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The Enterprise Program at Michigan Technological University*

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Entrepreneurial education has gained increased attention within the engineering education community in recent years resulting in the development of several new programs or options within existing programs. In response to this new national focus on entrepreneurial education and as part of the engineering curricular development at Michigan Technological University (MTU) associated with the calendar conversion from quarters to semesters, the university developed the Enterprise Program (www.enterprise.mtu.edu), a new and innovative experience that provides all students on campus, but especially engineering majors, an opportunity to start up and operate their own business. Within engineering programs the philosophy behind the Enterprise Program is to provide a flexible curricular structure that leads to a traditional engineering degree while at the same time enabling students to participate in the operation of a real enterprise over multiple years. Now in its fourth year of operation, the program has grown to nineteen different enterprises comprised of approximately 450 students from a variety of engineering, science, business, and communication disciplines. This paper presents an overview of the curricular structure of the program, a look at one of our established enterprises, the Wireless Communication Enterprise, and the results of assessment performed to date. Program feedback and successes and challenges associated with this innovative entrepreneurial curriculum will also be discussed.

INTRODUCTION

ENTREPRENEURIAL EDUCATION has gained increased attention within the engineering education community in recent years resulting in the development of several new programs or options within existing programs. At Brown University, students apply to participate in a two-semester course sequence, typically in their senior year, designed to introduce them to entrepreneurship though solving real-world problems [1]. 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.

Olin College has a vision of 'Superb Engineering' that is founded on immersion in Arts, Humanities, Creativity, Innovation, Entrepreneurship, Philanthropy and Ethics [2]. With this vision, graduates should be able to work naturally within both the engineering and business environments. Students at Olin College have three different entrepreneurship paths from which to choose:

1. Concentration in entrepreneurship as part of an engineering and applied science degree.
2. Entrepreneurship electives within the overall structure of a traditional engineering degree in one of the disciplines (e.g. Mechanical or Electrical).
3. Completion of standard Olin College entrepreneurship courses required of all graduates.

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.

Stanford University established the Stanford Technology Ventures Program (STVP) in 1995 within its School of Engineering [3]. 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 through their Educator's Course.

Case Western Reserve offers a Master's program in Physics Entrepreneurship that represents a partnership between the Department of Physics and the Weatherhead School of Management [4]. This graduate program features entrepreneurial coursework, a real-world internship, and a mingling of graduate students between engineering and business. The University of Texas-Austin has also developed courses in entrepreneurial education at both the undergraduate and the graduate levels

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through courses designed to foster cooperation across disciplinary boundaries [5]. UT-Austin faculty from engineering, business, natural sciences, and law have teamed up to develop courses in support of entrepreneurial education.

At the University of Missouri-Columbia, faculty from engineering and business have teamed up to develop a three-course sequence in entrepreneurship that are dual-listed between engineering and business [6]. The focus of the courses is the enterprise Conception, Design, and Operation. Students are recruited for these courses beginning in their sophomore year. Upon completion of the three-course sequence, students receive a certificate signed by both the Dean of Engineering and the Dean of Business.

ENTREPRENEURIAL EDUCATION AT MICHIGAN TECHNOLOGICAL UNIVERSITY

In response to this new national focus on entrepreneurial education and as part of the engineering curricular development at Michigan Technological University (MTU) associated with the calendar conversion from quarters to semesters, each engineering department was required to construct their new curricula within several college-prescribed boundary conditions. One of the constraints relevant to this paper was the required inclusion of a major design experience, preferably interdisciplinary in nature. As such, two options have been made available to all students. Within the 'traditiona'' path a year-long, six-semester credit senior design sequence is available in each engineering degree program. This common structure facilitates the formation of interdisciplinary teams when needed. The second option available to students, still leading to the same engineering degree, is referred to as the 'Enterprise' path and includes a greater emphasis on communications and business aspects of the engineering profession.

