AC 2008-1354: CREATING AN ENTREPRENEURIAL CULTURE IN AN ENGINEERING UNIVERSITY

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Creating an Entrepreneurial Culture in an Engineering University

Abstract

This paper describes the process followed at Michigan Technological University (MTU) over the past dozen years to develop an entrepreneurial culture, not only at the university but in the surrounding rural area as well. Michigan Tech offers programs primarily in the areas of engineering, the sciences, and business administration. The process of developing an entrepreneurial culture was gradual, and many obstacles had to be overcome, ranging from patent and licensing practices that discouraged innovation to faculty attitudes that were skeptical of "nontraditional" course content. Perhaps the greatest obstacle was a pervasive culture in the Upper Peninsula of Michigan that conditioned people to wait for somebody else to do something.

The process started with a course in creative problem solving for freshmen taught as an overload by volunteer faculty. Later, a grant from the National Collegiate Inventors and Innovators Alliance (NCIIA) made possible the development of a course for senior students that focused on developing products for commercialization. Subsequent grants from the National Science Foundation (NSF), NCIIA, the Michigan Entrepreneurship Education Network, and industrial firms and donors facilitated courses and programs related to entrepreneurship. The Michigan Tech Enterprise SmartZone was eventually established as an entrepreneurial incubator for technology-based businesses, with the first of these businesses "graduating" in the fall of 2007 to a freestanding business with its own facilities. Dozens of faculty members are investigating the prospects of commercializing technologies that they have developed, and students are becoming involved in the process. Michigan Tech now has one of the highest percentages of undergraduate students named on invention disclosures in the nation. Also, many local inventors are approaching the SmartZone and Michigan Tech for advice and assistance in starting and developing businesses.

1. Context: Historical Background and Location

Michigan Tech is an emerging research institution with over two-thirds of approximately 5,800 undergraduates majoring in science and engineering. It produces 40 to 50 engineering and science Ph.D.s per year from approximately 900 graduate students enrolled in MS and PhD programs. As shown in the map on the next page, it is located 420 miles north of Chicago in Michigan's Upper Peninsula near Lake Superior. Authorized in 1862 as a Morrill Act land grant university, it did not really get started until 1885 as the Michigan School of Mines, offering the "engineer of mines" degree. Its Board of Control consisted of executives from the various copper and iron mines in the region, which were at the time America's most important sources of these metals. The institution broadened during the twentieth century to offer degrees in most areas of engineering and eventually added programs in forestry, business administration, and more recently in a variety of non-technical fields. Directly influenced by local conditions today, "industrial archeology" is available as a course of study.

Geographic isolation contributes to the culture of the region, known as the Copper Country. About eighty percent of the land area in the Upper Peninsula is forest, and almost all of the

communities in the region are small. Michigan Tech and the SmartZone incubators are located in Houghton and Hancock. These sister cities with about 5,000 residents each face each other across the Portage Waterway and are connected with a unique lift bridge. The nearest larger city from the University is Green Bay, Wisconsin. It is roughly 260 miles from the Mackinac Bridge which connects the Upper Peninsula to Lower Michigan, and 550 miles from the metropolitan Detroit area where many of Michigan Tech's students come from. This geographic isolation contributed to a sense of intellectual isolation among the indigenous population from contemporary problems and opportunities which exist in the rest of the nation.

The geographic isolation also facilitated geographic monopoly. Most retail stores prior to the late 1970s faced little competition. This permitted an attitude by merchants—often third- or fourth-generation descendants of nineteenth century founders—that when you are "the only game in town" customers have to conform to your hours and prices. Customers would have to take time off from work in order to shop for clothes or furniture because stores were not open after 5 p.m. or on weekends. The culture of serving the customer was foreign to the area.

Another factor which affects the culture of the area is the role a monopolistic industry played there in social and political activities up through the 1960s. Starting in the 1840s, the copper firms dominated the region. They were paternalistic in good ways and bad ways, providing housing, clean drinking water, hospitals, infrastructure, and land for churches and recreational facilities, as well as demanding compliance with their rules. Immigrant laborers, recruited by the these firms, were reluctant to get out of line. Arrogant industry captains and violent antiunion measures conditioned the population to be passive and to wait for somebody else to do something—whatever the situation.

