Engaging Industry in Graduate Engineering/Technology Education

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Abstract

American industry has undergone significant changes due to global economic factors, outsourcing of manufacturing and high-tech jobs, and niche competition. Changes like these have produced negative consequences for many regions of the nation, primarily in the areas of economic and job growth. To mitigate dwindling regional economies, public policy initiatives are redefining the relationships between industry, government, and graduate engineering/technology education. Leaders in each arena are engaging in dialogue centered on strengthening the competitiveness of remaining industry and developing regional resources to support entrepreneurial startups. Leaders and scholars argue that a robust strategy includes collaborative engagement projects which create innovative technologies (intellectual property), a highly trained and creative professional workforce, and resources which support entrepreneurial startups. The purpose of this paper is to provide insight into efforts being made by Western Carolina University (WCU) and its graduate Engineering Technology (ET) program to simultaneously foster professional growth in its students and meet the technical needs of a unique region. The focus will be on approaches graduate education can take to address the growing need for technically prepared leaders in engineering fields. Specifically, partnership and engagement actions taken by WCU and the benefits gained will be presented. Through the Center for Integrated Technologies (CIT), graduate students have been involved in creative projects with organizations such as Oak Ridge National Laboratory, Caterpillar, Borg-Warner, Bombardier Recreational Products, and U.S. GreenTech. Additional information will be provided on equipment resources available for industry use through the CIT and the development of a millennium campus to provide additional resources for entrepreneurial startups. Because of the positive response from all parties involved, the Department of Engineering and Technology at WCU continues to bring creative and innovative opportunities to its students as well as help the regional economy through engagement and accessible resources.

Background

Outsourcing of manufacturing and high-tech jobs coupled with plant closings have resulted in the diminishment of many rural economies. Regions that have disproportionately relied on traditional manufacturing jobs as their main source for employment and livelihood have suffered substantially. In 2004, the Society of Manufacturing Engineers reported that there were 3 million less jobs in manufacturing as compared to 1998.[1] The rural region of Western North Carolina has experienced similar trends in manufacturing job-loss since 1998.
Due to plant closings and layoffs in 2002, North Carolina had the third highest unemployment rate in the country with 50,500 fewer people employed in manufacturing as compared to job

statistics for 2000, by 2003 the total employment in North Carolina decreased by 91,100 jobs.[2] At present, the unemployment rate for North Carolina is at 4.8%.[3] The magnitude of job loss in manufacturing and the effect on local economies have been reported as "near crises proportion."[4] Factors resulting in job loss and the necessary actions to mitigate these effects have sparked discussions from leaders in business, education, and government across the Nation.

It can be argued that strengthening the competitiveness of remaining industry through the development of regional based technology and educational resources, which serve as a dual support system for entrepreneurial startups, is a first-step in helping revive local economies. Additionally, increasing the number of professionally prepared engineering/technology graduates will prove equally important in regional economic development.

Scholars suggest that a sound strategy for reviving industry include collaborative engagement projects between education, government, and industry.[5,8,1] Specifically, engagement projects that create innovative technologies (intellectual capital) and facilitate technology transfer have the potential for strengthening the competitiveness of existing industry as well as entrepreneurial startups.[5] In 2004, the Society of Manufacturing Engineers (SME) produced a Global Manufacturing Fact Book that offered strategies for ensuring long-term economic prosperity. SME states,

> The creation of more effective partnerships between academia, business and industry, and government research institutions that allow for more effective means of technology transfers…The United States, in order to remain competitive, must embrace ingenuity and rely on its traditional strengths in innovation and technology to develop the emerging technologies of the future (e.g., alternative energy technology, biotechnology and nanotechnology) rather than clinging onto the industries of the past.[1]

Motivated by industry's need for a highly trained professional workforce with advance technical skills, which are necessary for the creation of innovative technologies at all stages of development, researchers have argued for reform in graduate engineering/technology education.[6] Reform must begin with the establishment of new graduate programs in engineering/technology that "foster professional engineering practice and leadership of technology development" in industry through collaborative engagements in which students learn by working with practicing engineers.[5] Higher education must continue to remain as the world leader in generating innovative technology and preparing the workforce for the demands of industry if the Nation is to remain preeminent in transforming knowledge to economic value.[7]