The Enterprise Program includes an extensive multi-year, multi-disciplinary design experience. Within this option the college/university establishes a number of engineering/business entities, called enterprises, and students choose to join the company and work with other students and faculty to make the enterprise a successful venture. Each enterprise, for the most part, operates much like a real company in the private sector. The employees (students) solve real-world problems, perform testing and analyses, make recommendations, build prototypes, manufacture parts, stay within budgets (real and imaginary), and manage multiple projects. The objectives of the Enterprise Program are to:

- create an environment for students to facilitate the transition from their undergraduate program to the professional workforce;
- 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 career goals;
- 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 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. Survey after survey of university, college and departmental industrial advisory boards identified the same shortfalls in today's engineering education [8–11]. 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. These attributes include:

- strong skills in communication and persuasion;
- ability to lead and work effectively as a member of a team;
- sound understanding of non-technical forces that affect engineering decisions;
- awareness of global markets and competition; and
- 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 in practice. The engineering programs at MTU took a 'giant leap of faith' and 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. This paper describes the curricular structure of the Enterprise Program and our experience thus far, now in the third year of operation.

Although the success of the program will not be completely determined for several years, the initial response from students and industry has been very enthusiastic. Eleven enterprises were started for the 2000–1 AY. Over 200 students were involved from 19 disciplines representing two colleges and two schools at MTU. Now in its fourth year of operation (AY2003–4) there are 19 established enterprises with over 450 students enrolled.

THE ENTERPRISE CURRICULAR STRUCTURE

Although the Enterprise Program by design is multidisciplinary in nature, the curricular structure was originally developed within the framework of the engineering degree programs. Consequently, participation by students in non-engineering programs has been less than optimal. The low participation by non-engineering majors in this unique experience is likely due to the fact that curricular requirements in the Enterprise Program had not been clearly articulated for majors outside engineering. In order to remedy this situation, a generic 'minor' was established to build off the original Enterprise curricular framework. In addition to the minor, which is open to all Michigan Tech students, engineering students can participate in the program by completing a 12-credit concentration within their discipline. These 12 credits replace existing courses in the program and are not added onto degree requirements.

Recognizing that the Enterprise Program would not appeal to all students, it has been implemented as an optional program within the engineering curriculum at Michigan Tech. If a student chooses, s/he can complete the 'regular' degree requirements within his/her department, foregoing participation in the Enterprise altogether. Students are recruited primarily through a presentation in the spring semester of their first year. Faculty and staff associated with the Enterprise make a 15-minute presentation in each section of the first-year engineering courses describing the program in general and providing information about the individual enterprises from which to choose. Students are free to join any enterprise that is working on projects that are of interest to them. Most students who elect the Enterprise Program at the beginning of their sophomore year are committed to the program and participate until graduation. There are also options available for students to join an enterprise at the beginning of their junior or even senior year.

The Enterprise Curriculum is a three-year experience. The 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. The requirements for completion of the Enterprise minor are:

- Minimum of 2 credits in teaming instruction.
- Minimum of 6 and maximum of 7 credits in project work. Sophomore and junior project-work courses are 1-credit each semester; senior project courses are 2-credits each.
- Minimum of 2 credits on Technical Communication courses.
- Minimum of 5 credits in business-related courses. Topics for these courses include things like budgeting, engineering economics, entrepreneurship, and project management.
- Remaining credits from any of the previous lists as well as a choice from several technical electives. For example, an electrical engineering student might choose a 1-credit module on manufacturing processes so that s/he can work more effectively with mechanical engineers on the Enterprise team.

Ideally, students enroll in the Enterprise Program for six continuous semesters (excluding co-op absences). Of the 20 semester credits in the 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 on each of the projects 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 remaining 13–14 credits in the Enterprise minor path stem from the student's involvement in structured mini-courses or instructional modules, some of which are required and others elective. Each module is equivalent to one semester credit or 15 contact hours of instruction. Hence, these modules are very concentrated in their 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 needs.

EXPERIENCE IN THE FIRST THREE YEARS OF OPERATION

The 2003–4 academic year marks the fourth year of operation of the Enterprise Program, and the second year of the Enterprise minor offering. Student and industrial participation in the program during this start-up phase has been extremely enthusiastic. There are presently 19 enterprises on campus, involving over 450 students from 19 disciplines within the College of Engineering, College of Sciences and Arts, School of Business and Economics, and the School of Technology.

