

2008 Proceedings Papers

NAIT 2008 Conference
November 18-22, 2008
Nashville, Tennessee, Airport Marriott



Globalization of Technology

Imagine the Possibilities!

Table of Contents – Proceedings Papers

Administration

Globalizing a Technology Program via International Internships and Study Abroad in China _____	6
MEMS Education for Technology Students _____	11
Quality Systems Assessment Project _____	18
Setting the Foundation: Rekindling Interest in Science, Technology, Engineering, and Mathematics (STEM) for Promising Students _____	27
A Woman’s Worth: Recruitment and Retention of Women in Industrial Technology _____	2

Construction

Adding Green to the Curriculum: An Examination of Integrating Green and Sustainable Building Practices into the Construction Curriculum from Customers’ Viewpoints _____	33
--	----

Distance Learning & Internet

Web 2.0 at Work: Managing Knowledge in a Collaborative Web Environment for Product Realization _____	43
--	----

Electrical, Electronics & Computer Technology

Development of a Training System Integrating RFID Technology with a PLC _____	52
Incorporating Field Data Received From the Cypdiso-8 Computer Interface Card into Commercial Inventory Software Programs _____	58
Theory, Practice, and Systems - A New Approach to Teaching Wireless Communications with MATLAB and IT Guru _____	65
Undergraduate Research Experience in Mobile Robot Design: From CAD to Electronic Control _____	71

Management

Using Quality Management Systems to Meet Food Traceability Requirements of the Bioterrorism Act of 2002 (<i>Best NAIT 2008 Conference Proceedings Paper</i>) _____	81
--	----

Manufacturing

Academia’s Response to a Changing Environment: Are We Keeping Pace? _____	90
International Manufacturing: A Compilation of Technical Management Case Examples, Best Practices, Practical Issues, and Solutions for Manufacturing Educators and Practitioners _____	101
On-Line Cutting Tool Condition Monitoring System Developments in CNC Turning Center Using a Signal Decomposition Technique and a New Approach of Searching Artificial Neural Networks Architecture _____	106

Safety

Incorporating Health and Safety into a Senior Capstone Course: Critical Exposure for Future Industrial Leaders _____	116
--	-----

Index of Authors

A	
Mr. Joe Ashby _____	52

B	
Mr. Bill D. Bailey _____	18
Mr. Tramaine L. Blount _____	71
Dr. Jessica L. Buck _____	2
Dr. Jessica L. Buck _____	27
Ms. Vishwanthi Busannagari _____	58

C	
Dr. R. Neal Callahan _____	90
Mr. Mark R. Chandler _____	18
Dr. Don Chen _____	33
Dr. William W. Clyburn _____	52
Dr. Patrick E. Connolly _____	6
Prof. Clark A. Cory _____	6
Dr. William Cupples _____	58

E	
Dr. Immanuel Edinbarough _____	11

G	
Dr. Jess Godbey _____	116

H	
Dr. Garrett “Dave” Hunter _____	58

J	
Dr. James W. Jones _____	33
Dr. Martin P. Jones _____	90

L	
Dr. Chad Laux, CSIT _____	81
Dr. Samson S. Lee _____	106
Dr. Xiaolong Li _____	65

M	
Prof. Kellen R. Maicher _____	6
Mr. Ted B. Mattis _____	18
Ms. Elizabeth McInnis _____	2
Ms. Elizabeth McInnis _____	27
Dr. Douglas McWilliams _____	43
Dr. Jaby Mohammed _____	65
Dr. James L. Mohler _____	6

N	
Dr. Lisa B. Ncube _____	43

P	
Dr. Matthias W. Pleil _____	11

R	
Dr. P.N. Rao _____	11
Dr. Kuldeep S. Rawat _____	71
Mr. George B. Riddick _____	71

S	
Dr. Marvin I. Sarapin _____	6
Dr. John W. Sinn _____	18
Mr. Rathel R. Smith _____	90

W	
Dr. Phillip S. Waldrop _____	101

Administration



Globalization of Technology

Imagine the Possibilities!