Implications and actions in western North Carolina

In 2001, a Western North Carolina regional summit was attended by business, education and government leaders to discuss the surmounting economic crises facing the region. The leaders concluded that university engagement must play a major role in reviving and sustaining the regional economy.[8] Specifically, the leaders called for the development of a regional high-tech center in which students, faculty, and staff engage industry in areas of emerging technology development.[8] Western Carolina University's chancellor, Dr. John Bardo, wasted no time in establishing a campus-wide mandate for regional engagement activities that focus on sustaining

businesses and boosting entrepreneurial startups by innovative and creative projects that develop intellectual capital through technology transfer.[9,10]

Center for Integrated Technologies

In 2001, Western Carolina University (WCU) secured federal funding for the construction of a new facility to house a regional high-tech center. The $8 million, 28,000 sq. ft. Center for Integrated Technologies (CIT) was completed in 2003. The center incorporates laboratories in optical and wireless communication, advanced manufacturing processes (product design, rapid prototyping, reverse engineering, and laser machining) and bio-adaptive mechanics.

The CIT's mission is to engage WCU in the sustainable economic growth of Western North Carolina by creating cores of excellence in emerging technologies, which enable the creation of new businesses in these emerging technologies as well as retain existing jobs. This mission will be achieved through collaboration with broad organizational reach (university, community colleges, industry, and government), highly leveraged private to public sector funding, and delivery of problem solving assistance by faculty, staff and students.[11]

In 2003, the procurement of equipment for the CIT was possible through grants and donations from state and federal sources, as well as corporate and private benefactors. Cost to companies for the use of facilities and equipment is restricted to recovery of material cost, maintenance, and upkeep of facilities. Equipment resources are as follows:

Automated Rapid Prototyping
- Stratasys FDM Titan®
- Stratasys Eden 333®
- ZCorp Z400®

Metrology and Reverse Engineering
- Zeiss Contura HTG® Coordinate Measuring Machine (CMM)
  - OGP SmartScope Flash 200® Video Measuring System
  - ADE Phase Shift MicroXAM® surface mapping microscope

Machining Centers
- HAAS® 2D Laser Cutting Center
- Four HAAS® Milling Machines
- Three HAAS® Lathes

Engineering Workstations
- 50 Dell® Model
- 21" LCD Monitors,
- PRO/ENGINEER Wildfire®
- and other related engineering software

Integrated control systems laboratory with related equipment and software

Polymer and materials laboratory with related equipment and software

Master of Science in Technology Program review and changes

In 2004, an external review of the Master of Science degree in Technology (MST) was conducted to align the program with the strategic mission of WCU and the Department of Engineering and Technology. The review board, comprised of leaders from academia and regional industry, determined that changes were necessary.[13] Prior to change, the MST program focus was narrow in scope and demand was directly related to the manufacturing base of the region. The board and department agreed that the MST would continue as a non-thesis/applied project program for the working professional with the exception of creating a holistic systems approach to courses and live-projects.

The MST program was revised to bring the program more in line with similar programs across the nation, and place an emphasis on technology management rather than manufacturing. One central change strategy was incorporating the management of technology encompassing engineering applications, research methods, and management principles. The transition from depth in a specific discipline to breath in technical knowledge is now even more critical in a high-tech global economy. As suggested by Khalil and Garcia-Arreola of the University of Miami Graduate School, "Management of Technology is not an easy task...it combines a variety of technical fields with business insight, requiring a wide perspective of both engineering and business issues. Such perspective is not provided by current MBA or engineering programs".[12] Thus, the goal of changing the MST program was to cross disciplines and foster a similar approach.

The MST program currently focuses upon analytical thinking, problem solving, and decision-making coupled with the integration of skills and knowledge necessary for the effective management of engineering technology-intensive systems. The program is directed to individuals with technical backgrounds who are moving or anticipate a move into management positions. Instruction provides a basis for enabling students to develop strategies based on accepted methods, models and research to enhance professional and technical backgrounds and to develop technical management skills by combining qualitative approaches and quantitative techniques in a balanced curriculum.