Industrial participation has also been more than gratifying. 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;

Table 1. Enterprise enrollment statistics

	2000–1	2001–2	2002–3	2003–4
Sophomores	85	140	120	166
Juniors	60	85	122	139
Seniors	85	86	140	161
Total	230	311	382	466
# of Enterprises	11	15	17	18

- 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; and
- financial support of $35K per year (at the partnership level).

Enrollment in the program has been growing. Table 1 includes enrollment statistics for Enterprise since its inception in 2000. Enrollment projections for 2004–5 are for 500 students in 21 enterprises.

The technical emphases of the nineteen enterprises presently in operation range from natural resource utilization to information technology and everything in between. Table 2 provides a list of the enterprises with a brief description of the business emphasis for each. The Enterprise Program is truly interdisciplinary: the majors of the students involved in the program are biomedical engineering, civil engineering, chemical engineering, environmental engineering, geological engineering, mechanical engineering, materials science and engineering, electrical engineering, computer engineering, mechanical engineering technology, electrical engineering technology, computer science, business, biology, and physics. In addition, we are adding new enterprises in global sustainability, entrepreneurship, nanotechnology, and international business in the fall of 2004.

The first three years of operation have been a tremendous learning experience for both students and faculty as they strive to understand the key elements of a new business start-up and establish the framework around which their business will be run—namely, a sound business plan, organizational structure, mission, goals and objectives and the business processes and procedures that will support a sustainable organization. To help give a flavor of the operational aspects of an enterprise, a more detailed description of one of our more successful enterprises is provided in the following.

Wireless communications enterprise

This enterprise consists of approximately 70 student 'employees'. The mission of this enterprise is to provide a profit-oriented, student-led enterprise that makes a significant positive impact in the world of wireless and optical communication. The WCE business model is to create cash flow through R&D contracts with industry, and use the profits for internal product development initiatives.

Because of just-in-time learning, our WCE students explore many subdisciplines before running into them in their coursework. 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

Table 2. Current enterprise teams and majors

Enterprise	Business Focus
AquaTerra Tech	Groundwater evaluation for the Keweenaw Bay Indian Community
PrISM	Program in integrated sustainable manufacturing
Wireless Communication	Test bed for wireless communication, hardware, and software development
IT Oxygen	Information technology consultants
Consumer Products Manufacturing	Development & manufacturing of disposable consumer paper products
Pavement Design and Construction	Consultants for construction aspects of the road pavement industry
Integrated Microsystems	Design and development of wireless integrated microsystem technologies
Automotive Systems	Engineering consulting for the automotive industry
Robotic Systems	Design and development of robotic manufacturing solutions
Planning & Development	Consulting engineering firm focused on the improvement of campus and community
Aerospace	Design and development of aeronautical/space craft
Alternative Fuels	Development of alternative fuel technologies
Future Truck	Hybrid Electric Sports Utility Vehicle for national design competition
Formula Car SAE	Indy-style race car for national design competition
Mini-Baja SAE	Mini-baja car for national design competition
Clean Snowmobile	Noise and emission reduction for national design competition
Innovative Castings	Products and services through quality research and engineering in the areas of Die Casting, Investment Castings, and Continuous Casting
Blue Marble Security	Development of security solutions for the home, community, industry, and international markets

learning model they will employ in professional life.

Project teams in WCE typically consist of 4 to 10 people. A key position on each team is Documentation Chief. This person coordinates the documentation efforts of each team—while taking pains to avoid doing all the work himself, given that he also has substantial engineering responsibilities. Each team must compile a binder every 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. A final report each semester summarizes the work, including contributions to intellectual property or recommended profit-sharing—by name. The semester's documentation then serves as the basis for each team's grade, which is determined by the faculty adviser. The adviser's philosophy is 'if it isn't documented, it didn't happen, and it doesn't exist.' Our current WCE students have experienced the value of good documentation from projects completed in previous years. Also, they have noticed that no information survives from a previous project except what is found in the team binder.