A Woman's Worth: Recruitment and Retention of Women in Industrial Technology

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Abstract

Women are continuing to shatter glass ceilings in the ever-changing global workforce; however, advancements in the managerial and technological fields pivot on the capacity to endorse these varied and inventive segments. Modifications to secondary and post-secondary education may ignite interest of female students and encourage their participation in such disciplines. Gender dynamics in the workforce reveal evidence of a moderate inclination in the Industrial Technology field to promote such change. In this paper, there will be an explanation of the moderate participation of female participation in Industrial Technology; secondary preparation for the discipline and postsecondary recruitment and retention; gender generalization and how to overcome it in the classroom; curriculum and program modifications to enhance gender diversity; gender dynamics in the workforce and how females are affected; and strategies that will increase participation in IT academic programs and the workforce.

Introduction

Industrial Technology has become more diverse in its areas of emphasis, which entails computer technology, construction/architectural technology, technology management, manufacturing, and much, much more. As the discipline expands to meet the challenges of a global workforce, it may appeal to persons varying in career aspirations, ethnic backgrounds, and gender. Women are increasing their presence in the workforce, but their still remains a moderate representation of females in Industrial Technology. According to the National Institute of Women in Trade, Technology, and Science (<http://www.niwtts.org>), women represent only 7.2% of corporate officers in Fortune 500 technology companies. In addition, there are 11.2% of women corporate officers transversely in industry. The demographic report from the National Association of Industrial Technology (<http://www.nait.com>) revealed that the Industrial Technology female faculty makes up only 13.5% 2007. In efforts to continue in the progression of integration into this area, females must be introduced into this discipline of study and made aware of the career opportunities early in their academic matriculations.

Secondary and post-secondary educational institutions are amplifying initiatives to encourage female participation in academic programs, such as Industrial Technology, that were once deemed as male dominated. According to Appiah (as cited by Buck, 2004) traditional disciplines for males include; science, technology, engineering, and mathematics (STEM). Females, on the other hand, were encouraged to pursue liberal arts disciplines such as educations and social sciences. Such perceptions may impact and direct career paths, especially in male or female students selecting a career in Industrial Technology. This should be done by having increasing female faculty, which would serve to draw more female students. According to Buck (2004), some female students do not choose Industrial Technology because the lack of female instructors. It was revealed that female students desire a female faculty in which to identify. Nelson (2004) contended that efforts to alleviate this issue is to develop more female faculty within the existing student body who are apart of growing Industrial Technology Programs. Female student should be encouraged to pursue careers and should be sponsored to pursue advanced degrees in this respective area through department-sponsored scholarships.

With Industrial Technology being a thriving discipline that is forefront of a flourishing archetype, educational administrators, curriculum developers, faculty/instructors, and employer (i. e. current or potential), are taking advantage of opportunities to welcome females into such non-traditional areas. In regards to curriculum, Marshall (2000) asserted

that Industrial Technology programs were being directed toward preparing students for technological and management careers; thus, supporting female participation. While female representation in Industrial Technology continues to rise, strategic action plans must persist in order to have a consistent inclination. There must be a renaissance of the Industrial Technology programs to become more appealing to the females. According to the Chronicle of Higher Education (as cited by Buck, 2004) there are improved recruitment and retention strategies for females in technological and scientific areas. Opportunities to encourage female participation should include early introduction, on a secondary level, of the Industrial Technology discipline, secondary summer enrichment programs, mentorship of female students by female Industrial Technology faculty and practitioners, and awareness of career opportunities. Such strides should assist in increasing female representation to assuage perceived historical barriers and stereotypes that affected moderate participation.