The land ownership structure was also a factor. The monopolistic mining companies owned almost all of the non-forest land, while a few paper firms such as Mead and International Paper owned most of the forest land in private hands. Into the 1980s, it was nearly impossible to buy land outside of the small towns for development. Even discount chain stores and fast food restaurants did not make an appearance until the late 1970s.

A final factor was out-migration. The copper mines in the region peaked during World War I and underwent a continuous decline until 1968 when the last copper mining firm, Calumet & Hecla, Inc., shut down its operations. The only other industry of any size in the region was logging, and this type of work was seasonal. The population of the region has slowly declined for almost a century, and over the same period, many of the educated and ambitious younger people left the area for job opportunities in America's industrial centers far away.[1] The remaining population, by default, was older and less ambitious.

For these reasons, the area was not characterized by much entrepreneurial activity. This is illustrated by an experience that one of the authors (Paul Nelson) had upon arriving at Michigan Tech as a faculty member in 1972. He loved to fish, and the surrounding area has outstanding lakes and rivers with almost every species of freshwater fish available in the nation from huge pike and walleye to lake trout, steelhead, and salmon. When he visited the local Chamber of Commerce office to inquire about where to rent a boat to go fishing, the staff replied that there were no boats to rent—in the entire region! Also, in spite of a rising student population in the 1960, the private sector did not construct modern apartment buildings until the 1970s, forcing the university to construct a 350-unit married student apartment complex.

2. Initial Focus on Entrepreneurship

After World War II, as enrollment grew with returning servicemen, a few faculty members at Michigan Technological University sensed that some engineers would benefit from an understanding of business and the marketplace. Michigan Tech had not yet established a business school, so the only courses in the engineering curriculum related even remotely to entrepreneurship were a course in economic principles and a course in engineering economy. Accordingly, in 1948 a Department of Engineering Administration was established and a B.S. in Engineering Administration degree was offered as a second undergraduate degree for persons obtaining engineering degrees. This fifth-year degree covered accounting, finance, marketing, management, and industrial relations, but its focus was on career responsibilities for engineers working in large firms, not on entrepreneurship.

The Department of Engineering Administration grew into a business school in the 1950s, but Michigan Tech did not offer a single course with the word "Entrepreneurship" in the title until the spring of 1973. However, the word was followed by a further descriptor: "BA481 Entrepreneurship: Managing the Small Business." The course, at that time, had little to do with development of novel business models, and nothing at all to do with technology-based businesses. It was not until the spring semester of 2001 that the School of Business and Economics offered a course in entrepreneurship that focused on technology ventures.

The process of developing an entrepreneurial culture at Michigan Tech began in 1993 when one of the authors arrived at the university as dean of engineering. The search committee that recruited the dean recognized that Michigan Tech needed a sharper focus on entrepreneurship and chose Edward Lumsdaine because of his prior work in creativity and entrepreneurship. Over the next few years—in a difficult climate—he started several initiatives.

Creative Problem Solving:
One of the first innovations of the new engineering dean was the development of a course open to all freshmen: "GN150 Creative Problem Solving." This 3-credit course on a quarter system was to be taught by volunteers from the faculty and staff. The dean held seminars to prepare people to teach the course. Each section of the course was designed for 25 students who were divided into teams of five students each based on an assessment of their thinking styles using the Herrmann Brain Dominance Instrument (HBDI)[2-5], with the goal of having a wide diversity of thinking preferences present in each team.[7] Students first learned how to function effectively in teams and how to overcome barriers to creative thinking. The teams then chose a product of interest that would have a price under $300, examined current offerings, and suggested several

possible "improvements." They surveyed a sample of students to determine if any of the "improvements" were valued. Patent searches helped the students to become familiar with intellectual property issues and to see what ideas were already protected. The Pugh method[6] was used to evaluate alternatives, and an abbreviated business plan was developed. Finally, in a general session with all of the teams, each team made a three-minute presentation on their improved product, complete with a pseudo-prototype, to a mock panel of venture capitalists.[8]

GN150 helped engineering students and others to understand that the purpose of their work would be to satisfy customers with innovative solutions to problems and that building a business around an innovation was something worth considering. Student course evaluations documented that students enjoyed the course and felt that it was worthwhile. It was quite different from the rigorous general education courses that occupy the first two-and-a-half years of an engineering curriculum. It helped students see how engineering fit in with business and how their technical courses were needed in order to develop superior solutions.

