from a range of electives in various business and special engineering topics such as leadership, project management, finance, design for manufacturability and concurrent product/process development.

As an example of the project work conducted in an enterprise, the MTU Wireless Communication Enterprise (WCE) has a 6-year long relationship with Rockwell Collins, an aerospace company. One key project for WCE was based on Rockwell's need to take precise RF field strength measurements inside an aircraft fuselage. The WCE team scoped the project and created a robotic measurement system to collect thousands of data points per hour and display results in an original 3-D graphics package. The first year's prototype was used successfully by Rockwell in their plant during the summer. During the summer, some of the student team members (on their own time) responded to inquiries from Rockwell regarding bugs in the software package which were quickly resolved. Rockwell reported to WCE that NASA has also developed a strong interest in use of the system. The subsequent year's project was to design and construct an improved production level version of the system, which was also completed successfully. As an enterprise partner, Rockwell sees the value in the relationship and has hired many students out of WCE. Additionally, they specify projects that have an impact in their company and in the marketplace. Working on "real world" projects that matter is vital to the motivation of the students as they learn skills in preparation for professional life.

### **Program Details**

The Enterprise program is currently operated entirely on soft-dollar contributions from

industry, government agencies, and alumni gifts. The current annual budget for the program is over \$750,000, nearly entirely provided through industry sponsored projects and gifts. Industrial response to the program has been exceptional. Many of the companies who recruit our students are advertising specifically for students who have participated in Enterprise. Sponsorship of an Enterprise takes several forms including:

- designation of professionals within the company to serve as mentors who communicate with students about technical matters
- provision of materials relevant to the project
- visits to the campus for program planning and evaluation of student reports and presentations
- provision of testing and processing facilities not available on campus
- financial support of \$40K per year

Enrollment in the program has been growing steadily since its inception in 2000, as seen by the enrollment statistics shown in Table 1. Current enrollment figures for 2005-06 indicate more than 600 students in 24 different Enterprises and several undergraduate disciplines (within and outside of engineering). As Table 1 shows, the students are voting with their feet with significant growth of the program projected into the future as we attract an even larger group of students from outside engineering.

**Table 1 - Enterprise Enrollments**

	2000-01	2001-02	2002-03	2003-04	2004-05	2005-06
Sophomores	85	140	120	166	194	153
Juniors	60	85	122	139	204	233
Seniors	85	86	140	161	157	218
Total	230	311	382	466	555	604
# of Enterprises	11	15	17	18	22	24

It has been suggested that the success of the Enterprise Program may be due in part to only higher performing students self-selecting into the program. Analysis of a recent group of engineering graduates of the Enterprise Program, as compared to a group of engineering students who followed the more traditional path culminating in a senior capstone project, indicates otherwise, as shown in Table 2. Looking at the math and composite ACT scores and GPAs of a sample of 119 electrical, computer and biomedical engineering students who graduated in Spring/Summer 2005, the only moderately significant difference found was in first year GPA, where the students choosing enterprise actually had a *lower* GPA than students choosing the traditional path ( $p < 0.1$ ).

**Table 2 – Enterprise vs. Senior Design**

	Math ACT	Composite ACT	HS GPA	1 <sup>st</sup> Year GPA	Final GPA	# Terms to Graduation
Enterprise (n=31)	28.1	25.9	3.62	3.06	3.17	9.06
Senior Design (n=88)	27.8	26.1	3.67	3.21	3.20	9.20

It should be noted that in addition to the learning outcomes achieved by Enterprise students, we are also seeing improved retention rates for these students. For the Fall 2001 entering class of engineering students, 95% of those who started in Enterprise are still on campus compared to only 70% of those students who did not enroll in Enterprise. Clearly, involving students in their education improves their chance of success and commitment to their degree program, which may in part explain the improvement in final GPA over first year GPA for the enterprise students.

The technical emphases of the 24 enterprises presently in operation range from natural resource utilization to information technology and everything in between. Table 3 provides a sampling of our current enterprises, showing the wide diversity in business/technology focus. The majors of the students involved in the program include all available engineering majors as well as electrical engineering technology, mechanical engineering technology, computer science, business, biology, scientific and technical communication, psychology, math and physics; however, the current program is dominated by engineering students accounting for ~90% of the student enrollment.