Female Participation in Technology

Since the beginning of time, females have been major contributors to technology. Females have been proven to be true creators and innovators that worked effectively with male counterparts. Slocum (as cited in Nelson, 2004) went on record of stating the females were among the first inventors, and they developed instrumentation critical for the continued existence of the species. Nevertheless, technology professions persist as a male-dominated despite female progress in the industrial arena. In addition to females utilizing technology at home and in industry, Nelson further indicated that females emerged to the forefront of industry during World War II. During this time, females dominated the garment, textile, and food processing industry to support their families while male counterparts were deployed. Females for the most part received “on the job training”, though the demand for formal education had begun to escalate.

To promote a formal education in the industrial discipline, Mary McLeod Bethune pioneered initiatives to begin the Daytona Normal and Industrial Training School in Daytona, Florida, which provided training in respective areas such as industrial and economic skills, home-making, millinery, and other crafts (Buck, 2004.) This rapidly grew from an institution of five females to a co-education secondary institution, blossoming to Bethune-Cookman College. Through the school's transition, it incorporated science, business, mathematics, English, and foreign languages into the curriculum. This was done to better equip female students for a male dominated and multi-facet workforce, and females would be better prepared for administrative and management positions (http://en.wikipedia.org/wiki/Mary_McLeod_Bethune).

Females Evolving in Management

Historically, males have served as administrators and managers. Industrial Technology is an academic discipline designed to prepare for technological and/or management oriented professionals for employment in business, industry, education, and government (<http://www.nait.org>). McGowan (as cited in Buck, 2004) added that Industrial Technology focuses on the management, operation, and maintenance of complex technological systems. Since Industrial Technology is a management oriented profession, Orr (as cited in Buck, 2004) contended that females exhibited reluctance to manage large organizations or male counterparts. Kasi (1999) reported the management arena, traditionally, was not welcoming to females. Although Orr (as cited in Buck, 2004) indicated that studies showed females manage as well as their male counterparts, Kasi (1999) stated that female managers may be deemed as either overly aggressive and too demanding or passive and indecisive. With such perception, Bostic (1999) indicate that females were paid less than male counterparts (i. e. 78 cent to the male dollar earnings). This appeared to be evident that females had not achieved demographic parity or occupational equity with males (Kasi and Dugger, 2000). Nevertheless, academic programs are beginning more initiatives to minimize or alleviate this aged old problem.

Preparation for a Technological Workforce

Secondary education stands at the vanguard of promoting change in field of Industrial Technology. The National Council of Research on Women (as cited in Washburn & Miller, 2004) revealed that mentorship is essential in supporting women in science and technological fields. Washburn and Miller indicated that having role models who can put a “human face” on science, engineering, and technology will aid in establish a productive learning community that is centered on common interests.

Furthermore, the Minnesota Career and Technical Education: Perkins Nontraditional Careers' Final Report (2008), encouraged local secondary and post-secondary institutions to heighten awareness of gender bias in education and career options; increase awareness of educational and vocational options; increase understanding of the connection between secondary and post-secondary educational electives with career objectives; and provide an introduction to the

business community and the inter-relatedness of workforce preparedness to the economy. Research from this project also affirmed the importance of progressive inventiveness such as providing clear description of Industrial Technology areas include welding and fabrication, construction, and architecture; identifying IT related to industry and engineering; and inviting lunchtime speakers for local secondary schools. Field trips also served an instrumental part to encourage females to participate in Industrial Technology disciplines. These are benchmarks to effective recruitment and retention methods.

Effectives Recruitment and Retention Practices

Secondary and postsecondary institutions have numerous methods that reflect strategic plans of action to recruit and retain females into Industrial Technology. A study conducted by Buck (2004) revealed that effective recruitment practices included: distribution of literature on Industrial Technology Programs to high schools and community colleges reflecting male and female participation; visitations to high schools and community colleges; and presentations at recruitment fairs and college freshman orientation describing the Industrial Technology program, its requirements, and career opportunities.

