AC 2008-42: USING AN INNOVATION TEAM IN MANUFACTURING EDUCATION

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Using an Innovation Team in Manufacturing Education

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Abstract: Three-plus years ago, the Electrical Engineering Department at North Dakota State University introduced 'scholar teams' as a mechanism for enhancing learning in engineering, with especial emphasis on the undergraduate level. These teams contain participants from beginning undergraduates through advanced graduate students, supervised by one or more faculty. Each team addresses a focused area of technology where the faculty supervisor possesses particular expertise, most often through current research. Over the first three years, the concept has emerged as an occasional engine for generation of new product innovation and has launched one new fledgling commercial venture that has achieved state-wide recognition. Several of the scholar teams have now morphed into product and enterprise innovation groups. Along the same time-line, the Manufacturing Engineering faculty have been striving to introduce new process science and production technologies into undergraduate learning. These two notions have been merged into an innovation-focused scholar team in the realm of micro-manufacturing, initially focusing on product innovation in medical and dental surgical instrument and implant applications. The paper will begin by outlining the scholar team concept and summarizing first-three-year results. Then, the background, structure and activities of the micro-manufacturing scholar-venture team will be discussed. Integration of exploration and learning will be highlighted. Concluding observations will be offered concerning possible migration of the concept to other interested institutions.

A Search for New Learning Methods: During academic year 2004, faculty in the Electrical and Computer Engineering Department of North Dakota State University conducted an intensive study of ways and means to enhance the effectiveness of already robust undergraduate programs. Through the expected many iterations and blind alleys, the search led to a concept of vertical integration of learning -- christened the "scholar team".

This concept hypothesized that students of every academic level can effectively learn in a vertically integrated academic setting. The "scholar team" was conceived as collaboration of freshmen through graduate students, all working under the direction of one faculty in a technological area of that professor's expertise and interest.

Vertically Integrated Scholars: Scholar teams were launched by the ECE Department in Autumn semester 2004. In that first year, here were fifteen scholar teams, representing virtually every technical specialty within the department -- biomedical, controls, computer, signals/communications, electronics, electromagnetics, power, optics. The initial concept of the scholar team was somewhat slanted towards learning-through-research. However, the core

creativity of engineering soon surfaced, and several of the teams developed a decided product focus and morphed into a learning-through-innovation slant.

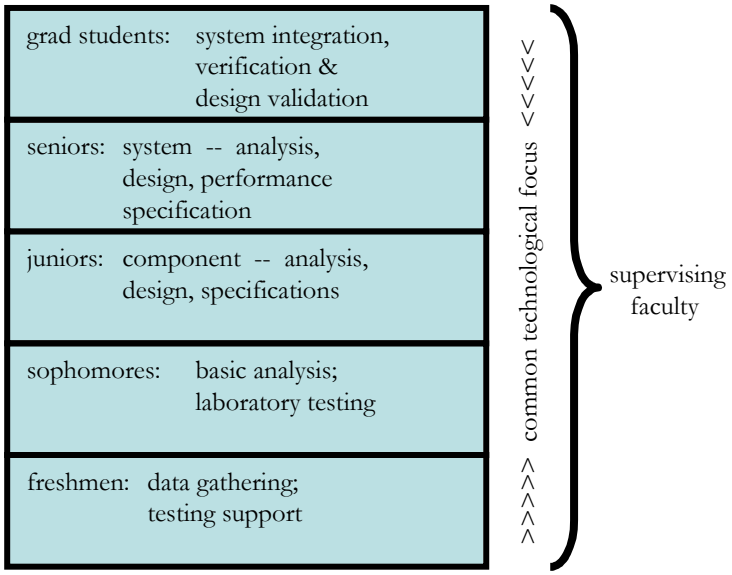

Figure 1: Initial Concept for a Vertically-integrated Scholar Team

Academic Integration and Growth of Learning through Innovation: During this period of time, interest in innovation and collaboration was growing across the entire campus. Senior administrators were placing new emphasis on the value of intellectual property to the university's long-term prosperity. Certain faculty were quick to adapt an innovation-focus to the teaching mission. Inasmuch as NDSU has long had a campus culture favorable to cross-disciplinary collaboration, the newly popular notion of innovation and invention was a natural ground where multi-disciplinary partnerships could find substance.

This collaborative atmosphere led to the next step in the evolution of the scholar team concept. The ECE Chair had been an active and persuasive advocate throughout the campus for the learning-through-innovating concept. After one of his presentations, a Finance student responded with interest -- which led to an initial contact between the ECE Department and the College of Business Administration. Initially, two MBA students became attached to scholar teams, and the CBA involvement quickly escalated to include honors undergraduate business students.