WCE's first Engineering Services contract originated when some students discovered that MTU was about to solicit bids from engineering firms to establish a digital wireless link to a remote site. Our students formed a proposal team, won the contract, and performed the work successfully. The bid included engineering labor hours, which resulted in cash in the students' pockets. The work entailed considerable system engineering, testing of state-of-the-art hardware, installation, and checkout. The system is still operating well long after the project's completion.

During the 2002–2003 academic year WCE delivered on five R&D projects. For Rockwell Collins, a team designed and built a robotic 3-D measurement and data acquisition system to analyze multipath communication effects inside commercial aircraft. A second Rockwell Collins project team built a detailed simulation of a mobile satellite communications system. For IR Telemetrics, a team developed a new technique that will serve as the basis of the next generation of telemetry transponders to extract operational data from the inside of working automotive engines. For Keweenaw Research Center, a team developed a TV-based control system for the operator of the Streamsweeper, a small barge designed to suction sand from stream beds that have deteriorated—in order to bring the streams back to life. In WCE's largest project this past year, under a grant provided by SBC Ameritech, a team developed a new workshop for MTU's Summer Youth Program to bring high-school students and teachers to campus for an intense short course in wireless and photonics technology.

ASSESSMENT

Assessment of the educational outcomes associated with the Enterprise Program is also underway. There are currently several different assessment methods being used to determine the level of success in achieving the desired business, teaming and communication 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. A brief description of each method, as well as a summary of results obtained to date, follows.

Business component

To assess the business component of the program, a test instrument designed to measure knowledge and awareness of economic and management aspects of engineering projects was developed by the School of Business and Economics. To date, this has been administered in both a pre-test and post-test fashion. For a pre-assessment, the instrument was administered to a random sampling of first-year students prior to selection of the Enterprise curricular option. For post-test assessment, the instrument has been administered to a sample of fourth-year (senior level) Enterprise students. Use of this instrument is intended to measure gains in awareness and interest in economic/management issues in the business world. A summary of the resulting average test scores and their standard deviations are shown for each data set in Table 3.

Statistical analysis was performed on the test results. For this analysis, the difference in means between the pre- and post-tests was statistically significant ($p < 0.0005$).

Teaming component

To assess the effectiveness of the Enterprise Program in preparing students to problem-solve effectively in team-based environments, we have developed a rubric to evaluate the team effectiveness of Enterprise students, as their teams are video-taped while working together to solve 'real-world' engineering problems. A random sample of video tapes was viewed by the Associate Dean of Engineering at Michigan Tech and the rubric was used to score overall team effectiveness. The items on the rubric were:

1. The team had a clear task/purpose.
2. Meetings were well organized, efficient, and

Table 3. Pre- and post-test results for business instrument

Type	Sample Size	Class	Average Score	SD
Post-Test	42	Senior	44.05	14.32
Pre-Test	133	Freshman	31.11	16.89

effective (an agenda was utilized and objectives were accomplished).
3. Communication was specific, descriptive, and problem oriented.
4. Team members listened to each other.
5. Everyone was involved—no one dominated or was completely passive.
6. Team members worked interdependently.
7. Team members challenged each other, respectfully (avoided groupthink).
8. There was evidence of both task and relationship roles and an absence of blocking roles.
9. Conflict was appropriately managed using collaboration and compromise rather than avoidance and/or dominance.
10. Team members appeared to trust each other and enjoy working as a team.

The evaluator viewed several videotapes and assessed team performance on each item using a 4-point scale, with 1 = Low and 4 = High. All of the students in the videotapes were enrolled in a teaming curricular module within the Enterprise Program. Some sessions were taped at the beginning of the semester—i.e. before they had learned about successful teaming strategies—and some were taped at the end of the semester. Table 4 includes average scores for the videotaped meetings of the Enterprise student teams.