However, only two of several engineering departments made GN150 a required course. Some faculty members felt that the type of activity in the course was not "real engineering." Others felt threatened by the issues addressed in the course, perhaps because customer-focus and teamwork were unfamiliar to them. Even the Herrmann thinking styles assessment (with its terminology) was viewed with suspicion. When MTU switched to a semester system and common first year for all engineering students, the course was dropped. However, the foundation that was laid did not disappear—faculty who had volunteered to teach the creative problem solving course continued to support its objectives and later became involved in other programs.

Innovation Center:
With a $100,000 grant from General Electric, the new dean started an Innovation Center. During 1995, the Center supported a two-day engineering and technology faculty workshop, a creativity forum with keynote speaker Dr. Paul McCready (with participation from several universities and industry), as well as the creative problem solving classes and the associated HBDI thinking styles assessment for the students and participating faculty. The Center's vision included an academic program option in innovation and student exchange with several historically black institutions. The Center also sponsored CIRT, a student-initiated creative industrial research team. Unfortunately, lack of support by the university's top administrators prevented the Center's growth and ultimately led to its discontinuance.

Course in Invention and Entrepreneuring:
A grant from the National Collegiate and Inventors and Innovators Alliance (NCIIA)[9] was awarded to the dean, and the authors began their cooperation in teaching entrepreneurship. They developed a course where students could work together with faculty and professionals on the development of an idea, product, or invention, or to solve a problem in a way that could lead to an enterprise that would generate jobs and other social benefits. Students were placed in multidisciplinary student/faculty ***E-teams*** that identified real-world problems and then solved those problems. Instruction was provided as needed for just-in-time learning in areas related to teamwork, creative problem solving, patent searches and procedures, entrepreneurship, design revision and evaluation, marketing, and cost analysis. The course was offered in the fall and spring quarters of the 1999/2000 academic year.

Initial enrollment in the course was low, and it was only permitted to be offered because of the NCIIA grant. The Mechanical Engineering course designation discouraged students from other engineering departments to enroll. Yet the course was very successful in demonstrating the concept of E-teams and invention to students and faculty, as shown below.

3. Growth of Entrepreneurship Initiatives

The last seven years have seen the start and growth of important activities in entrepreneurship at Michigan Tech, which reached out and began to involve the local communities.

The Enterprise Program:
In the fall of 2000, with start-up funding supplied by the National Science Foundation (NSF)[10] ($750,000) and industry ($766,000), Michigan Tech introduced a new engineering curriculum option intended to serve the needs of both students and industry. Called the Enterprise Program, the new curriculum gives a team of students from varied disciplines the opportunity to work for several years (sophomore through senior years) in a business-like setting to solve real-world engineering problems supplied by industry.[11]

Each enterprise was intended to have from 20 to 30 students, operate like a real company in the private sector and be run by the students. Each student would have specific responsibilities and seniors would mentor sophomores and juniors. Projects would be supplied and funded by industry. Today, 26 enterprises are operating, some with over a million dollars in funding. Engineering students receive senior design credit for participation.[12] Most enterprises include some students from non-engineering disciplines.

The Entrepreneurial Enterprise (advised by the authors) attempts to commercialize products and processes developed by students in the enterprise, as well as find other promising ideas on the shelf from completed senior design projects, faculty research projects, and other enterprises. The authors received a grant from NCIIA[13] in 2003 to further develop and operate this enterprise. This grant provided the recognition and visibility, both on campus and off, to enable Michigan Tech to compete favorably for additional funding from NSF. In order to broaden student exposure to entrepreneurship, one of the authors (Edward Lumsdaine) structured almost two dozen mechanical engineering senior design teams (using the thinking styles assessment) into E-teams, and both authors offered a non-credit evening course in entrepreneurship for the benefit of representatives from the teams for the 2006/07 academic year.

Center for Technological Innovation, Leadership, and Entrepreneurship (CenTILE):
CenTILE was established at Michigan Tech in 2001 through a joint initiative of the deans of the School of Business and Economics, the College of Engineering, and the College of Sciences and Arts in order to promote interdisciplinary education and research and develop cooperative initiatives across the campus aimed at technological innovation, leadership, and entrepreneurship. Funding was provided by endowments from a 1953 metallurgical engineering alumnus, Dr. Robert Carnahan, and the Gates Family Foundation.

