The Enterprise Program at Michigan Technological University Results and Assessment To Date

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Abstract
In 2000, Michigan Technological University restructured its entire curricular offering in association with an academic calendar change from quarters to semesters. As part of this restructuring 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 third year of operation, the program has grown to seventeen enterprises comprised of approximately 400 students from 19 disciplines. This paper presents an overview of the curricular structure of the program (recently approved as a Minor) and the results of assessment performed to date. Successes and challenges associated with this innovative entrepreneurial curriculum will also be discussed.

I. Introduction

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 'traditional' path a year-long, 6-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

- provide opportunities for students and faculty to develop entrepreneurial and innovative engineering skills,
- provide students with a multi-disciplinary design experience that involves other baccalaureate programs, such as Business and the Basic Sciences,
- provide a framework for faculty to mentor students in a learning setting that closely resembles an industrial or professional environment,
- include learning activities that arise from the approaches used to solve real-world problems provided by industrial and/or professional sponsors,
- 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, and
- enable students to participate in activities that coincide with the stages of their professional development.

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 [1-3]. 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
- 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 2000-01 AY. Over 200 students were involved from 19 disciplines and representing two colleges and two schools at MTU. Now in its third year of operation (AY2002-03) there are 17 established enterprises with over 400 students enrolled. It is expected that

the program will eventually grow to approximately 20 enterprises involving approximately 500 students representing all majors on campus. This will now be more easily realized with the advent of the Enterprise Minor which allows all majors on campus to more readily participate in the program.

II. The Enterprise Curricular Structure

The background behind the development of the original Enterprise curricular structure was described in detail in a paper included in the 2001 ASEE Conference Proceedings. In the spring of 2002, MTU took the Enterprise Program a step further by establishing an 'Enterprise Minor,' which will formally recognize student completion of this unique and innovative educational experience and at the same time provide an incentive for non-engineering majors to participate in the Enterprise Program.

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. After completing the first year of the program it appears that a more efficient way to administer the participation of engineering students in the Enterprise Program is also through the use of the 'Minor' framework.

The Enterprise Curriculum is a 3-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 20 semester credits. Table I outlines the curriculum associated with the recently established Enterprise Minor.

Table I – Enterprise Minor Curricular Structure

Requirements	Course #	Course Name	Credits
Minimum 2 Credits	ENG2961	Teaming in the Enterprise *	2
	BA2700	Business Problem Solving	4
Minimum 6 Maximum 7 Credits	ENG1960	Enterprise Orientation	1
	ENG2950	Enterprise Project Work I	1
	ENG2960	Enterprise Project Work II	1
	ENG3950	Enterprise Project Work III	1
	ENG3960	Enterprise Project Work IV	1
	ENG4950	Enterprise Project Work V	2
	ENG4960	Enterprise Project Work VI	2
Minimum 2 Credits	ENG2962	Communication Contexts *	1
	ENG3962	Communication Strategies *	1
	ENG4952	Complex Communication Strategies *	1
	ENG4953	Writing About Engineering in a Societal Context *	1
	CM4310	Technical Communications for Chemical Engineers *	3
	HU3120	Scientific and Technical Communications *	3
Minimum 5 Credits	EC3400	Economic Decision Analysis	1-3
	EC3001	Principles of Economics *	3
	ENG3954 (or BA3800)	Enterprise Market Principles Principles of Marketing	
	ENG3961 (or BA4700) (or AF3001)	Enterprise Strategic Leadership * Strategic Leadership * USAF Leadership Studies I *	1 3 3
	ENG3963 (or BA3780)	Enterprise Entrepreneurship Entrepreneurship	1 3
	ENG3964 (or BA4610)	Enterprise Project Management Project Management	1 3
	ENG3971	Seven Habits of Highly Effective People	1
	ENG4951	Budgeting – Intrapreneurial Engineering	1
	ENG4954	Global Competition *	1
Remaining Credits needed to fulfill minor from any of the above or this list	ENG2963	Electronic Circuit Design and Fabrication	1
	ENG3955	Conceptual Design/Problem Solving	1
	ENG3956 (or CM4310)	Industrial Health and Safety Chemical Process Safety/Environment	1 3
	ENG3957	Product and Process Development I	1
	ENG3958 CE3331	Engineering Ethics Professional Practice	1 2
	ENG3965	Material Flow in an Industrial Society	1
	ENG3966	Design for Manufacturing	1
	ENG3967	Product and Process Development II	1
	ENG3968	Manufacturing Processes and Simulation	1
	ENG3969	Project Phases of Design and Implementation	1
	ENG4955	Concurrent Engineering and Project Data Management	1

(*) May be used to satisfy General Education Distribution Course Requirements if not required by major.
NOTE – Fulfillment of the minor requires a minimum of 6 credits at the 3000 level or higher which are not specifically required for a student's major, except as free electives.

Ideally, students enroll in the Enterprise Program for 6 continuous semesters (excluding co-op absences). Of the 20 semester credits, 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 credits in the Enterprise path result from the student involvement in structured mini-courses or instructional modules, some of which are required and others elective. Each module is equivalent to 1 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.

III. Experience in the First Three Years of Operation

The 2002-03 academic year marks the third year of operation of the Enterprise Program, and the first 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 17 Enterprises on campus, involving over 400 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
- provision of materials relevant to the project
- visits to the campus from program planning and evaluation of student reports and presentations
- provision of testing and processing facilities not available on campus
- $35K per year for a minimum of 3 years

To date all but four of the enterprises have full industrial support. We anticipate having 20 enterprises involving approximately 500 students in the steady state operation of the program.