Additionally, the results from Buck’s studied revealed that effective recruitment practices from the NAIT Accredited Industrial Technology programs in Mississippi included: letters and emails to potential students describing the Industrial Technology discipline and opportunities (e.g. scholarship, recruitment events, conferences and competitions, and career opportunities), distribution of literature to high schools and community colleges reflective of male and female participation in the discipline, visitations to high schools and community colleges, presentations during freshman orientation and high school and community college recruitment activities, informative and interactive websites that highlights the programs accomplishments and student centeredness. Family, friends, and female faculty also have an important role in encouraging females to pursue an Industrial Technology degree. However, inventive approaches were also implemented to retain students in the programs.

Furthermore, Buck’s study reported that effective retention practices included: promotion an “unbiased” learning environment that appeals to both male and female students, interaction of Industrial Technology alumnae to contact current female students, and information for female students regarding advanced degree education and career opportunities. In considering the impact of recruitment and retention, Industrial Technology administrators, faculty, and staff must render their endeavors helpful and continue to identify techniques to enhance efforts (see Table 1).

Table 1: Effective Recruitment and Retention Initiatives of NAIT-Accredited Institutions in MS

Recruitment Initiatives	Retention Initiatives
Letters and emails to potential students	Unbiased/gender friendly learning environment
Distribution of Industrial Technology literature	Interaction with female I.T. alumnae
Visits to high schools and community colleges	Information regarding I. T. opportunities
Presentations during orientation and etc.	Advanced degrees and career options
Informative and interactive websites	
Encouragement from family, female faculty, etc.	

The Significance of Retention for Female Faculty and Students

Retention is not only fundamental in keeping female students well informed of Industrial Technology opportunities; however, female faculty must have an avenue of support. A study by Washburn and Miller (2004) found that dinners, retreats, and other outings were influential in developing a strong network for female faculty in technological disciplines, and it provided opportunities to brainstorm, propose ideas, and establish working relationships. Washburn and Miller also contended that the development of a living-learning center would be beneficial for female students “to study together, live together, and take classes together” (p. 164). The additional function of the living learning centers is the have upper-class students (e.g. graduate, seniors, juniors) tutor and mentor the lower-class students (e.g. freshmen, sophomores, and transfers). Moreover, Washburn and Miller asserted that such a community would foster a supportive environment

where females would be able to help sustain each other through graduation, and they would ascertain lasting networks of colleagues who would be resourceful in future endeavors.

Conclusion

This research identified the existence of generalization in Industrial Technology programs and in the workforce. Although females have encountered stereotypes and hindrances in the male-dominated discipline, great strides have been made to strengthen their presence in the Industrial Technology arena. Nevertheless, the aim is to encourage the continued growth of female representation, and to maintain policies that will promote enlightenment toward recruitment and retention.

Industrial Technology should no longer be deemed as uncharted or occasionally charted territory for females, but it must be considered as a “gender friendly” domain. Nelson (2004) rendered that there is a sense of urgency for female recruitment in this area, because females lead in securing high tech jobs. Females must be given the proper training, technical and managerial, and given fair opportunities for advancement. Females will be integral decision makers in technological arenas. With this in mind, females should be key targets for recruitment by being well informed about scholarships, advanced degree opportunities, internships and co-ops, and careers. Yet, female faculty is a pivotal point of attracting more females into the discipline. Kasi and Dugger (2000) established that gender role categorizing was the origin of male domination. Nelson (2004) pointed out that numerous Industrial Technology faculty and staff had adopted this point of view. If this mind set is endorsed within thriving Industrial Technology programs, this negatively impacts the endeavors toward a gender diverse faculty and student body. Industrial Technology administrators, staffs, and practitioners, must continue in the progression of promoting a female or “woman’s worth” in the discipline and being persist to institute gender equity.

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Globalizing a Technology Program via International Internships and Study Abroad in China

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Abstract

As the inexorable trend towards globalization continues, providing an international perspective for higher education programs becomes a vital component for success in the 21st century. Along with several other developing nations, China will continue to play an ever-increasing role on the world stage. To integrate into this new world perspective, academic institutions in the United States must overcome several deficiencies in adapting educational programs to a global mindset. By putting more resources behind international initiatives and encouraging a deeper understanding of our neighbors abroad, the U.S. will prepare its students and faculty to be competitive in the near future. This paper details an effort to start one such initiative in the Department of Computer Graphics Technology at Purdue University and the lessons learned from its inception. The paper concludes with a discussion of developmental and implementation strategies formulated through on-site visitations and interviews with representatives from several Chinese industrial partners.

