AC 2011-237: PARTNERING SMALL BUSINESS NEEDS WITH ENGINEERING TECHNOLOGY EDUCATION

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Abstract

Small businesses face extremely difficult times in the current economic climate. They are faced with international price competition, yet are unable to afford the very resources needed to help them become more competitive. At the same time, Engineering Technology education focuses on practical engineering methods, but has few opportunities to offer students practical case studies in which to apply their training. This is an opportunity to match these needs, and perhaps expand the potential employment base for our students.

This paper explores the development of hands-on, project-centered learning opportunities by applying engineering technology coursework to specific small business productivity and design problems. A case study illustrates why these needs are important, how they're symbiotic, their evolution, what was learned, and where it should be repeated.

Introduction

The products offered for sale by American retailers sometimes indicate that everything we buy is probably made overseas. These products imply that domestic manufacturing has become a faded concept. The truth is not found on consumer sales receipts. In fact, the United States is still the world's largest manufacturing economy, producing 21percent of all manufactured goods[6], and valued at $1.64 trillion[6] in 2008. The size of this amount is difficult to digest, but by itself, $1.64 trillion would represent the world's 8th largest economy[6]. This group of domestic manufacturers employed 9% of the total workforce, or nearly 12 million Americans[6]. But surprisingly, the U.S. manufacturing sector is dominated by small companies. Seventy percent of the 286,039 American manufacturing firms[6] had less than 20 employees in 2008. The largest sector (110,000 manufacturers) employed less than five, while the smallest sector (18,000 firms) had 100 or more employees[6].

That is the good news. The bad news is that it is harder and harder to maintain America's manufacturing dominance in the world. While our global market share has not changed more than one percent since 1980 (22%)[6], the foundation of our dominance is being eroded. America is not the world's highest quality producer, nor is it the least cost producer. It does not even have the largest percentage of technically-trained workers within its population. We are losing our leadership role in worldwide manufacturing. And we know it.

In October 2005, a 20-person committee acting under the direction of the National Academy of Science, the National Academy of Engineering, and the Institute of Medicine published a 16-page executive summary[5] titled "Rising Above The Gathering Storm." The research showed that "Americans are feeling the gradual and subtle effects of globalization that challenge the economic and strategic leadership that the United States has enjoyed since World War II. A substantial portion of our workforce finds itself in direct competition for jobs with lower-wage workers around the globe, and leading edge scientific and engineering work is being accomplished in many parts of the world. Thanks to globalization, driven by modern communications and other advances, workers in virtually every sector must now face competitors who live just a mouse-click away in Ireland, Finland, China, (and) India . . ." The committee also determined that multinational companies choose the locations of their manufacturing facilities based on the availability of qualified workforce, innovation talent, and the quality of research universities. They concluded that the remedy to this emerging competition is to focus national attention on the development of Science, Technology, Engineering, and Mathematics (STEM) educational programs. In 2010, the National Association of Manufacturers voiced its supporting view[7]; ". . . innovation is cited by manufacturing senior executives around the world as integral to their companies' success." Innovation is people-driven, and people who are skilled, technically-educated, and talented are the drivers of innovation in manufacturing.

In January 2006, discussion to remedy the eroding manufacturing base culminated in an announcement by President Bush of a ten-year federal assistance program[8] termed the "American Competitiveness Initiative (ACI)." This initiative was subsequently replaced by the "America COMPETES Act" in 2007, and later expanded by the "America COMPETES Reauthorization Act of 2010."[8] While these nationally broad-based programs have been effective, they often failed to connect the largest manufacturing sector with STEM education – small manufacturing companies. This oversight was addressed in October 2010 with President Obama's initiative[10]; "Skills for America's Future." The President identified the basic issue; "The idea here is simple: we want to make it easier to connect students looking for jobs with businesses looking to hire." The objective of the initiative is to connect employers and schools, and then help share the knowledge about what practices work best[2,10]. Small manufacturers especially need this help because they do not have the technical resources to spend on incremental process and product improvements. Where resources do exist in these firms they are notoriously utilized to solve time-critical problems affecting the survivability of the company. There are simply too many things to do by too few employees.

