The Convergence of Creative Enterprise and Engineering Technology Education

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Introduction

American industry has undergone significant change in the past decade as evidenced by the outsourcing of manufacturing and high technology jobs due, in large part, to the globalization of technology. The loss of 2.6 million manufacturing jobs and, more recently, new trends in outsourcing high-tech and service industry jobs has been in response to wage differentials, valuation of the dollar, and a shortage of engineering and technology program graduates.[1] The traditional career path sought by engineering technology program graduates was to seek employment at a mid-to-large size corporation with the implied opportunity to climb the technical/managerial ladder during a lifetime of commitment to that single employer. This scenario is a thing of the past as multinational corporations downsize, outsource, and streamline management hierarchies and thin the ranks of technical professionals.

At the same time, the growth in small businesses by entrepreneurs and small start-ups providing components to larger companies has provided an alternative career path for newly degreed engineers and technologists. According to the U.S. Census Bureau, small businesses accounted for nearly 75% of employment growth in the United States since 1990[2] and start-up businesses in their first two years of existence have accounted for nearly all new jobs.[3] These are significant numbers for our recovering economy and have given business managers, governmental officials, and post-secondary educators more reasons to think differently about the workplace of the future. In response to these trends, engineering technology programs must address the probability that their alumni will be working for small businesses or as entrepreneurs, especially in more remote areas of country.[4]

South Dakota Issues

The state of South Dakota has a well-established reputation as a tourist destination for families visiting the scenic Black Hills and bikers rallying at Sturgis each summer in addition to attracting tens of thousands of sportsmen during pheasant hunting season in the fall. Less well-known for its manufacturing and high technology industries, the state ranks at or near the bottom nationally in total industrial employment, number of manufacturers and in federal research and development dollars invested. Ironically, South Dakota ranks first in terms of being the most entrepreneur-friendly state for its business environment.[5] These dichotomies appear daunting for

innovative business and technological development, but actually illustrate the great opportunities for future growth especially in small-scale technology and knowledge-based industries.

According to Manufacturing News, South Dakota had 1338 manufacturing companies in 2002 with over half employing one to nine people and only seven firms employing more than 500 people.[6] In a state with just over 750,000 inhabitants, only 32,060 persons were employed in production or management occupations in 2002.[7] This is roughly 10% of total state employment as tracked by the U.S. Bureau of Labor Standards (BLS). Service industries, education, and agriculture are the primary occupations for South Dakotans, especially in the sparsely populated western regions of the state.

The Great Plains Rapid Prototyping Consortium

In 1996, the Manufacturing Engineering Technology (MNET) program in the College of Engineering was established at South Dakota State University. This new Bachelor of Science degree was initiated as a response to regional demand for technical/managerial personnel capable of applying engineering concepts in the production environment. The program has grown over the past seven years to nearly 70 declared majors and has been highly successful in providing much needed talent for South Dakota industry. Much of this success can be attributed to well-considered investments in laboratory technology, recruitment of skilled faculty and staff, and successful partnering with industry. Outreach and collaboration with regional manufacturers by MNET program faculty have been primarily accomplished as a result of the Great Plains Rapid Prototyping Consortium (GPRPC).

The GPRPC was launched in 2000 by three industrial partners and South Dakota State University and supported by consortium partner investments and a Partnership For Innovation grant from the National Science Foundation (#0090422). The mission of the GPRPC is to support educational activities, product development, research and technology exchange for engineering and technology students and consortium members by developing a rapid prototyping (RP) laboratory and service bureau at SDSU and through educational courses, seminars and consortium member meetings.[8]

Since its inception, the GPRPC has served the members through product prototype construction and modification, technical seminars and specialized in-plant training, and industrial design and development projects by MNET students and staff. The six primary objectives of the GPRPC project are:

1. Provide access to and hands on training for students and partners in rapid prototyping equipment both on-site and via the Internet.
2. Provide a venue whereby students and educators can cooperate with industry leaders and potential employers in the design process.
3. Provide a venue whereby partners can regularly discuss design problems related to rapid prototyping, offer advice and information regarding new ideas and potential pitfalls, and have access to additional information through seminars on related technology.