As can be seen from the data presented in Table 4, the post-assessment scores were generally higher than the pre-assessment scores with respect to teaming activities. It was noted that several undesirable traits were present in the pre-assessment videos that were not apparent in the post-assessment videos. For example, in one pre-assessment video, one team member played video games during the meeting. In another, a team member was working in the machine shop manufacturing a part while the rest of the team met. In most of the pre-assessment videos, only one or two people participated and the others looked disengaged from the process. These behaviors were largely absent in the post-assessment videos.

Communications component

Assessment in this area is particularly challenging, as it tends to be most qualitative in nature. Furthermore, there is an inherent difference in what is considered to be 'effective' communication between an academic environment and an industrial workplace. In an initial attempt at assessing communication skills, students were asked to submit a memo summarizing their design experiences over the course of the 2002–3 AY. A random sample of these memos were evaluated based on the following criteria:

1. heading;
2. introduction;
3. body;
4. tone;
5. visual design;
6. language level; and
7. 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. The highest score assigned was 25, the lowest was 7. Several problems in this assessment procedure were identified and will be corrected in the future.

Design component

Industrial sponsors of the Enterprise Program were asked to write a memo regarding their assessment of the quality of the 'products' the students designed and whether or not the objectives of the Professional Component (criterion 4) of ABET accreditation criteria are met [12]. Not all of the industrial sponsors have responded at this point in time; however, initial feedback has been positive. An excerpt from one letter from an industrial sponsor follows:

> I was also impressed with the students' 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

Table 4. Teaming assessment scores

Rubric Item	Mean Pre-Assessment (n = 8)	Mean Post-Assessment (n = 5)
The team had a clear task/purpose.	2.31	3.30
Meetings were well organized, efficient, and effective (and agenda was utilized and objectives were accomplished).	1.94	3.00
Communication was specific, descriptive, and problem oriented.	2.31	3.40
Team members listened to each other.	2.44	3.50
Everyone was involved: no one dominated or was completely passive.	1.50	3.10
Team members worked interdependently.	1.34	2.80
Team members challenged each other, respectfully (avoided groupthink).	1.81	2.60
There was evidence of both task and relationship roles and an absence of blocking roles.	1.81	2.90
Conflict was appropriately managed using collaboration and compromise rather than avoidance and/or dominance.	2.06	2.70
Team members appeared to trust each other and enjoy working as a team.	2.44	3.4
Average	2.00	3.07

> 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.
>
> The memos, reports and presentations exhibited strong communication skills on the part of the Working Group as a whole. The textual materials were well written and concise. The presentations and other printed materials were attractive and conveyed a great deal of information very effectively.
>
> All in all, I was impressed with the progress made over the past school year. The students laid an excellent foundation for the Group and I look forward to the accomplishments that are still to come.

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.

EVALUATION OF ASSESSMENT PROCESS AND RESULTS

Initial assessment results have resulted in several programmatic changes to date. The Communication Contexts instructional module was completely revised in the second year of the program to improve its focus on business communication. The development of the minor path was a direct result of feedback from students outside of engineering for participation.

Results of our assessment also indicate the need for a more comprehensive method of assessment. During the 2003–4 AY, the assessment methods will be modified to include:

- a pre- and post-survey to be administered to students completing the required Enterprise communications courses to assess their overall effectiveness in the area of team-based and individual communication practices typically seen in an industrial workplace setting; and
- samples of students' work taken over three points in time over the course of each communications module is being collected and assessed for changes in key aspects of document design such as tone, use of visual aids, and format.

Additional methods of assessing the overall program that are planned for the future include:

- a comparison of work completed by Enterprise students with that of traditional students using techniques such as interviewing and a review of portfolios developed by the students showing the progression of their work over the course of their educational experience;
- graduate surveys on the usefulness and applicability of skills developed through participation in the Enterprise Program;
- internship/co-ops with partnering companies and the associated on-the-job performance; and
- industry partner surveys.

PROGRAM FEEDBACK

Although we do not have statistical data, we have considerable anecdotal evidence that our Enterprise graduates enjoy an edge in interviewing for their first jobs. Employers rave about the experience of our students documented on their résumés, plus the real-world engineering stories conveyed during interviews. In fact, the MTU Engineering Enterprise Program was motivated in part by discussion with our industrial advisory boards, which encouraged us to bring more real-world experiences into the curriculum.