In parallel, interest was growing within the College of Engineering and Architecture. A few faculty and students in Mechanical Engineering and Applied Mechanics and in Agricultural and Biosystems Engineering either joined existing scholar teams or formed new ones. In Spring 2006, a business student and some mechanical engineering students joined one of ECE scholar teams. This team is very product-focused, with the objective of developing an executive exercise office chair. The role of the business students was and is to devise a business plan for the team.

By Autumn semester 2006, active college-to-college collaboration in scholar teams was well-established. Two new MBA students joined each of two scholar teams -- one working in development of a test platform for biomedical devices and the other working on design of an instrumented space suit. Again, the role of the business students was in creating business planning for commercialization of the new products and eventual launch of new companies.

Throughout this entire period, the atmosphere across the State of North Dakota became more and more favorable to innovation, invention and the commercialization of research. Among the several initiatives sponsored by the governor's office, the Congressional delegation and the business community is the InnovateND competition. This program is an initiative of Governor John Hoeven and is managed by the North Dakota Department of Commerce, with support and assistance from the entrepreneurial centers at each of the state's two major research universities. The goal is to stimulate the formation of viable new commercial enterprises in the state.

Scholar teams were encouraged to enter this competition. The first competition was held in 2006 and attracted a total of sixty-seven entries. The NDSU scholar team working on development of a biomedical test device emerged as one of the five winners, who each received a stipend of $5,000. [1]

This success prompted a conscious migration of the 'scholar' focus towards an 'innovation' orientation, with explicit acknowledgement that useful invention is a purposeful goal and that the launching of new enterprises from the platform of scholar/innovation teams would be cause for celebration. During the Autumn of 2006, the notion of a campus-wide Bison Ventures program emerged. [2]

Bison Ventures is a collaborative between the College of Engineering and Architecture, the College of Business Administration and the Research and Technology Park. It is a multi-disciplinary, academic, economic development plan. At the core is the long-established practice of the senior design or capstone project. Every academic year, approximately one hundred teams of engineering students are formed in our College to address problems of technological and industrial relevance. A significant portion of these also include students from other disciplines, notably business, facilities management and computer science. Moreover, project-based education is a heavily-used methodology in many upper-division courses for juniors and seniors in most of the engineering disciplines represented on the NDSU campus.

The collaborative concept visualizes that, say, five percent of the senior design projects could produce results that may have commercial potential. If one in ten of those 'successes' becomes commercially viable, the result would be one spin-off new product or process every two years. Even at such a 0.5 percent commercialization rate, this process would provide a valuable economic stimulus for the entire North Plains region, while also adding significantly to the university's abilities to attract and retain top faculty.

Thus, Bison Ventures is purposed to provide a framework for encouraging engineering and business students to think in terms of product and enterprise innovation and invention, to position their fundamental discipline learning in terms of its application in an economic society. It is also a vehicle for fomenting industrial collaboration in undergraduate education, by

providing a vehicle and incentive for private companies to invest in the potential fruits of processes of learning and innovation.

The competitive success in the 2006 Innovate ND has generated some off-campus momentum, as well. As of this moment, a collaboration is emerging between the Bison Venture program and the Entrepreneurial Center of Excellence at Dickinson State University. DSU is the western-most anchor of the North Dakota University System. Dickinson lies some 300 miles west of NDSU's home in Fargo. Moreover, the NDSU program has attracted some initial interest from potential investors. The Bison Venture leadership is working to develop a framework for treating intellectual property issues and potential spin-off company formation that will permit infusion of outside investment in student innovation and invention. At the same time, commercialization plans are developing apace. One new company has been launched and another is in final stages of formation.

As the notion of scholar teams has evolved, some have continued to grow and prosper, others have withered and disappeared, and still others have been newly formed. As of Spring 2008, there are ten Bison Venture scholar/innovation teams at NDSU. Supervising faculty come from the Departments of Electrical and Computer Engineering, Industrial and Manufacturing Engineering and Agricultural and Biosystems Engineering. Faculty from Mechanical Engineering and Applied Mechanics, and Architecture and Landscape Architecture are also involved.