In its first few years, CenTILE brought distinguished entrepreneurial speakers to campus such as Art Fry, the 3M inventor/developer of Post-It Notes™. It also sponsored the Entrepreneurs and Inventors Club, which was open to students—from Michigan Tech and neighboring Finlandia

University in Hancock—as well as faculty, staff, and people from the surrounding communities. The club helped people formulate and present their ideas for inventions and get feedback. It also offered workshops on writing business plans and applying for patents. One of the authors (Paul Nelson) served as Co-Director of CenTILE for many years and as faculty advisor to the club. In 2007, Robert Mark, a retired serial entrepreneur now on the business school's faculty, became the CenTILE Director and initiated a number of programs which build on earlier successes. During the Spring 2008 semester, CenTILE is sponsoring an "elevator pitch" competition with a $1000 first prize in order to promote entrepreneurial thinking among graduate and undergraduate students at both Michigan Tech and Finlandia University.

Michigan Tech Enterprise SmartZone:
The State of Michigan, through the Michigan Economic Development Corporation, planned to establish several SmartZones in 2000 to promote high-tech business and technology transfer. The cities of Houghton and Hancock, together with Michigan Tech and Finlandia University, created the Michigan Tech Enterprise Corporation (MTEC) in 2001 which applied for and received the SmartZone designation. With an initial grant from the State, the SmartZone became a high-tech business incubator, eventually operating three facilities in which to nurture new high-tech businesses. The newest facility, the Advanced Technology Development Center (ATDC), was constructed with federal and industrial funds[14] in 2004.

The MTEC SmartZone has had much success in helping new high-tech businesses develop and grow. In 2005, ThermoAnalytics, an employee-owned firm which is a leading developer of thermal, fluid-flow and infrared modeling software, was named SmartZone Company of the Year by Michigan Governor Jennifer Grandholm. In 2007, the SmartZone's first tenant, GS Engineering (a 38-employee defense contractor company that performs concept modeling and prototyping, instrumented vehicle testing, and dynamic simulation of performance problems in military vehicles) graduated to a new building of its own—the first SmartZone incubator tenant to become a freestanding local high-tech business.

The MTEC SmartZone is closely linked with Michigan Tech in facilities, personnel, and students. It has an office in the business school and Michigan Tech students, faculty, and staff aid in helping nurture new businesses. Recently, the authors' Technopreneurship Enterprise is considering merging with the SmartZone SmartTrac program, a 10-week summer program for juniors and seniors who work, for salary, on new business feasibility, prototyping and commercialization projects. The combined program would offer academic credit, possibly including senior design credit[12], along with salary over the entire calendar year.

Graduate Courses in Entrepreneurship:
In 2003, the authors received a grant through the Michigan Entrepreneurial Education Network from the Michigan Economic Development Corporation to develop three graduate courses in Entrepreneurship. The courses would be open to students from all fields. Three courses were developed:

- Entrepreneurship I: Launching New Ventures
- Entrepreneurship II: Growing and Managing New Ventures
- Technopreneurship: Entrepreneurial Creativity and Problem Solving.

The first two courses were offered through the Business School during the 2004-2005 academic year as undergraduate/graduate courses because the graduate enrollment at that time in business was not large enough to support the courses. The Technopreneurship course was offered through the Mechanical Engineering-Engineering Mechanics Department. Unfortunately, a number of issues thwarted the initial success of the courses, in addition to enrollment problems. The first involved the issue of entrepreneurship as an identifiable field within the School of Business and Economics. Some faculty thought that while a single course in entrepreneurship would provide value for those who had an interest in starting a business, a graduate student in business administration certainly should not choose such an eclectic area as a field of concentration rather than an established field such as accounting, finance, marketing, or operations management. Other faculty felt that graduate courses in business should not be open to students who did not have substantial prior coursework in business administration. A final issue was a transformation of the business graduate program from a Master of Science program, which required the student to select a concentration, to the more conventional MBA program, which did not have designated concentrations.

A single graduate course in entrepreneurship survived and is currently being offered to graduate students from all fields. One beneficial outcome of the effort to develop and publicize coursework in the area of entrepreneurship is that most of the students in this course are in graduate programs in engineering, suggesting that engineering graduate program advisors, who must approve student degree schedules, are now beginning to value entrepreneurship.