4. Provide means to improve the knowledge base in rapid prototyping and related technology through research activities at South Dakota State University.
5. Create an atmosphere whereby partners can enhance their ability to provide new innovative products to the customer and enhance economic development in South Dakota and the surrounding region.
6. Increase the number of memberships to cover expenses after the initial start-up.[8]

The groundwork for the consortium was laid by the manufacturing program coordinator as a result of contacts made through professional societies, such as Society of Manufacturing Engineers, meetings with local business leaders, and momentum created by a small group of SDSU foundation contributors with a vested interest in the future success of the newly established manufacturing engineering technology program. The operations manager for the GPRPC was added to the staff in 2000 and is an industrial engineer with extensive manufacturing production experience and the new department head also has a strong manufacturing background. As a result, GPRPC management has been able to leverage industry support, manufacturing engineering technology faculty and students' abilities, and networking efforts to create a steady flow of process engineering consulting, modeling, and short-run production projects. It is anticipated the GPRPC will be able to achieve its goal of self-sufficiency at the end of the grant period.

In the first three years of existence, the GPRPC has produced a wide variety of prototypes for the members and other companies purchasing time on the RP equipment. Undergraduate and graduate students have been employed part-time by the GPRPC to perform day-to-day tasks, serve as production workers for short-run manufacturing projects, and conduct applied research and problem solving for consortium partners. Seminars, workshops, and regular university courses have been delivered on Lean Manufacturing, ProEngineer™, and Rapid Product Development. Demand for specifically tailored short courses for industry is growing and there are plans to consolidate student industry internships with faculty research interests under the GPRPC umbrella.

Rapid Product Development in the Undergraduate Curriculum

For students in the Manufacturing Engineering Technology (MNET) program, the GPRPC has been used as a teaching tool and source of employment. We have integrated rapid product development themes into the curriculum in a variety of ways. First year students in the introductory processes course are brought into the consortium center and given an overview of RP technology and its capabilities.

Second year and third year MNET majors take a minimum of three courses that utilize the GPRPC for learning opportunities. In the safety class, workplace hazards are addressed including: hazardous materials handling, ergonomic analysis of workstations and personal protective equipment requirements are covered. At this point in their academic career, students may be hired as employees of the consortium. For those with paid positions, students maintain material safety data sheets (MSDS) records and write safety procedures for operations based on

what they have learned in class. In the CAD course, students often experience problems with visualization, especially from 2D to 3D applications. The 3D models designed by the students can be transferred to the RP machines for verifying function and the correctness of the design. The CAM / CNC course offers another opportunity to create parts on different machine tools. A rapid product realization section in the course is beneficial for students to understand alternative methods to product development and manufacture.

At the senior level, students are given additional opportunities to hone their manufacturing management skills. In Manufacturing Cost Analysis, the emphasis is on cost estimating related to various manufacturing processes and products and developing budget proposals and for analysis and evaluation of manufacturing capital expenditure. One of the major projects in this class is to estimate the return on investment of a new rapid prototyping facility and to determine what level of production is necessary to make the investment worthwhile. To do this, the students must determine all the relevant costs and determine a break even point.

One of the primary outcomes of this curricular path is that the MNET student is well prepared to enter the manufacturing environment and solve product development and production problems especially for the small job shop enterprise. The GPRPC provides an avenue for students to learn early lessons about rapid product development under the guidance of the faculty and GPRPC staff and later, as upper division students, work directly with GPRPC members or other clients.

Success Stories from the GPRPC

A common problem for small companies is the inability to devote time to new product development. Often relegated to one or two individuals in the organization (frequently the founder in new start-up companies), new products are frequently brought into being by chance or to address requests from current customers. Investment in new technology is limited to the tried and true or whatever fits within the operations budget and rapid prototyping techniques and technicians are too expensive for most companies in South Dakota. With the creation of the GPRPC, a logical resource for product development rose from the prairie. The GPRPC was intended to fill the rapid product development gap for small companies in South Dakota. The GPRPC operates costly and highly specialized rapid product development tools and offers expertise in data acquisition, statistical analysis, and specialized training for manufacturers. Similar to quality management implementation in small companies, the GPRPC is a flexible resource for consortium members and other small companies in South Dakota.