The technical emphases of the seventeen enterprises presently in operation range from natural resource utilization to information technology and everything in between. Table II provides a list of the enterprises with a brief description of the business emphasis for each.

Table II – Current Enterprise Teams

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 national design competition
Clean Snowmobile	Noise and emission reduction national design competition
AquaTerra Tech	Ground water 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
Campus Planning & Development	Consulting engineering firm focused on the improvement of campus and community
Entrepreneurial Ventures	Concept-to-market of innovative products and technologies
Aerospace	Design and development of aeronautical/space craft
Alternative Fuels	Development of alternative fuel technologies

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 for the variety and types of projects being addressed by the various enterprises, more detailed descriptions are provided here for three successful enterprises:

Wireless Communications Enterprise – This enterprise consists of approximately 80 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. Projects within this enterprise are many and varied, but include such things as the design and build of a robotic measurement system to explore multi-path propagation effects inside commercial aircraft, development of an advanced telemetry system to extract data from the guts of operating automotive engines, and most recently, with a grant from SBC Ameritech, WCE students are working to develop a Summer Youth Workshop at MTU for a diverse set of high school students and teachers. The grant encompasses the development of curricula and kits for wireless and photonics technology.

Consumer Products Manufacturing – The mission of this enterprise is to help its students to develop the entrepreneurial, technical, and professional skills needed to conceive, develop, and market successful products in a company setting. Skills learned in the manufacturing of disposable consumer products will be readily applicable to other types of products and commodities. This enterprise has successfully designed, prototyped and market-tested a disposable bib product. Students are applying for patents on several of the unique features of their product.

Aerospace Enterprise – The mission of this team is to provide hands-on aerospace education and experience to Michigan Tech undergraduate students in a student led, self-sustaining enterprise that will provide real-world experiences to students in a company atmosphere. The ultimate objective of the Aerospace Enterprise is to design and launch an MTU student-built spacecraft. MTU's Aerospace Enterprise was selected as one of 10 university participants in NASA's University Nanosat 3 program. The ten selected universities will build a nano satellite and compete for the prize of launching it into orbit. Michigan Tech's Nanosat will be designed to measure variations in radio wave emissions that would show how much, if any, manmade radiation is seeping into the frequencies characteristic of soil moisture which will hopefully help us to better understand and predict the Earth's climate.

IV. Assessment

Assessment of the educational outcomes associated with the Enterprise Program is also under-way. 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 both a random sampling of first year students prior to selection of the Enterprise curricular option, and a random sampling of first year (sophomore level) enterprise students. For post-test assessment, the instrument has been administered to a sample of fourth year (senior level) students, both Enterprise and traditional. Use of this instrument is intended to measure differences in learning across the enterprise and traditional curricula, convergence or divergence in awareness and interest in economic/management issues in the two paths, and an indication as to whether students are self-selecting the enterprise path on the basis of interest in these issues. While test results have been tabulated for over 300 students to date, findings are at this point inconclusive. A summary of resulting average test scores and their standard deviations are shown for each data set in Table III.

Table III

Type	Sample Size	Class	Average Score	Std Dev
Post Test – Traditional	35	Senior	52.00	12.56
Post Test – Enterprise	42	Senior	44.05	14.32
Pre Test – Pre-Selection	133	Freshman	31.11	16.89
Pre Test – Enterprise	117	Sophomore	36.97	19.38

While the results clearly indicate an improvement in post-test scores over pre-test scores, the results between traditional and enterprise post-test students is not as we would have expected. Upon further analysis of the data, however, we've identified some potential problems with the data set that require further investigation. For example, it is apparent from the data set that the sampling of post-test students is not representative of the overall population of engineering students in that the traditional set consists predominantly of Electrical Engineering majors, whereas the enterprise set is predominantly Mechanical Engineering majors. This would indicate that there are potentially other variables that may be skewing the results. We are in the process of collecting additional post-test data from both traditional and enterprise students and plan to have those results available to share at the 2003 ASEE Conference.

Teaming Component – To assess the effectiveness of the Enterprise Program in preparing students to problem-solve effectively in team-based environments, we are in the process of developing a video-based assessment tool. A rubric is being developed which will facilitate the comparison of traditional and enterprise students, as their teams are video-taped while working together to solve "real-world" engineering problems. Video footage has been collected for samples of both enterprise and traditional student engineering teams. Upon completion of the rubric, assessment will be conducted.

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 attempt to deal with this challenge, a pre- and post-survey is being 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. In addition, 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. The initial round of communication assessment results will be available at the conclusion of the current spring semester.

Additional methods that are planned for the future include:

- A comparison of work completed by enterprise students to 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 Enterprise Program

- Internship/co-ops with partnering companies and the associated on-the-job performance
- Industry Partner surveys

V. Student Feedback

A key objective of the Enterprise Program is that of continuous improvement – to obtain feedback regarding the curriculum and operation of the program from students, faculty and industry partners alike, and to take steps to improve the program as a result of that feedback. A student survey instrument has been developed and administered to currently enrolled enterprise students. To date, completed surveys have been received from approximately 150 of the 400 students. Results are being tabulated and will be used to identify ways of enhancing the program – from scheduling of courses, instructional module content, machine shop resources, office and computing facilities and overall program administration.

VI. Summary

In summary, the Enterprise Program, in its third year of operation, is clearly showing promise of successful delivery of its educational objectives. By working together in a business-like setting, teams of students 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.

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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