4. Creating an Entrepreneurial Culture in a Rural Setting

The authors, along with David Reed, Michigan Tech Vice President of Research, and the CEO of the MTEC SmartZone, applied for and received a 3-year NSF Partnerships for Innovation Program grant[15] in March of 2006. The project's aims are to create a rural entrepreneurial culture that captures the economic and social benefits of innovation. A three-pronged initiative is building on the existing infrastructure and on current endeavors to foster economic development by state and local governments and by Michigan Technological University.

First, this project is offering an education component that adapts MTU's highly-regarded engineering Enterprise Program to a new Technopreneurial Enterprise in which science, engineering and business undergraduate students are working as teams with real-world entrepreneurs to conduct and integrate technology and marketing assessments with business plan development for proposed or emerging potentially high-growth entrepreneurial industries. Second, this project will strengthen the interconnectedness and support among the local entrepreneurial community through networking and mentorship programs that develop linkages with the Michigan Tech community of faculty and students. Third, this project is supporting activities in technology commercialization by improving access to university expertise, facilities, and equipment.

This project will be replicable across the U.S. in similar rural settings. Work on this project is about two-thirds complete. Results are beginning to be seen, but the most important consequences will have a long gestation period: individuals who are now students will one day be entrepreneurs in the community.

5. Results

Much has happened in the past fourteen years in the Copper Country. Courses in entrepreneurship are being offered, and hundreds of students from across disciplines in the Enterprise Program are becoming more and more involved in market assessment and commercialization. Businesses are being started, and local job opportunities for engineering graduates are expanding.

Intellectual Property Protection:
A restrictive Patent and Licensing Agreement for enterprise students, graduate students, and faculty and staff from the early 1990s has been replaced with an agreement that offers real incentives to inventors: Michigan Tech in short order choose either to claim rights to subject technology or to release it entirely to the inventor. If it claims the rights, it will finance the attempt to secure patent protection, and if the successful technology generates royalty income, Michigan Tech will recover its costs and then share the proceeds with the inventor(s). Michigan Technological University now has one of the highest percentages of undergraduate students named on invention disclosures in the nation (20 students in the last three years)[16]:

FY05: 50 disclosures, 18% had undergraduates on them
FY06: 41 disclosures, 10% had undergraduates on them
FY07: 44 disclosures, 16% had undergraduates on them

Many faculty members are investigating the prospects of commercializing technologies they have developed, and students are becoming involved, sometimes deeply involved, in the process.

Business Incubators:
Attracted by publicity from the SmartZone and Michigan Tech, dozens of local inventors are approaching the SmartZone and the University for advice and assistance in developing businesses. Michigan Tech's Enterprise Corporation SmartZone now has ten businesses located in its three facilities. It offers the following services to tenants in addition to cheap rent:

- Technology assessments
- Business feasibility studies and market analysis
- Assistance with writing business plans
- Entrepreneurial training
- Venture capital preparation and introductions
- Introductions to technology commercialization partners
- Small Business Innovation Research (SBIR) and Small Business Technology Transfer Program (SSTR) assistance
- Grant writing assistance
- Product development
- Assistance in recruiting technical and managerial personnel
- Business development mentoring

One of the businesses in the incubator is the International Business Ventures Enterprise with about twenty Michigan Tech students from all majors. At the moment, it has three projects:

1. *Infant Heart Monitor:* This is a continuance of a senior design project in biomedical engineering. An inexpensive device that can be used to monitor infant heart rate after birth is not readily available. This lack has lead to nonresponsive but living babies being treated as still births and dismissed without treatment. As this is a worldwide problem, a team of students with a diverse background in engineering and business is developing new ideas and techniques to measure the heart beat of infants. After many revisions of the design, a working circuit prototype has been developed and a packaging solution is expected to follow quickly. The device will be tested on members of the team and infants at the local medical care facility under doctor supervision before the final product is delivered to Ghana during the summer semester of 2008 for real-world implementation.

2. *IBV Ventilator:* Typically hospitals maintain sufficient numbers of ventilators to meet current health care demands. However, a rapid influx of patients in hospitals could easily result from disasters or pandemics. In the U.S. a need for ventilator stockpiles has been identified—more than 700,000 ventilators would be needed in case of a national flu epidemic, but only 105,000 are currently functioning in hospitals nationwide, with merely an additional 6000 stockpiled due to high cost. The IBV Enterprise is working on the development of a simple, reliable, pneumatically powered, low cost (<$1000) ventilator, with a working prototype expected by the end of 2008.