Project management, telecommunications, and automatic data capture courses were added to the core curriculum. Similarly, financial and managerial economics were added as an option for the supporting management area. Students are required to conduct research in all graduate courses. Specific research methods are covered in ET 603, Applied Research and Design. For the ET 603 course, students are required to complete a research study using accepted methods and statistical analysis. Additionally, all students have the option to take ET 648, Research in Manufacturing. A requirement in this course is the completion of a research study and the submission of a paper for publication consideration in an appropriate technical journal. The emphasis on research throughout the program is the practical application of research designs and statistical methods for quality improvement. Candidates for the MS degree must also complete a directed project. This capstone experience is required in lieu of the traditional thesis. Projects must be approved by the program director or department head and remain under their direction through completion.

The MST program is currently in-line to fulfill a societal need by providing opportunities for advancement of working professionals within business and industry as well as engagement opportunities at regional industrial and business facilities; engagement projects which involve working with practicing engineers in the development of highly creative and innovative technology related products and processes are highly desired. [13]

Engagement projects CIT/MST program

Following the MST program changes, graduate students have been involved in a number of engagement projects. The following is a summary of completed, ongoing, and future projects.

Oak Ridge National Laboratory:
Western Carolina University was awarded a contract through the Department of Energy to develop a marketable energy efficient hybrid water heating and dehumidifying product. Partners in the project include Oak Ridge National Laboratory (ORNL), Asheville-Buncombe Technical Community College (ABTCC), and American Carolina Stamping (ACS). Specifically, the project built on concepts and preliminary prototypes developed by scientists and engineers at ORNL and P.I.E.R. WCU faculty and students were involved in product development, engineering models and documentation, refrigeration system development, prototyping of test units, control system development, instrumentation selection and installation laboratory testing of prototypes.

The project provided an excellent opportunity for students and faculty to gain engineering related experiences in several aspects of the project. Project tasks included test site preparation, installation and calibration instrumentation for monitoring and data collection, generating engineering models and drawings, machining and fabrication of heat exchangers, and analysis of test data. Graduate students also were involved with project management and planning for a second phase.

Currently, development work has resulted in prototypes ready for further testing at ORNL. Products will undergo extensive testing in a controlled environmental chamber to evaluate performance under stimulated loadings and changing conditions. Upon successful completion of this phase of testing, a second phase will be initiated. During the second phase, designs will be refined, and field test units will be developed. Should a third phase be funded, it would consist of the actual field-testing for pre-production units.

In addition to the opportunities for professional development of faculty and engineering applications for students, this engagement project has proven to be mutually beneficial to all partners. A stronger relationship has been developed between ORNL and WCU with the potential of pursuing other technology transfer projects. Support was provided to ACS that enabled a small company to prepare for potentially launching a new product. Similarly, through cooperative work between WCU and ABTCC, a strengthened partnership was created.

Caterpillar:
Western Carolina University has maintained a close relationship with the precision seals division of Caterpillar. Through part-time and class projects, students have gained valuable experiences

in preparation for engineering careers. The following is an example of the type of projects completed by students at Western Carolina University.

During the Spring semester of 2003, the Engineering Technology Department was approached by Caterpillar to assist in solving a processing problem for heat treatment of metal seals. Specifically, the project dealt with the design and fabrication of a fixture to prevent multiple parts from entering an induction heat treatment workstation. The fixture was also required to detect mis-feeds and signal an operator of an existing machine fault.

The project was solely completed by a graduate student completing the M.S. Technology program. A mechanical fixture was designed and modeled using a 3-D parametric modeling software package. Tolerances and fits were evaluated, and an assembly created prior to fabrication. From the assembly, an animation was created to demonstrate the workability of the fixture and presented to the manufacturing engineering department at Caterpillar facility in Franklin, NC. Upon approval from the engineering staff, the mechanical fixture was fabricated at WCU's machining laboratory, and taken to Caterpillar for installation.

The project has been in operation since May, 2003 without any known malfunctions. Further, the company recognized savings both in avoidance of line stoppage, and the elimination of a previously required operator to correct mis-feeds and identify defective parts.

WCU will continue the relationship with Caterpillar and seek out similar projects to engage both undergraduate and graduate students. Projects such as this provide outstanding opportunities for students to gain practical experiences and make key contacts for future career paths.