A few anecdotes will help to illustrate the effect of the enterprise experience. A recent graduate who held the WCE President's job was hired by an aerospace firm into a fast-track system engineering position, leapfrogging other entry level hires by several years, specifically because of his WCE experience. Another graduate who served as a Project Manager for a large product team within WCE was the lone hire by a defense firm that brought in 17 candidates to its plant, including two MS graduates from major universities.

It should be noted that enterprise students make up roughly 7% 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 the start of the program in 2000.

One former WCE leader, who is now attending graduate school at the University of Southern California, had this to say in a recent e-mail to his former Enterprise adviser:

> 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.

The current President of the WCE Enterprise is set to graduate in May 2004 and will spin-off his own company shortly after that, in large part due to his Enterprise experience. He has this to say about the program:

> When I signed up for the Enterprise Program, I had no idea what to expect. I was a sophomore undergraduate with limited exposure to coursework and no real expectations. During my second week I was assigned to a project team of six undergraduates working for an industry client, and it was the most eye-opening experience of my collegiate career. I had barely finished freshman chemistry and here I was working on something that was giving real engineers problems. It was a grueling, intense six months, but in the end the client was satisfied.

> I went on to a number of other projects during my three-and-a-half year run with the program, and each one showed me something the others had not. I learned that there's not a strong correlation between performance in the classroom and performance in the business world. In fact, at times I felt as if I was learning more technical concepts through the Enterprise than I was in my current classes.
>
> Every engineering college graduate takes basically the same courses. In an interview, my distinguishing characteristic is never my grade point average, it's always my Enterprise experience. Employers are pleasantly surprised to learn that not only have I just completed an engineering degree, but I was effectively working as an engineer for most of that time.

Another Enterprise student writes:

> In my nine semesters of CPM I have served on the Finance, Marketing, Production, and Public Relations Teams. Currently, I serve on the Executive Board as President. On the Finance Team, I learned how to manage the finances of a small company; while on the Marketing Team I interacted with consumers to determine their needs and preferences in a consumer product. As a member of the Production Team, I performed cash flow analysis and determined the operating expenses for a production process. As a member of the Public Relations Team, I interacted with the campus on behalf of CPM and helped recruit new members. Finally, as president, I am exposed to every aspect of the enterprise from helping new students register, to conflict resolution amongst teams, to budget concerns.
>
> The small company environment that CPM and the Enterprise Program promote helped me to succeed in my co-op terms at Kimberly-Clark Corporation and secure a full-time job with The Dow Chemical Company. While on co-op, I easily transitioned from the world of academia to the world of 'Corporate America' largely in part due to my Enterprise experience. My hiring manager at The Dow Chemical Company informed me that he extended a job offer because of my Enterprise experience.
>
> I am more proud of the education that I have received at Michigan Tech because of the skills that I developed as an Enterprise student. As graduation approaches I am confident that I will have a successful career and draw upon my Enterprise experiences for years to come.

Below is a quote from Patricia Galloway, who recently visited Michigan Tech. Ms. Galloway is the President of the American Society for Civil Engineers and CEO for the Neilsen-Wurster Group (as president-elect, during the 2002–3 academic year, she visited more than 200 universities that offer engineering degrees):

> Engineering today is about team work, communication and working with the public. Unfortunately, these skills are not taught in many of the engineering programs at our Universities. The Enterprise Program at MTU combines all these skills in the program and better prepares students for entering the professional workforce. It is one of the most impressive programs that I have seen in all my travels to Universities across the country.

Mr. Richard Anderson, president-elect of ABET 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, retiring 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. It was rather intimidating to the undergraduates to have to present an oral report on their team's progress to a group of successful contractors and engineers, knowing that we were going to critique them, and, at the same time were looking at them as potential summer and permanent employees.
>
> In the approximately five years that the PDCM Enterprise has been operating, many of the participants have graduated and moved on to full-time employment and/or graduate school. 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.