The Opportunity to Match Needs

Engineering Technology (ET) is a hands-on technical profession. It requires knowledge of mathematics and physical sciences that are obtained through education and practical experience. While the ET curriculum generally includes algebra, applied calculus and physical science, the content is not as theoretical as traditional engineering. Engineering Technology education is aimed at preparing graduates to develop and implement technology innovation; evidenced by the nearly 60% of classes that include laboratory content.

Laboratory exercises are designed to simulate manufacturing process and product design problems. While labs are critical to gaining technology experience, they are not engineering projects. The only engineering project exposure a student gets is usually the program's capstone course; the Senior Design. Here, the student is typically asked to state a problem, design and sometimes construct the solution, and present the results as the course deliverable. As the name implies, it is offered to seniors and typically in their last semester. Timing of the class often results in reduced benefit as the student rushes to complete the solution just to close out his or her college career. The benefit worsens when the project is not applicable to a job waiting upon graduation.

What is needed by an Engineering Technology student is exactly what is needed by small manufacturing firms; a non-trivial engineering project. ET students need it for the practical experience of applying engineering coursework. Small manufacturing firms need it to strengthen their competitive position in the global marketplace.

Case Study – Valve Flow Coefficient

In March 2010, a small manufacturer of solenoid valves approached our university for technical assistance to determine the flow coefficient (C_v) for a number of its products. Their valve design wasn't applicable to industry-standard C_v test methods, and they didn't have the internal expertise or facilities to develop an appropriate test. Under the guidance of their Fluid Power professor and one of the manufacturer's employees, three junior-level Mechanical Engineering Technology students volunteered to design and build the test equipment and perform the tests. The project began with a late-May meeting between the project team and valve manufacturer and focused on the valve design's problem with standard C_v test methods. Over the next seven weeks the student team designed and machined the detail elements, welded the frame, assembled the components, wired and plumbed the system, and calibrated the equipment. Product testing took another week, and preliminary results were presented to the manufacturer.

Researching the Flow Coefficient: The project team found that the flow coefficient (C_v) rating of a valve is used by fluid power designers to calculate circuit flow, and compare one valve design against another as part of the sourcing decision. As such, it is important that a valve manufacturer publish an accurate C_v rating in order to provide customers the needed application data. The team determined that C_v accurately predicts flow (Q) or pressure drop (dp), using the specific gravity (SG) of the fluid with expression[9]; $Q = C_V\sqrt{\frac{dp}{SG}}$. They also discovered that valve C_v is determined using a standard test protocol, FCI 68-2-1998, published by the Fluid Controls Institute[3]. The standard mandates that C_v must be determined using water (fluid) at 60^{O}F, and a valve pressure drop of one psid (bar). When valves are tested with water (SG=1) at the required pressure drop, the equation is simplified to establish C_v equal to the number of gallons (liters) per minute that flows through the valve[3,4], or; $C_V = Q$.

The teams' research determined that this test protocol works very well with direct acting valves; valves that only use the force of an electric solenoid to open the main flow port. These valves completely open at any pressure, and the internal cross-sectional geometry of the flow path is constant throughout the flow range of the valve. The valve design used by the small manufacturer is not direct-acting; it falls into a classification known as pilot-operated valves. Pilot-operation uses the pressure drop, or differential pressure (psid), to apply force against a spring-loaded plug, opening the main flow path. As the spring compresses, the plug gradually opens until full compression and complete opening. The team felt that problems could arise using the C_v test protocol when the required one psid (was not enough to fully compresses the spring and completely open the flow path[1,3]. They reasoned that as the spring compresses and the plug opens the flow path, the C_v changes. This condition would violate the underlying assumption for the C_v test protocol; that the valve's internal cross-sectional flow geometry is constant throughout the flow range. They felt this was not anticipated when the standard was developed.