Thomas and Webb observed that small companies face the dual challenge of limited resources in terms of spare time, emerging technology, and trained personnel.[9] Additionally, these types of organizations often do not have the ability to generate appropriate data that will enables them to see the broader possibilities for implementation of advanced statistical tools. When faced with a shortfall in time and personnel resources, small companies 'economize' by focusing on pressing tactical issues, satisfying external demands from customers, and meeting the basic job training needs for their personnel. Thus, limited resources will often lead to limited training, especially when it comes to application of statistics to company specific processes. Small companies risk falling further behind in the global marketplace as the application of statistical tools is a

relatively inexpensive method to improve cost and time savings. The GPRPC has served as a training resource for consortium partners offering workshops in Design of Experiments, basic statistical applications, and ProE™ training. A review of various implementations of GPRPC equipment and personnel skills highlights some of the benefits we have been able to bring to manufacturers in the region. It must be noted that, for each of the projects described below, undergraduate and graduate students and Manufacturing Engineering Technology faculty were active participants in the process. From running the RP equipment, machining special parts, meeting with industry personnel, to brainstorming solutions, students, faculty and staff were intimately involved from start to finish.

Smith Equipment, First District, and GPRPC

The first example illustrates the use of local government funds for a new product. The First District Association of Local Governments covers an 11 county area of the northeast corner of South Dakota. As a member organization in the consortium, the First District provided prototyping services through the GPRPC at no cost to the party interested in prototyping services. Gary Foos, Project Engineer for Smith Equipment, a leading manufacturer of oxy-fuel cutting and welding equipment, of Watertown, SD contacted GPRPC for proving a new cutting torch design. "Rapid prototyping proved the concept and allowed us to get on with the project," said Foos. "New designs are where rapid prototyping (RP) comes in." RP provided Smith Equipment with a quick turnaround by reducing the previous development cycle by 4-6 weeks. The ergonomic design for the torch was verified and produced through the use of a stereolithographic prototype built by GPRPC. Following the delivery of the first handle from GPRPC, Foos implemented a revision due to the discovery of an ergonomic flaw. This flaw could not have been identified through any other means available to Smith Equipment. Only by installing the handle and testing it in field conditions provided this insight. In fact, virtual CAD system would not provide consumer feedback related to fit and feel.[10]

Raven Industries and GPRPC

Raven Industries is a South Dakota Based manufacturer of engineered films, flow control systems for agricultural applications, and contract electronics manufacturing. Steve Jensen, product engineer for Raven Industries' Flow Controls Division, required a test comparing actual and theoretical values of both flow rate and pressure drop on a valve. GPRPC provided Jensen with a stereolithography model for the prototype valve assembly. This functional prototype ran on the test stand at pressures over 100 PSI (see Figure 1). GPRPC provided this operational prototype in three days instead of previous turn around of three weeks. Jensen asserts this prototype met his expectations for part performance and was a cost effective solution.[11]

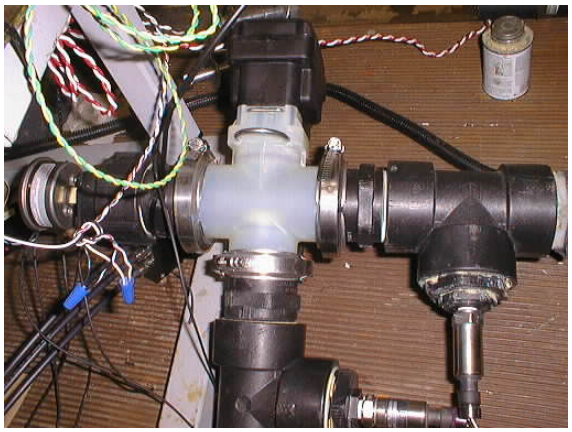

Figure 1. Valve body prototype on test machine at Raven Industries.