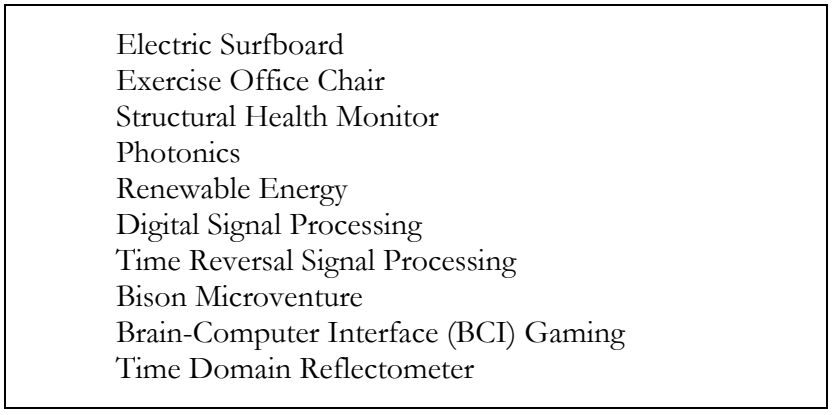

Figure 2: Scholar Teams in Spring 2008

Enter Manufacturing Engineering: The Manufacturing Engineering program at NDSU has been migrating towards an emphasis in micro-manufacturing for several years. While more traditional manufacturing remains important in the northern plains, the growth in the region's economy is being driven by companies employing newer and more advanced processing. The industrial landscape retains traditional stalwarts in manufacture of agricultural and construction equipment and in recreational products, but while these firms remain strong, their employment is characterized as stable-to-slight-growth. Increasingly, manufacturing growth in the northern plains has been driven by more technologically-based production in such areas as circuit-board-

based electronics, microelectronics, sub-millimeter-scale assemblies and medical instruments. Employers in these areas have become very aggressive in seeking graduates of our program.

Thus, in the academic curriculum, metal working for large parts (as used in agricultural and construction machinery) and fabrication of plastics/composites (as used, for example, in recreational vehicles) remain as important learning streams in undergraduate Manufacturing Engineering. However, meso-scale and micro-manufacturing have become more prominent in graduate theses, and several of these topics have begun migrating into undergraduate education.

By Spring 2007, the thrust towards manufacturing-in-the-small on our campus had been refined to three principal themes -- manufacturing processing for manufacture of ... microelectronics and microsensors; meso-scale devices and tooling; medical and dental implants and surgical instruments. At that juncture, worthwhile experience had been accumulated in several direct-write technologies, micro-milling, micro-assembly and, to a lesser extent, micro-forming and -molding. There is also a useful capability in the technologies used in assembly of printed circuit boards. Dedicated courses or significant components of others had, by that time, been offered in assembly of printed circuit boards, micro-forming, meso-scale injection molding and micro-milling. [3,4]

This migration of micro-manufacturing from graduate student thesis research into undergraduate coursework created fertile ground for reception of the scholar-team ideas growing in other parts of the College. In the late Spring of 2007, these ideas met, merged and led to planning for the formation of an innovation team based in the Manufacturing Engineering program.

The Bison Microventure: In Autumn 2007, an innovation team -- the Bison Microventure -- was launched on a platform of threads assembled from several prior activities. [3] The team was formed to explore technologies of micro-manufacturing, with a focus on applications in medical and dental instruments and implants. The intent is that, first, the students involved will acquire deep knowledge of the sciences, technologies and applications of the processing of materials at dimensions substantially smaller than those addressed in the traditional manufacturing engineering coursework. This objective is to be served through projects that manufacture small-scale articles. Secondly, selection of projects will guided by opportunities for development of new intellectual property. This is one of the primary premises upon which the notion of the Bison Venture innovation teams is based. An ideal additional result would be the formation of new commercial enterprises, based on advanced technology products and/or processes, founded by students working in an innovation team.

The Bison Microventure will work in product and process development, with the intent of producing prototype articles. An arbitrary working definition of “micro” manufacturing was established: articles and part features with principal dimensions between 25 microns and 3 millimeters. Workpiece materials will be limited only by their suitability for use in products and features within the selected dimensional range. Processes to be included in the scope of investigation would initially include ... milling, stamping, blanking, extrusion, injection molding, printing and other deposition methods.