Development of a New Test Protocol: In order to test for these hypothesized C_v changes, the team determined that a test apparatus had to accurately measure flow at differential pressures above and below one psid. They researched instrumentation suitable for low-level pressure and flow measurement and selected the appropriate devices. During an early concept meeting at the small manufacturer, the team agreed that the test apparatus should incorporate all of the requirements of FCI 68-2-1998 in its design, but also provide the accurate measurements at other differential pressures. The students and their professor returned to the university and began a series of brainstorming sessions to conceptualize and detail the test apparatus design. Two weeks of design iteration led to a formal Design Review meeting with the small manufacturer, and orders to purchase material were issued.

Building the Test Apparatus: The University has a well-equipped machine shop in the basement of the ET building that was used to construct the test apparatus. Two students with prior welding experience were assigned to build the apparatus framework. Under the supervision of the machine shop lab manager, they used band-saws, grinders, vertical mills, MIG welders and hand tools to construct and assemble the frame. Next, the meters, pump and water reservoir were plumbed and seven sizes of valve test assemblies were built. Each pipe size was threaded for the NPT connection of the valve body, and flexible water hose and barbed fitting connectors served as a rapid change-over connection to the test apparatus. The professor and one of the students built the controls enclosure, and the team wired the flow meters, pressure and temperature transducers, and pump motor. The test apparatus was ready for testing and calibration after seven weeks of construction.

Testing the Valves: Valve C_v testing started at the end of the seventh week. The valve test assembly was attached to the apparatus and flow adjusted to read one psid at the valve. C_v test data was recorded in student lab notebooks in a series of half-psid increments. Testing all of the valves took nearly a week to complete, and a preliminary report of the data analysis was given to the small manufacturer.

The Technical Report: The report clearly demonstrated that the industry test protocol FCI 68-2-1998 is not suitable for pilot-operated valves. Every one of the test valves showed changes to their C_v ratings as the differential pressure increased from 1 to 5 psi. The flow coefficient of a pilot-operated solenoid valve cannot accurately be stated using a single, standard differential pressure value across the valve. The report surmised that C_v for this type of valve is not constant; it changes as the valve's main port transitions from closed to fully open. It recommended that C_v be stated at maximum port opening and referenced as the maximum C_v, and flow below that differential pressure value should be charted.

Results of the Case Study

The small manufacturer took ownership of the test apparatus following the formal technical report. They indicated that the report would be used to initiate changes in FCI 68-2-1998 to include provisions to test pilot-operated valves at their fully opened condition. It is important to note that the small manufacturer would have probably not chosen to invoke this level of product testing without the availability of relatively inexpensive university resources. Traditional outsourcing of product testing is usually performed using existing industry standards and on available test equipment. If a new test protocol and equipment are needed, fees multiply quickly.

The students worked with a potential future employer to help solve a problem important to the business. When presented with a blank sheet of paper looking for an idea, they did not think they could pull it off. As the team discussed, designed and re-designed, the students realized they just might. When they overcame incomplete design assumptions and found the solution, they decided they actually could. The growth and confidence built over this two month project is seldom developed in a laboratory simulation. Confidence is an emotion, and this emotion sprang from overcoming their fear of failure and completing a non-trivial engineering project.

Recommendation to Repeat the Experience

If there are 200 thousand small manufacturers in America there are over 200 thousand opportunities to repeat this Case Study scenario. The small manufacturer depicted here is like any small manufacturer struggling to remain competitive in an increasingly global market. The pressures are numerous and accelerating; cost, quality, delivery, product enhancement, communication challenges, internet presence, new market opportunities, and others we're unaware of.

Yet there are few affordable technical resources available to these firms. Universities are brimming with displaced workers seeking to improve or attain technical skills. Students in ET programs go without needed internships, and sometimes even menial summer jobs. This is the opportunity to close the loop of unfulfilled needs. It is also the time to create a solution.

Summer Industrial Projects Program

Organization: Most university ET programs have an existing structure linking them with industry advisors and research grant opportunities. For example, our university has an Industrial Advisory Board which meets regularly with the ET administrators, faculty and members of our student body. Our technical outreach program is already the contact point for manufacturers with projects such as that described in this case study. Another example is Indiana's Small Manufacturing Assistance Program (SMAP), which works with small firms to provide assistance reducing their use of toxic raw materials, and pollution from the manufacturing processes. These concepts markedly expand contact by reaching out to the large and subserviced community of small manufacturers.