Background

A Brief History of Academic Partnerships with International Industry

Collaboration between international industrial partners and academic institutions in the United States is by no means a new concept. To some degree, foreign companies have worked with U.S. schools practically since their inception, not a surprise given the diverse roots of our immigrant nation. Exchange programs and study abroad initiatives have been common practice for decades, and collaborative research activities have a long history that is well-documented in the literature (Floyd, 2003).

In the years following World War II, focused initiatives in international education became commonplace as American leaders recognized the need to maintain a global context for future students. The 1946 Fulbright Act exemplified this postwar school of thought, an act that provided legislation to encourage funding for international education and research through the sale of surplus military equipment (Funk & Wagnalls, 1979). Unfortunately, this international trend waned somewhat with the conclusion of the Cold War, as the importance of international affairs seemed less pressing than many domestic concerns of the remaining superpower (*An International Education Policy*, 2007). The fact that the majority of international efforts tended to be Euro-centric further diminished the effectiveness of establishing a broader international perspective.

Recent Stimuli for Higher Education Globalization

Several factors in recent years have contributed to a newly reinvigorated interest in global awareness, especially in non-European countries. In addition to a post-September 11th environment that has underscored an important need for international context in terms of politics and national security, the rapid development of emerging market nations such as India, Indonesia, and China have also contributed to this interest. The bright economic and developmental outlook for these countries is engaging, to say the least, and offers higher education institutions the potential for many new partnerships and collaborative opportunities. Given the fast-paced nature of these developments, there seems to be a general sense of urgency within the academic community to lay the appropriate groundwork for fostering new relationships and research partnerships.

China: Unlimited Potential

Perhaps no country on Earth typifies the potential of developing nations more than China. Comprising one-fifth of the world's population, the obvious potential of the Chinese society and economy is staggering. Possessing an average annual GDP growth rate of more than 10% for the last quarter-century and the second largest economy in the world after the United States ("Economy of the People's Republic of China," 2007), this potential seems well on the way to being realized. Advances and growth in the Chinese academic environment are equally impressive, which adds to the appeal of establishing new collaborative relationships.

Obstacles to Overcome in Regaining a Global Context for US Education

Unfortunately, the previously mentioned complacency of the post-Cold War era has left the United States in a rather unenviable position as American students continue to fall farther behind the international curve. A recent report issued by the Committee for Economic Development clearly indicates how the American educational system still fails to produce graduates capable of succeeding in the global workforce (*An International Education Policy*, 2007). In comparison to other countries, very few American students speak other languages or are aware of international cultural issues, current events, and many other areas pertaining to foreign affairs. Without this skill and knowledge, it is reasonable to speculate that American students will continue to fall behind at future detriment to U.S. economic and educational standing. As such, new efforts and resources must be directed to provide U.S. students with the tools needed to compete in the global economy.

Industrial Internships and Study Abroad Programs: A Means of Righting the Ship

Industrial internships and study abroad programs are familiar mechanisms for helping students acquire important global skills during their college careers. The benefits of these programs are well-established in a variety of fields and are widely recognized by educational institutions, international corporations, and governments around the world (Peacock, 2005.) The hands-on and immersive experience they provide allows students to fast-track their global education in unique and effective settings that provide many opportunities that cannot be attained in the States.

The Relationship between Global Awareness and Student-Learning Outcomes and Competencies

From an educational perspective, the effects of globalization on the landscape of learning objectives and competencies are dramatic. International technologies, standards, and content must now be included when developing and implementing curricula and the corresponding student outcomes. While in the past it has been acceptable practice for students to adopt a primarily U.S. paradigm, today's students must pursue their objectives within the larger context in order to remain competitive. This is especially true considering the advent of the information age, where communication over vast distances now occurs at the click of a button.