Falcon Plastics and GPRPC

Falcon Plastics, based in Brookings, South Dakota, is a custom injection molding manufacturer and is also one of the originating companies in the consortium. In late 2002, Falcon approached the GPRPC with a request to develop a series of prototypes for a new design for a pill cutter for a customer. Falcon Plastics' Vice President of Engineering, Shaun Riedesel explains, "Rapid prototyping is a natural link in our business. The biggest challenges for our company are to reduce production cost for our customers while adding more services to keep pace with technology." Falcon Plastics worked with their customer to bring this new product to market. This consumer product went through dozens of design revisions. The GPRPC provided stereolithography models as well as RTV molded, operational prototypes to assist in product functionality testing and aesthetics checking (see Figure 2). This product has literally gone from the CAD screen to the shelves at Wal-Mart in less than six months.[12]

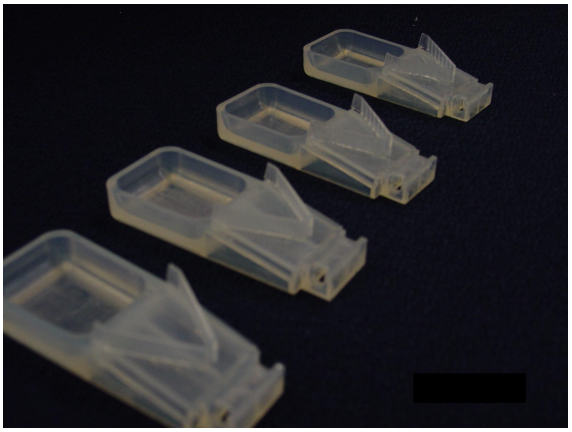

Figure 2. Row of pill cutter prototypes for Falcon Plastics.

Larson Manufacturing and GPRPC

The GPRPC was able to serve Larson Manufacturing, manufacturer of storm doors and windows, by quick turnaround on hardware and internal components. GPRPC has been able to quickly produce parts from emailed files, sometimes turning them around in less than 48 hours. "Your staff responded quickly and we were treated well," stated Al Lee, Engineering Manager for Larson Manufacturing of Brookings, SD. Design Engineer, Kelly Nordgaard says, "New product development and the marketplace are constantly demanding different designs. We apply for a lot more patents now. Rapid prototyping is a tool of communication for marketing and a tool of engineering to determine tolerance and fit."

Alan Dixon, Larson Engineering Technician, noted, "Rapid prototyping is great for new products. Larson has prototyped several handles. Rapid prototyping allows us to actually hold the handle and see how it is going to feel. We have prototyped various molded parts for different products. Not only can you see what the parts will look like when they are assembled but you can test functionality."[13] GPRPC continues to work with Larson on new devices for upcoming door and window lines.

Figure 3. GPRPC staff and MNET faculty meet with industry representatives.

Lessons Learned

The culture of the upper Midwest is influenced by the northern European immigrants who came to the Great Plains in the 1800s and early 1900s. Self-reliance was a necessary trait in order to survive the harsh winters and hot, dry summers. As a result, their descendants still exhibit a strong independence, preferring to solve problems themselves rather than reaching out for assistance. This has proved to be a challenge to be overcome by the GPRPC. Being cautious of 'outsiders' offering help, it takes time, patience, and persistence to win the trust of these companies.

Another challenge has been the lack of additional funds at these small companies for investment in memberships in the consortium or for speculative projects. Indeed, product development budgets are very slim if they exist at all for most South Dakota companies. Companies do not like to risk the investment in a yearly membership but, after reviewing expenditures with the

GPRPC, some would have more than paid for the membership for any given year. Conservative spending habits area a cultural issue we have not yet completely overcome.

Isolation is also a factor. South Dakota has many small businesses spread across more than 75,000 square miles. Driving to visit company facilities or trying to work with individuals in remote regions is time consuming and costly. We are working to market GPRPC and its capabilities at regional manufacturing meetings, conferences, working to build partnerships with other departments on campus, and collaborating with the Enterprise Institute, part of the SDSU Foundation. These efforts are beginning to generate inquiries and visits to the SDSU campus. It is important to note that since moving to our new facilities on the SDSU campus in August 2003, we have seen a large increase in visibility and new projects.

The last lesson has been that the consortium will not be successful if only rapid prototyping services are offered, especially in this region of the country. Additional services must be available to make the GPRPC viable in the long term after the NSF grant has finished. Some of ways we have been exploring include conversion of data into a 3-D model, small run production, and product finishing. As the mission of the GPRPC evolves, we have become a more successful enterprise as a rapid product realization business.

Our future success depends on meeting the needs of our industrial partners, effectively utilizing the capabilities of manufacturing engineering technology faculty and students, and the ability to take advantage of trends in the industry as they affect South Dakota manufacturing. We look forward to meeting these challenges.

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