Bombardier Recreational Products:
Bombardier Recreational Products , Inc. manufactures snowmobiles, watercraft, sport boats, outboard engines, and all-terrain vehicles. The Bombardier plant in Andrews, North Carolina manufactures the connecting rods for their Evinrude E-TEC outboard engine, which is advertised to operate for three years, maintenance-free—not even an oil change. This requirement places high performance standards on all their components. The rods are sent to the assembly plant in Wisconsin, where there has been a fallout rate of approximately 10%, due primarily to a perceived mismatch when the rod is assembled onto the crankshaft.

The internal surface is ideally a perfect circle with no steps at the split line. Once assembled, this internal surface cannot be verified, so the assemblers attempt to verify the integrity of the internal surface by checking an external surface. Although this is the current mode of verification, it has never been statistically validated. Most of the parts that return to Andrews are still acceptable parts, so there is a great deal of waste in the process—assembly time, shipping costs, rework, re-inspection, etc. Rob Dillard, the quality engineer at Bombardier's Andrews plant, contacted the Engineering and Technology Department at WCU for assistance in resolving their problem.

Two faculty members and one graduate student from WCU visited the plant, toured the manufacturing process, and returned to WCU with five connecting rods. For his directed graduate project, Preston McCrary, a graduate student in the MST program, investigated the

possible correlation between these internal and external surfaces on the connecting rods. Mr. McCrary analyzed the connecting rods on the Zeiss CMM, using its scanning feature to collect thousands of points along predefined paths, rather than the traditional "woodpecker" mode of gathering individual points for each probe hit.

The data for the surfaces were collected and analyzed using three methods: correlation analysis, single-factor ANOVA (analysis of variance), and paired T-test. From these analyses, it was determined that based five connecting rods, there is no apparent predictor of internal surface quality by any external features. This is valuable information to the Andrews plant, as they can inform the assembly plant that their dental pick technique is not ensuring the quality they need, but is instead creating costly manufacturing losses for the company.

This conclusion is tempered by the fact that only five parts were used in the study. Now that the method has been developed, the same analysis can be applied to a large sample of parts. Bombardier-Andrews has already agreed to supply additional connecting rods for the continued analysis to be resumed in the Spring 2005 semester, when another one or two MST students will follow up with an extensive DOE (design of experiments) on a much larger sample size.

This particular project has been invaluable from an academic and an industrial perspective. Mr. McCrary has been exposed to a real manufacturing problem, not a fabricated classroom simulation, and has seen the business implications of both the problem and the solution. Involved faculty continue to remain in tune with industry needs and issues. And Bombardier has received assistance with a manufacturing issue that is preventing efficient operations, in addition to exposing itself on campus at WCU to many potential Bombardier employees of the future.

Borg-Warner Turbo Systems:
Fall 2004, Steve Roby of Borg-Warner Turbo Systems - Arden North Carolina approached the MST program about the possibilities of an external engagement project for one or more graduate students. The project involves research and design of a turbo charger sensor. The sensors primary function is to detect oil leaks at the turbine shaft within one second of activation. Additionally, the sensor must detect leak stoppage. Compatibility between the switch and the Electronic Control Module recording device is also a design constraint. Research is currently focusing on the various types of sensors capable of performing this task under the harsh working environment. Immediate solutions were found to be unusable; three of the most promising methods are currently under investigation.

U.S. GreenTech Inc.
Spring 2004, Randy Reddick of U.S. GreenTech Inc., Synthetic Turf Systems, Calhoun, GA requested consultation and the development of a 3D constraint-based solid model and rapid prototype for an Astroturf structural membrane product and patent. Students successfully delivered the solid model and prototype.

Andy Petree Racing Project:
Fall 2002, the task of determining how to reduce piston failure and improve engine performance in racing engines, via verification of piston geometric dimensions and tolerances (GD&T), was chosen as a project. John Dysinger of Andy Petree Racing (APR) supplied a batch of pistons

that are used in APR engines. The use of a Zeiss Contura CMM and Calypso software have allowed for the determination of specific GD&T values related to the performance of race-type engines. Future applied research by MST students could present data that would provide engine builders knowledge of best practices in piston selection. One additional goal is the long-term analysis of processes used to fabricate race-type pistons.