**Table 3: Sampling of Current Enterprise Teams**

Team	Business Focus
AquaTerra Tech	Environmental consulting firm focusing on development of safe water resources in developing communities
IT Oxygen	Development of open source software for use in the non-profit sector
Integrated Microsystems	Development of wireless integrated microsystem technologies
Alternative Fuels Group	Development of alternative fuel technologies
Blue Marble Security	Development of security solutions for the home, community, industry, and international markets
Husky Game Development	Design and development of products for the video gaming industry
International Business Ventures	International collaboration in product conceptualization, business plan development and product commercialization
Entrepreneurial Enterprise	Market development service provider to enhance products and technologies for commercialization
STC/Arts Enterprise	Communication, design and media development services

As an example, the Blue Marble Security Enterprise (BMS) consists of approximately 70 student “employees” with a mission to provide a profit-oriented, student-led Enterprise that makes a significant positive impact in the world of personal and national security. Because of just-in-time learning, BMS students explore many subdisciplines before running into them in their coursework. A formal assessment plan is in place for the program; however, anecdotally our faculty report that Enterprise students ask many questions and generally are more engaged in course material that they have experienced already in product development activities when compared to their non-Enterprise counterparts. Most importantly, the students are using the learning model they will employ in professional life. Project teams in BMS typically consist of 4 to 10 people. Each team must compile a binder each semester that documents background research, sketches, designs, calculations, analysis, vendor quotes, and anything substantive associated with the team’s work that semester. An engineering notebook is maintained with pages dated and signed that relate to potential intellectual property.

The Enterprise program at Michigan Tech has started to take on a life of its own as student leaders form and shape their Enterprises, as the Enterprises contract and subcontract with other Enterprises, and as the Enterprise teams push well beyond their sponsor’s expectations and create new products and knowledge. Since the most significant future job growth is projected to be in small companies, our Enterprise program is preparing graduates for the future US economy now. The skills that Enterprise students gain through participation in the program are also attractive to large companies in terms of creativity, innovation and general business knowledge.

### **Program Feedback and Assessment**

We, and our industry partners, believe that the practices we have developed in Enterprise Program will serve as a national model for radically altering the complexion of engineering education into the coming century. The Dean of Engineering (Dr. Robert Warrington) has presented the Michigan Tech Enterprise program during more than fifteen invited talks to engineering schools across the country and has had numerous requests for follow-up visits to assist others in implementing programs similar to ours. For this proposal we have firm commitments from five other institutions wishing to adapt our program (see Supplementary Documents section of this proposal).

There are currently several different assessment methods being used to determine the level of success in achieving the desired business, teaming, communication and design outcomes. A guiding mindset used in the development of these tools has been the desire of the Enterprise Program to assess what students have learned through their experiences in the program, rather than what they have been taught. Key areas of assessment for the program are related to the effectiveness of the Enterprise Program in preparing students to design, problem-solve and communicate effectively in team-based environments. A brief description of each method, and a summary of results obtained to date, follows.

To assess the teaming aspect, we have developed a rubric to evaluate the effectiveness of enterprise students, as their project teams are video-taped while working together to solve the problems identified by their enterprise. Each team is taped twice during the semester, to gain a pre- and post- perspective on the Teaming module. A random sample of video tapes is viewed after each

offering of the Teaming module and the rubric is used to score overall team effectiveness. The post-assessment scores were generally higher than the pre-assessment scores with respect to teaming activities. It was noted that several undesirable traits present in the pre-assessment videos were not apparent in the post-assessment videos. In most of the pre-assessment videos, only one or two people participated and the others looked disengaged from the process, behaviors which were largely absent in the post-assessment videos.