Another Enterprise supporter is Mr. Randy Hill, Vice-President of Product and Technology Development for Kimberly-Clark Corporation, who writes:

> Kimberly-Clark Corporation (K-C) worked with Michigan Tech to establish the Consumer Products Manufacturing (CPM) Enterprise in 2000. K-C has financially sponsored the CPM Enterprise, and K-C employees have been active as industrial contacts and mentors to provide students and faculty advisors with feedback, training, and assistance with their projects since the 2000–01 academic year. These projects have allowed students to gain hands-on experience in product research, manufacturing, and business with the guidance of experienced mentors. K-C originally got involved because we saw a strong need for this type of program to better prepare engineering students to contribute more broadly as part of multidisciplinary business teams. We have been very pleased with the results of the program and its evolution to the current point where it has become an integral part of the university's programming and is acting as a model for similar programs at other engineering institutions. Michigan Tech started with a truly innovative idea and has executed it with excellence.
>
> In summary, I believe that the Michigan Tech Enterprise is a leading program in preparing engineering students with leadership skills, attitudes, and valuable insights to enable rapid personal and professional excellence. I also believe that this program supports a critical U.S. Engineering educational need to prepare students to thrive in the fast paced, rapidly changing environment that is facing all U.S. industry. This environment involves collaborative global partnerships to develop and advance technology and manufacture products which will require not only technical skills but also strong communications,

multi-disciplinary, and business knowledge and leadership skills of the engineering employees of U.S. based firms.

PROBLEMS IN IMPLEMENTING THE ENTERPRISE PROGRAM

Although industry enthusiasm for the program has been strong and student interest has been high, there have been some problems in implementing the program. Several problems stemmed from our inclusion of vehicle competitions as part of the program. Previous to the Enterprise Program, vehicle teams were autonomous and were able to work unsupervised in shop areas. This led to some unsafe practices. With the development of Enterprise shop policies, some students, who were accustomed to complete autonomy in the shop, became disgruntled and vocally challenged the shop supervisor as well as other figures of authority in the program. The nature of the vehicle competitions has also caused some problems in implementing the program. We are currently assessing these four enterprises to determine if they fit well within the overall structure of the program.

Another problem that we encountered in implementing the Enterprise Program was in the determination of the curricular structure. We have tried several alternatives before settling on the current structure. It is probably too early to determine if this is the optimal structure, and we will likely need to make some changes in the future. We believe that the ability to choose from either a concentration or a minor will enable students to flexibly meet degree requirements. Engineering students at Michigan Tech now have several choices available to them in the completion of the professional component of their degree programs—an Enterprise minor, an Enterprise concentration, or a traditional senior design project. This flexibility forms the basis for a student-centered learning environment within our programs.

One other problem that we are currently working through is in the area of faculty incentive for participation. Faculty volunteer to advise an enterprise and are given release from one course per year to do so. Many advisers feel that they spend more time than this on Enterprise advising, but department chairs are reluctant to release them further from their teaching assignments. Faculty advisers also do not feel that Enterprise advising counts for much in terms of tenure/promotion criteria. We are currently working through these issues and have recently created overload pay incentives for faculty involvement in the program.

CONCLUSION

In summary, the Enterprise Program, entering its fourth year of operation, has become a signature program for Michigan Tech's College of Engineering. By working together in a business-like setting, teams of students from every part of campus are not only enhancing their technical skills through the application of engineering concepts and practices, but are also developing a working understanding of the issues surrounding start-up and operation of a business, including the social, environmental, and economical concerns. Working in this environment, they see the value of communication skills, teamwork, and life-log learning. With this program Michigan Tech is truly following its guiding principle that the success of our students is the measure of *our* success. In addition, true to our university mission we really are 'preparing students to create the future'.

Support from industry has been overwhelmingly positive with numerous private and government organizations seeking involvement in this innovative program, which they believe will enhance the quality of engineering education and produce engineering graduates who are able to be immediately productive upon entering the workforce.

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