3. *Organic Fast-Food Takeout:* The goal of this project was to develop a proposal and business plan for a wholesome organic fast-food take-out restaurant for a major national firm (Whole Foods Markets). It has been on hold for a while but will start-up again after additional non-engineering students are recruited into the International Business Ventures Enterprise for this "marketing" project.

SmartTrac Program:
This program is designed to support a limited number of enterprise students in summer entrepreneurship internships to either work with local entrepreneurial companies or to develop market assessment and business plans to commercialize technologies that originated at Michigan Technological University and have been identified to have commercial potential by CenTILE and other regional economic development stakeholders. Applications are accepted from any of the over 600 students in the Michigan Tech Enterprise Program. SmartTrac interns will focus on market assessment and development of a business plan, thus providing undergraduate students at Michigan Tech with a real-world experience in entrepreneurship. However, the SmartZone SmartTrac program is not an enterprise in the Enterprise Program and does not offer college credit, but instead pays students salaries for summer work, and more recently, for work during the school year.

For example, a SmartTrac team consisting of five undergraduate students from engineering, business, and scientific and technical communication explored the possibility of developing a new product for hospitals. The team worked on completing technical and market feasibility studies, prototype development, and an initial business plan for commercializing a compressible hospital mattress system. The newly developed *CPR Mattress* has the capability to support CPR

for the patient without having to go through the usual time-consuming process of getting hard support under a standard foam mattress before CPR can begin, thus improving efficiency by over 40 percent. This initial time savings increases the likelihood of successful resuscitation and thus saving the lives of patients who need medical treatment as quickly as possible. The CPRM is intended to replace the foam mattresses currently used within a hospital's general ward and intensive care unit (ICU). This target market was identified through discussions with regional hospitals regarding areas that pose the greatest threat of cardiac arrest and present the best market opportunity for CPRM. The SmartTrac team has demonstrated the product to local and regional hospitals, as well as medical equipment manufacturers, including Stryker Medical.

Following these discussions, the team received very positive input that supported further commercial development. The team also learned that it would be virtually impossible to license this technology to an existing company until there was greater proof of effectiveness and acceptance in the marketplace. The SmartTrac students, with State and University support, decided that the most effective route to commercialization was to form a company that could pursue further prototype development, testing, and evaluation. The SmartTrac team is thus forming an LLC, tentatively to be called CPRM, Inc., and has recently received $23,000 in funding from the Michigan University Commercialization Initiative to support further prototype development and product evaluation.

As a result of this success, a second company is being formed, tentatively called Tech Initiatives LLC. It will provide a platform for further commercialization opportunities identified by future SmartTrac teams. While it is not expected that every SmartTrac team will pursue formation of a company, it was recognized by the project leaders that having a framework such as this in place would allow further commercialization activities to proceed more quickly and efficiently.

Creative Problem Solving in Engineering Capstone Design and Entrepreneurship:
In the years since the original GN150 Creative Problem Solving Course was first introduced at MTU, the model has been applied to engineering design and to entrepreneurship, resulting in textbooks.[17,18] Many senior capstone design projects are funded by industry. One company from outside the area sent two engineers to work with their sponsored team whose assignment for the first semester was to develop a process for innovation, including brainstorming a list of products or processes with commercial potential the company could develop to expand its product line beyond its traditional automotive supplier business. During the second semester—at the sponsor's request—the student team designed a weed sensor for outboard motors (one of the identified products). The company then sponsored two additional teams, one to work on the design of an electronic shift-by-wire system for aftermarket user installation, the other to design and prototype a detection/warning system that would prevent restrained occupants in vehicles (many of them small children) from dying when an unattended automobile overheats.

Another project sponsored by a small company in the region involves the design of a practical cover for transporting snowmobiles. Additional projects that have a potential for commercial development include a window-washing robot and an innovative illuminated Halloween bucket. All mechanical engineering seniors in the Enterprise Program are now required to learn the creative design process[19], and several teams have mentioned that knowing this process and tools will enhance the quality and effectiveness of their projects and thus their commercial potential.