Assessment of the communications aspect of the program is particularly challenging as it tends to be most qualitative in nature. Furthermore, there is an inherent difference between an academic environment and an industrial workplace in what is considered to be "effective" communication. In an initial attempt at assessing communication skills, students were asked to submit a memo summarizing their design experiences over the course of the academic year. A random sample of these memos was evaluated based on the following criteria: heading, introduction, body, tone, visual design, language level, and conclusion. Using a 4-point scale, with a resulting possible high score of 28, most memos were assessed in the 13-18 range, with a scattering falling above and below these scores ranging from 25 to a low of 7. In addition to this assessment method, other mechanisms are in place to assess various other forms of student communications including memos, reports and presentations. As a result of assessment, continuous improvements have been made to the structure and content of the communication course.

To assess the design and problem-solving ability of the students, Industry Partners of the Enterprise Program are asked each year to complete a rubric reflecting their assessment of the quality of the "products" the students designed. It should be noted that most industrial sponsors maintain a close working relationship with the student groups throughout the year, serving as clients as well as resources. Many sponsors travel to the university each spring to attend our Undergraduate Expo where Enterprise projects are featured and student presentations regarding their work are made. Feedback to date has generally been very positive. An excerpt from one letter from an industrial sponsor follows:

*"I was impressed with the student's progress in breaking down the overall program into components and then building up a leadership structure and teams to address each area. Also, I think it was important that the group realized that they will need to draw on other engineering majors to pull in individuals with all of the talents needed to succeed in this endeavor. This shows that the group understands the importance of a multi-disciplinary approach to solving complex engineering problems."*

Perhaps one of the best measures of the program's success is the extremely positive response from both industry and students alike. For example, Mr. Richard Anderson, ABET president and Principal Engineer of SOMAT, Inc., has been on the industrial advisory board for our PDCM Enterprise for the past several years. He has this to say about Enterprise:

*"It was truly amazing to us to see how the students responded to the challenges presented to them via the Enterprise Program. Shy, returning students with no concept of leadership were forced to accept responsibility, and because of this, they developed the concurrent leadership skills. Their communication skills also grew at an exponential rate. Participation in the Enterprise Program has really given these young engineers a step-up on their peers who have not participated in the Enterprise program. The skills and attitudes that are targeted by the Enterprise concept, such as leadership, communication, teamwork, and motivation for lifelong learning, have been successfully learned by the students, and now they are budding "superstars" for the contractors and engineering firms that have hired him."*

One former enterprise student leader, who is now attending graduate school at the University of Southern California, had this to say in a recent email to his former Enterprise advisor:

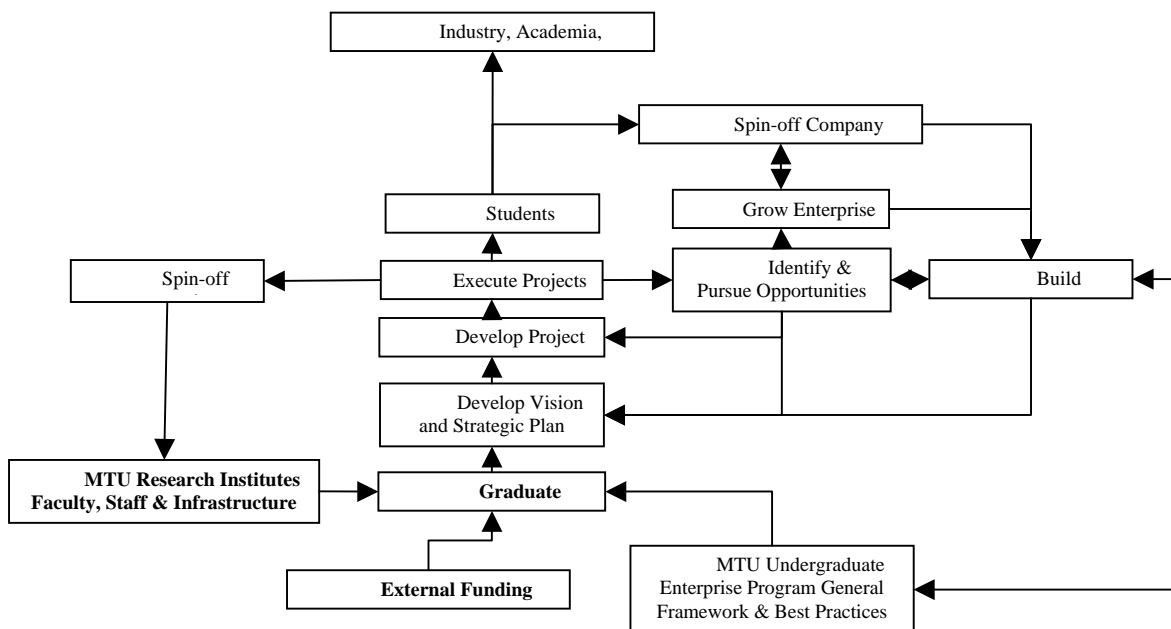
*"About Enterprise. I think joining the WCE was the best decision I made as an undergraduate. The scope of the enterprise is astonishing. As [a] result of enterprise my skills range from design engineering and project management to technical writing and documentation. I have interacted with many other incoming graduates from other universities and no university has any program that even closely resembles ours."*