Additional Completed Projects

University of North Carolina at Charlotte, Charlotte NC: Created polycarbonate prototype of propulsion screw for Virginia class submarine

TDP Electronics, Swannanoa NC: Created prototype of an electronics enclosure out of polycarbonate

Associated Packaging, Waynesville NC: Created plastic tray prototype out of polycarbonate for proof of concept

Ball Machine, Candler NC: Developed prototype and generated NC code for production of adjustable clamping device

Unicomp, Inc., Fletcher NC: Created polycarbonate prototypes for magnetic stripe readers used in field testing

Volvo Construction Equipment, Asheville, NC: Creation of airflow enclosure prototype for heavy trucks. The prototype will be used in field testing

Other Engagement Projects Initiated or Under Consideration:

Mother of Pearl Company, Inc., Franklin NC: Joe Culpepper. 3D constraint based modeling, tooling and fixturing design, and CNC programming project.

Watuga Opportunities Inc., Boone, NC: Development of 3D solid model, rapid prototype, and mold cavity

Provair Inc. Hendersonville, NC: Evaluation of performance of revolutionary water filter

Consolidated Metco Inc., Waynesville, NC: Rapid prototypes for evaluation of new products

Industrial Opportunities Inc., Andrews, NC: Development of automated system for production

Educational merit and benefits gained

The MST faculty at WCU believe the addition of engagement projects involving applied research have enhanced the learning opportunities for students. Students have received a great deal of experience from the implementation of knowledge in work environments as opposed to lecture and laboratory exercises only. Statements made by "traditional" graduate students offer insight into their experiences.

> We found out very quickly that everything does not always go smoothly as planned; thinking out-of-the-box and innovation becomes very important in the "real world." Because we were not directly employed at the company, we were able to offer a fresh perspective on the problems presented and present ideas that may not have been considered as possible solutions to the problems. We were uninhibited and attempted all viable solutions because of no real fear of failure, bias toward one solution, or the amount of time we could afford to spend on viability testing.

Working professional students have benefited by learning and applying the new knowledge daily at their place of employment. Feedback form their employers have been positive. Altogether, MST faculty members believe that students are better prepared to enter the professional workforce than past graduates. Managing live-project dynamics and working directly with practicing engineers have improved the student's professional maturity as well as their ability to problem solve in more creative and innovative ways.

New tooling and supplies purchased by companies for engagement projects have improved the engineering technology laboratories (graduate and undergraduate) at no cost to the institution; the equipment purchased can be used in future laboratory courses and engagement projects. Faculty have gained technical knowledge in current products and processes by mentoring students involved in projects. Additionally, engagement projects have helped to build stronger relationships with industry and government agencies.

Future directions

The MST program at WCU will continue in its endeavor to meet the needs of students, industry, and the region in which it serves. Due to the educational value and benefits to the region, a concerted effort to engage in projects that require creative and innovative solutions will remain at the forefront of the programs' mission. The program continues to undergo review for the purpose evaluating the success of meeting the needs of the region.

The development of a Millennial Campus will provide additional engagement opportunities for MST students. The primary mission of the 200 acre Millennial Campus is to provide a university-wide focal point for attracting and assisting regional businesses through the collective resources of the university. The involvement of all departments on campus is expected. As quoted from WCU's Center for Regional Development Web site:

Critical actions to support economic development, including:

- Acquiring property to promote business development
- Developing flexible site arrangements to achieve specific economic development objectives
- Providing services to businesses to promote their location or development
- Issuing revenue bonds (with Board of Governors approval) to support business development

- Engaging in public/private partnerships, developing joint use facilities, and co-operating with enterprises to promote economic development
- Incubating businesses[14]

Conclusion

Events in regional and global economies are changing the relationships between government, education, and industry. The challenges and problems facing regions of our Nation will require the collaborative efforts of each domain in order to solve those problems with robust holistic solutions. Graduate engineering/technology programs can provide intellectual and specialized equipment resources unlike any other sector of our societal structure. Through engagement, students benefit by gaining experience and live training while collaborating with working professionals in effort to develop creative and innovative technological solutions to problems. Additionally, faculty benefit by strengthening technical competencies and by keeping abreast of emerging trends and problems facing industry and our Nation. In turn, industry benefits by gaining a competitive edge and by fostering the professional development of future employees in their perspective fields of work; government agencies benefit from the solutions offered to solve the ever-increasing problems facing our Nation. The authors believe that engagement projects offer a unique win-win situation for all who are involved.

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