The entrepreneurship book[19] (co-authored with a British business professor from the University of Nottingham and a mechanical engineering professor from Michigan Tech) had an interesting development history, in that it was first custom-published by a large national publisher (McGraw-Hill). But to bring the cost down substantially to make it affordable overseas, the authors decided to self-publish it by printing it in the area. However, because of the isolation, reliable shipping turned out to be a problem. Therefore, printing and shipping is now done by a Canadian print-on-demand publisher (Trafford). The largest customers are in the UK, South Africa, China, Korea, Singapore, and Slovenia. This business model has the advantage that the book can be constantly updated at little expense; thus it is easy to keep the contents current. Michigan Tech is now planning a six-week summer course to be held at the University of Nottingham's Institute for Enterprise and Innovation for engineering undergraduates, to give them a real-world experience in the global aspects of entrepreneurship.

Regional Employment Opportunities:
According to Phil Musser, Executive Director of the Keweenaw Economic Development Alliance, about forty engineering and technology positions in the area are being filled by recent Michigan Tech graduates, and the Alliance's website has additional postings in a very active job market.[20]

6. Conclusion

Changing the culture in an established educational institution is not easy, particularly when it is located in a surrounding culture that also has long-standing cultural barriers against change and innovation. It is a process that required buy-in, cooperation, and teamwork from many stakeholders. Also, at Michigan Technological University, real change and a more open mind toward innovation did not begin to happen until a new team of top administrators was in place.

Financial support by NCIIA, NSF, the State of Michigan, industry, and private donors was crucial to get the original process going and expanding, to where it shows signs of being sustainable or institutionalized even when the original champions will have retired. Another important factor was the foundation built when faculty members became familiar with creative problem solving and began looking for business opportunities.

Continuing the process is vitally important, if local and regional businesses (and Michigan Tech graduates) want to be able to compete in the global marketplace.

Two valuable resources are now available to further encourage the local entrepreneurial culture:

- A number of individuals that had grown up in the area or had attended Michigan Tech in the 1950s and 1960s and then moved away to become successful executives and entrepreneurs have now retired and returned to the area; these individuals have volunteered to work with students on projects and serve as role models.
- Several national chain stores and restaurants have entered the region, creating new competitive pressure on older businesses. This pressure and the example of "non-local" managers have created a climate which is now more open to change and innovation.

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Bibliography and Notes

1. William. B. Gates, Jr., *Michigan Copper and Boston Dollars: An Economic History of the Michigan Copper Mining Industry,* Harvard University Press, 1951. Copper Country copper output peaked in 1906 at over 230 million pounds (Table 6, p. 198) and Copper Country population peaked at over 90,000 in 1910 (Figure 6, p. 196). The population has shrunk to less than half over the last century.
2. Ned Herrmann developed the Herrmann Brain Dominance Instrument (HBDI) while he was a manager at General Electric. The HBDI measures a person's preference both for right-brain and left-brain thinking. Engineers tend to be analytical, mathematical, and logical in their thinking (Quadrant A) whereas other people may be more structured/detailed (Quadrant B), more interpersonal/emotional (Quadrant C), or more holistic/imaginative (Quadrant D). For a brief introduction to the HBDI and its application in an educational environment, see www.hbdi.com → Resources → Video → Carte Blanche: Watch video! This video is a South African news program about the HBDI and its implementation at the University of Pretoria.
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9. NCIIA Project #166-98, *Developing a New Course in "Invention and Entrepreneuring."*
10. National Science Foundation's Action Agenda for Systematic Engineering Education Reform Program.
11. For more information about the enterprise program at MTU, see http://www.enterprise.mtu.edu/about.html.
12. In an effort to increase the quality of design education for all mechanical engineering students, the Mechanical Engineering-Engineering Mechanics Department—starting with the Fall 2007 term—is now requiring the

enterprise students to take one semester of the senior capstone design course. Further changes are in process or being recommended, as described in another paper to be presented at the 2008 ASEE Annual Conference by Edward Lumsdaine and Monika Lumsdaine, "Improving the Quality of Senior Design Project Reports," (Design in Engineering Education Division).

13. NCIIA Grant #1626-03, *Entrepreneurial Enterprise Using E-Teams at Michigan Technological University.*
14. The 27,500 square-foot ATDC was funded by a $2.5 million grant from the U.S. Economic Development Agency and a $1.1 million grant from Ford Motor Company.
15. NSF Award #0438528, *Creating an Entrepreneurial Culture in a Rural Setting*.
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19. Edward Lumsdaine, "Creative Problem Solving in Capstone Design," *Proceedings,* 2007 ASEE Annual Conference.
20. See www.keweenawprofessionaljobs.com. Click on FIND, then browse by category.