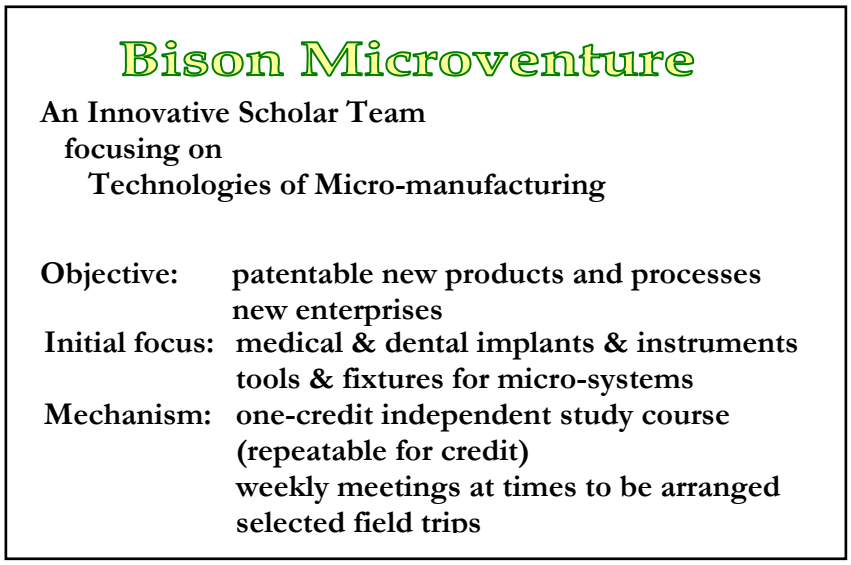

Figure 3: Extract from Bison Microventure Recruiting Poster

The Bison Microventure (Bμv) innovation team was originally designed to incorporate engineering students from sophomore through graduate standing; very quickly business students at senior and MBA levels were added to the candidate mix. The structure is a one-credit course that may be repeated as many times as the student elects. At the start, this course was established under the "independent study" rubric -- IME 494, section 01; Micromanufacturing Technologies. The credits are applicable to the technical elective requirement for the Bachelor of Science in Manufacturing Engineering or Industrial Engineering and Management. Several other majors have also approved these credits for inclusion in baccalaureate degree requirements. A graduate version (IME 793) was also established, with those credits also counting towards degree requirements.

The operational planning contemplated mentoring of the student team by one professor and two research technicians. In the first cadre of students attracted were three from engineering, one from university studies and two from business (one of whom withdrew part-way through the semester).

The Team decided to devote the first semester to examination of selected technologies and opportunities, with an objective of selecting a specific project before the end of the semester for development during Spring. The processes included ... substantive library research; weekly group discussions; guest presentations by a dental implant manufacturer and an orthopedic surgeon; visits to three companies that manufacture cardiac surgical tools; a field trip to the Medical Device Manufacturing Show in Minneapolis. The weekly team meetings were originally planned for one hour, but quickly became, by unanimous acclaim, two hours.

After ten weeks of exploration, the Team had identified nine attractive candidate projects. Then, in a two-week iterative process, one project was selected for the first concentrated development effort -- a hydrophylic ceramic dental implant. A target goal was established to

produce a first prototype article before the end of April 2008. A distribution of tasks was determined, with each student taking on tasking that suits their personal aspirations fairly well.

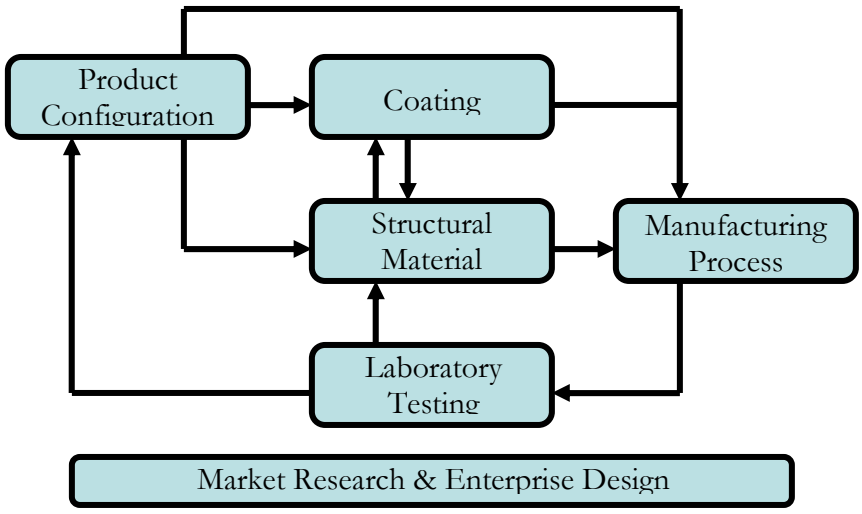

Figure 4: Project Organization for Product Innovation in the Bison Microventure Innovation Team

Up-to-the-Minute: As this paper is being written, the Microventure team is expanding. After the first month of working to the prototype-development tasking, it became apparent that additional skill sets are needed. Three new engineering students and two microbiology majors were added to the Team in January. Two of the new engineering students have assumed the assignment for testing, and the other is partnering in the process design task. The student(s) from biological sciences support the material, coating and testing groups by providing more knowledgeable input on such matters as bone growth mechanisms and kinetics, biological compatibility of implant and coating materials, integration of natural and synthetic materials, and laboratory processes for prototyping and testing.