Timing: Summer is usually the best period for a program like this. Many students and academic mentors are available for summer projects. Neither group has curriculum requirements at this time, and university laboratories, libraries, and facilities are generally available for project activities. These activities should begin in May and end before August to avoid conflicts with academic schedules.

Projects: The project's length should be short duration and its outcome important to the small manufacturer. It should generally have small budget and include a company representative as a project team member. Projects may include small-scale capital equipment, fixtures or tooling construction. They may be technology upgrades directed at product, process, quality, or productivity improvements. They may also be computer or internet programming tasks, or even statistical studies of product and process performance or reliability. They may include computer aided design (CAD), drafting or engineering analysis (FEA), and perhaps even physical prototypes or simulations. Investigations into energy management and conservation are also project opportunities, as would be other studies similar in scope.

ET Staffing: Fifty percent of the ET student body consists of sophomore and junior-level students. Every person in an ET curriculum already possesses a combination of mastered and evolving engineering skills. The key to a successful project outcome is matching these skills with those of the other project team members, and assigning a project within their combined skill set and ability to master. ET students are attracted to projects that are stimulating, offer competitive wages and are associated with potential future employers. A university mentor and an industry partner are also needed to complete the roles of the project team.

Funding: A mutual relationship shares the burden of cost. There is as much benefit to the education of the ET student as there is to the small manufacturer. Synergy is a balance of needs, and both sides of that balance must contribute financially. Since the physical outcome of the project will reside within the small manufacturer, all of the materials used for a project should be borne by it. Since the human capital of the project resides with the university, it should bear that cost. The university has the unique availability to potentially compensate students with work-study allowances and academic credit hours. Additionally, a well-conceived program can attract grant monies available through STEM initiatives of the last decade.

Conclusion

As a result of this Case Study project, the small manufacturer found the technical solution it needed in two months. The student team members applied their knowledge from Engineering Technology classes including; Fluid Power, Introduction to Design, Machine Elements, Applied Statics, and Technical Report Writing.

But beyond course content, the students gained important first-hand knowledge of all the critical phases of a capital equipment project. They researched the industry C_v test standard and its applications. They participated in 'customer' meetings and helped develop the project plan. They designed and built a test apparatus. They tested product using their new test protocol. They used their lab notebooks to record the project experience and to later write technical reports. And most importantly, they became an Engineer for the first time.

References

1. American National Standard Institute, Instrument Society of America Standard. "Control Valve Capacity Test Procedure", ANSI/ISA–75.02-1998, sponsor Instrument Society of American, Research Triangle, 1998

2. Eric Gorski –AP, "Skills for America's Future", The Daily Item, October 5, 2010, http://www.dailyitem.com/homepage/x1274847682/Skills-for-Americas-future

3. Fluid Controls Institute. FCI 68-2-1998 "Recommended Procedure in Rating Flow and Pressure Characteristics of Solenoid Valves for Liquid Service", Fluid Control Institute, Inc., Cleveland, 1998

4. Joint Committee on Orifice Coefficients of the American Gas Association and the American Society of Mechanical Engineers. "History of orifice meters and the calibration, construction, and operation of orifices for metering", first edition, The American Society of Mechanical Engineers., New York, 1936

5. National Academies of Science, of Engineering, and the Institute of Medicine, 'Rising Above The Gathering Storm', October 2005, http://www.nationalacademies.org/cosepup

6. National Association of Manufacturers, "Facts About Manufacturing", http://www.nam.org/Resource-Center/Facts-About -Manufacturing/Landing.aspx

7. National Association of Manufacturers, "Education and Workforce", http://institute.nam.org/page/edu_workforce

8. U.S. Department of Education, "American Competitiveness Initiative", Feb 2007, http://www2.ed.gov/about/inits/ed/**competitiveness**/index.html

9. Vennard. "Elementary Fluid Mechanics", fourth edition, John Wiley & Sons, Inc., New York, 1961

10. White House Press Office, "President Obama to Announce Launch of Skills for America's Future", October 2010, http://www.whitehouse.gov/the-press-office/2010/10/04/president-obama-announce