In addition to the positive anecdotal feedback, data has been gathered regarding patent disclosures for enterprise students. It is noted that enterprise students make up roughly 10% of the undergraduate student body, but they account for 30% of the undergraduate patent disclosures. In all, there were nine patent disclosures filed for enterprise teams since its inception.

The program has been exceptionally successful in its educational goals as measured by feedback from students and the companies they have gone to work for. In this regard, the program has benefited the individual participants and the economy at large by preparing students to be economically productive immediately upon graduation. Enterprise students are now highly sought after by companies recruiting at MTU, where a student's participation on an enterprise team is viewed as equivalent, if not better than, a more traditional co-op experience. The program has been less successful, however, in generating actual student based startup companies or marketable student developed products. While the economy of the state has benefited from the increased productivity of these students as effective and well prepared employees, the next step for the program is to support the development of actual student led businesses and the commercialization of student developed products and technologies. One of the key areas for continuous improvement identified for the Enterprise Program through assessment and feedback is the need to substantially improve the resources available to our students in the area of technology commercialization support and education. Our students are successfully solving problems for their industry clients, and in the process developing some exciting new products and technologies of their own as indicated by the impressive patent disclosure activity. The next key area of growth for the program then is to help the students take that next step toward commercialization.

**Future Plans**

Based on the success of the Enterprise program at Michigan Tech, we are making plans for expansion into other arenas. For example, we have had requests from a number of external partners to help them develop their own entrepreneurial program based on the Enterprise. We recently submitted a proposal to the NSF, partnering with Universidad de Turabo in Puerto Rico, Montana State University, and Northeastern University, to help them develop a similar program on their campuses. Several advisors to Enterprises are also working with High Schools to bring the Enterprise experience to them. Finally, we are working on plans to develop a graduate Enterprise program. The graduate program would be structured much like our undergraduate program—students would take 1-credit modular courses on business or professional development topics (proposal-writing for example) and work in a multi-disciplinary team to conduct their research. PhD students will manage Masters-level students and will be guided by a faculty mentor. Figure 1 shows the structure of our envisioned graduate Enterprises.



**Figure 1: Graduate Enterprise Structure**

**Conclusions**

It is interesting that words such as innovation, business, entrepreneurial, and innovation do not readily appear in the new accreditation criteria developed by ABET over the past few years. It is, however, precisely these skills that will define the engineers that will lead their companies into the 21<sup>st</sup> Century. Not only are these skills desirable, they are necessary and they can be acquired without

compromising the technical skills of our graduates in engineering. As more “routine” engineering jobs are being outsourced from the US to India and China, and as they graduate more of their own engineers, it is imperative that the comparatively few engineers that the US graduates annually become the leaders in today’s technologically oriented world. We can do this by integrating communication and business topics throughout the curriculum and by giving our students the opportunity to be entrepreneurs early in their educational program and throughout their time on campus. The Michigan Tech Enterprise program is a model for curricular innovation that meets the needs of our engineering student for the changing global landscape.

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