The hydrophilic ceramic dental implant has been the focus for entries into two 2008 competitions. The Bison Microventure has filed an entry into the 2008 InnovateND competition. We were notified that our entry in one of 78 selected for Phase 2, and a more elaborate business plan, which includes more detail in marketing and product technical elements, was submitted in February. From there, 20 surviving entries will be selected for the final competitive stage. We also entered the BMEidea competition and have been recently notified that we have been awarded a small planning stipend and are eligible for the semifinals. That expanded entry is due in April. An additional national competition has been identified, with a submission date in early May.

Lessons Learned and Future Planning: The first conclusion from the early experience with the Bison Microventure is that it is, indeed, an effective learning mechanism. Emphasis on documentation necessary for intellectual property and productization purposes is quite relevant

for assessment of learning achievement. Refinements in learning objectives has been a matter of some attention and evolution. The first semester assessment of outcomes is very positive. The students have developed sufficient acquaintance with the relevant technologies that they can (and do) engage in substantive dialogue with professionals in dental fields. In addition, the expertise displayed in materials and processing technologies for this project are, at this stage, quite satisfactory.

A request is being initiated to regularize the Bison Microventure learning experience by instituting a regular course (i.e., not 'independent study') to house this innovation team. The request will be presented for approval through the normal formalities that pertain to launching of new courses in our university. It will be proposed as a variable credit course, repeatable multiple times. Prerequisites will be structured to accommodate students from multiple disciplines through engineering, sciences, business, economics and, perhaps, others.

A second conclusion is that this type of learning would be significantly improved by a dedicated laboratory space. Thus far, the Microventure Team operates in a corner of the Manufacturing Engineering Laboratory, which is primarily a teaching venue. There is no dedicated space for project work, which inhibits the effort.

A third conclusion is that specialized laboratory equipment is needed. Processing of materials at he dimensions involved in the dental implant project is marginally manageable with conventional manufacturing equipment. Experience with other, similar projects suggests that cycle time will be long, and tool wear will be significantly increased, but that the necessary part features can be produced. Finishes and tolerances are more questionable, but this type of product has only one feature requiring close dimensional fit. Part of the selection criteria for choosing this project form the list of nine candidates was assessment of suitability of current equipment. Continued study of micromanufacturing on a less restricted basis would require new machine tols and measuring apparatus expressly suited to materials processing at sub-millimeter dimensions.

Finally, it is still too early to assess the effectiveness of this learning mechanism for creating intellectual property and/or new enterprises. While there is undoubted intellectual ferment accompanying every meeting of the Microventure team, no formal patent applications have yet been filed, nor have any new companies been founded. Measurement of achievement of the Microventure commercial objectives must await future developments.

Acknowledgements: A vital and integral portion of the work of the Bison Microventure is provided by the two research technicians who contribute their considerable technical expertise to mentoring the students. Armon E. "Gene" Myrick is a Research Technician 2 in the IME Department. Mr. Myrick teaches manufacturing engineering laboratories in our program. He is an expert toolmaker, with over thirty years experience in a variety of sophisticated metal manufacturing ventures. Lewis Dailey is a volunteer research technician in the Manufacturing Engineering Laboratory. Mr. Dailey is an expert CNC programmer and has created complex machined parts for us requiring many thousands of lines of code. Both of these gentlemen bring vast experience, perspective, creative insight and fresh enthusiasm to the Team.

It is also vital to acknowledge the enthusiastic and effective participation by the Microventure students: Matthew Lanoue, sophomore in Manufacturing Engineering; Joshua Brantner, senior in Industrial Engineering and Management; Mayank Verma, graduate student in Manufacturing Engineering; Casey Radtke, junior in University Studies; Stephen Wurm, senior in Business Administration. New recruits are … Caitlyn Aho and Laura Axvig, sophomores in Microbiology; Jared Graetz, junior in Manufacturing Engineering; Michael Hedlund, senior in Industrial Engineering and Management, and David Stenseth, senior in Manufacturing Engineering. These folks have been dedicated, creative and effective in establishing a project focus from a very broad topical area, researching and analyzing the technologies involved and creating a vision for the Team -- and not so incidentally, teaching their mentors.

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