Program Overview

Foundations of an Industrial Outreach and Exchange Program

Over the years many international educational initiatives have been conducted at Purdue at the departmental, college, and university levels. Purdue boasts a strong Study Abroad program that features over 200 separate initiatives, with many of the faculty in the College of Technology having established similar programs with European countries such as Poland and Russia. Within the department of Computer Graphics Technology, a Chinese cultural exchange program has already been established as of 2007. However, most of these programs fail to address the industrial aspects of cultural exchange, which led to the authors' proposal of the China Industrial Outreach and Exchange Program (CIOEP.)

The primary mission of the CIOEP is to explore and foster collaborative relationships between students and faculty in the College of Technology (COT) at Purdue University and targeted industrial partners in China. Originally funded by a Purdue Study Abroad and International Learning (SAIL) seed grant, the program was designed to focus primarily on industrial aspects of education and collaboration rather than solely targeting cultural exchanges. While cultural exchange is obviously an important element of any globalization initiative, the authors determined that similar programs focusing on cultural education already existed at Purdue and that developing another would be redundant. Given the importance of industrial research partnerships within the College of Technology and the tremendous growth in the Chinese industrial sector, an industrial exchange program provided the next logical step.

In addition to the overarching mission of industrial exchange, other goals of the CIOEP include:

- Investigating the possibility of placing student interns in China-based corporations.
- Assessing the needs of Chinese companies and how those needs might be filled.
- Establishing common grounds in learning, discovery and engagement both with Chinese corporations and academic institutions involved in industrial collaborations.
- Better understanding the Chinese educational environment and associated peer institutions.
- Establishing a financially sustainable program through strategic marketing, identification of funding institutions, and adoption of corporate and academic partners.

Assessment

In an effort to assess the potential for the fledgling industrial program, two faculty representatives from Purdue University visited a variety of industrial and academic institutions in city of Beijing, China for ten days in the spring of 2008. Although observations from a single city in a country as large as China may be limited to some degree, the participating faculty determined that a more thorough investigation of a single target city would be more beneficial to the assessment. One of the reasons for this conclusion was the fact that other COT faculty had recently performed similar fact-finding missions within China over the last several years. As one of the largest cities within China and with its reputation as the central hub for commerce and industry, Beijing was determined to be the ideal location for assessment of the CIOEP program.

Meetings with Corporate Representatives

The primary point of contact for this assessment visitation was a distinguished COT alumnus, Dr. Jane Liedtke, and her company, *Our Chinese Daughters Foundation* (OCDF.) Originally founded as an organization that facilitated the adoption of Chinese children, OCDF has since expanded its mission to include cultural exchange and Chinese contact facilitations for academic and industrial partners. From the standpoint of facilitating the program assessment, OCDF proved to be an invaluable resource not only in terms of navigating the complex channels of Chinese culture but also in initiating contact with target institutions and individuals within greater Beijing. Dr. Liedtke's extensive experience as a former technology faculty member at several U. S. university technology programs was similarly advantageous.

Working in concert with OCDF, participating faculty met with representatives and officials from a variety of corporations and academic institutions over the 10-day period. These entities were selected on the basis of commonalities with the Department of Computer Graphics Technology (CGT) and College of Technology (COT) at Purdue University. Larger companies included Boeing, IBM, and Caterpillar. Faculty members also met with representatives from smaller companies such as United Technologies, Universal Idea Consultants, ChinaBeat Design Studios, Better Chinese Design Studios, and the MAD Architectural Studio.

As previously mentioned, academic institutions were also targeted for assessment and were similarly identified based on commonalities with the CGT department and COT. These programs consisted of the Institute of Digital Design, Beijing Institute of Graphic Communication, and the Department of Information Design at Tsinghua University. Other meetings included interviews with representatives from the American Chamber of Commerce in China, the U.S. Information Technology Office, and the Pacific Islands Forum Trade Office.

Assessment Insights

The 10-day assessment visitation proved invaluable in providing information to determine the feasibility and future direction of the CIOEP. Although considerable research and investigation had been conducted prior to the visitation for the purpose of developing the CIOEP proposal, the authors contend that on-site visitation was absolutely critical towards obtaining a better understanding of the Chinese climate in which the CIOEP would function.

Obstacles to Industrial Partnerships and the CIOEP

Preliminary discussions with industry representatives were initially discouraging, especially when discussing the possibility of placing U.S.-based students in Chinese internships. According to many of the representatives interviewed, the inherent limitations in placing U.S. students outweighed the potential benefits, with the language barrier being the most-cited obstacle. Speaking Mandarin or some other Chinese dialect is not only critical to functioning within most China-based corporations, but also to the day-to-day living conditions in a city as dynamic and unique as Beijing. This culture shock combined with the considerable communications difficulties most American students would face led to the consensus that placing interns would be difficult at best.

Another obstacle included the proposed duration of the internships in question. According to industry representatives, 3-6 month internships would not be a cost-effective solution for Chinese corporations. Those interviewed shared the opinion that only those students with long-term aspirations for living in China would be worth the cost and investment. This is especially true considering that the tremendous expansion of Chinese economy, industry, and academia in the last 25 years now provides countless numbers of qualified local student candidates. Hence, the questions often boiled down to the practicality of recruiting students from thousands of miles away versus those that are, quite literally, “in their own backyard.”

The third obstacle that was most often cited referred to cost of living differences between China and the U.S. Most representatives expressed the concern that few U.S.-based students would be willing to go through the considerable trouble and expense of relocating (even temporarily) to China in order to earn far less in terms of payment related to similar experiences at home. Given the current status of the U.S. economy and the expenses those students would incur, this argument appears to have some merit.

However, while the obstacles to placing interns cited were indeed daunting most representatives stated that accommodations could be made in placing U.S. interns if they met some or all of following criteria:

- Student is of Chinese descent or has previously lived in China for an extended period.
- Speaks Chinese (Mandarin or whatever dialect is required.)
- Student has long-term aspirations for living in China.
- Student has had previous state-side company experience and now seeks experience with the same company in China.

Given that Purdue University has a strong population of Chinese students, these accommodations were encouraging to a certain degree. Although the prospects for those students lacking any prior connection to China would certainly be limited, the door for potential future internship placement was still open. Combined with the generally positive reception to the idea of other forms of exchange between U.S. academic institutions such as collaborative research and engagement projects, the prospect of future partnerships with Chinese corporations seemed hopeful.

Building on Discoveries: Potential Strategies

Upon conclusion of the CIOEP visitation, it was determined that insight gained from this assessment would be applied in two primary ways. First, the knowledge gained would be applied to the continued development of the CIOEP itself. Secondly, the information would be used to suggest and adopt the appropriate changes to the relevant curricula, learning outcomes, and student competencies in the CGT Department at Purdue University.

Developing the CIOEP and the CGT Curriculum

Based on the information obtained in the assessment visitation, several strategies were formulated that would be used in the continued development of the China Industrial Outreach and Exchange Program and the curriculum of the CGT department. These strategies included:

- Reducing the importance of placing interns and enhancing the focus of creating new collaborative research partnerships that can be conducted via distance.
- Recruiting students of Chinese descent or experience when internships become available.
- Eliminating redundant efforts amongst faculty and finding common ground on which to consolidate similar exchange programs.
- Encouraging students to take elective courses in the Chinese language.

- Identifying areas in the existing curriculum where globalization can be effectively integrated, and actively working to modify or enhance course competencies and student outcomes in order to provide a better fit with the global paradigm.

Summary

The tremendous potential benefits of industrial exchange with China will continue to be critical for the development of students and faculty in the United States. As the Chinese economy and infrastructure continue to grow in the coming years, increasing importance will be placed on understanding the global perspective and the role we play in it. Although there are several deficiencies that must still be addressed in order to obtain this understanding, these problems are not yet insurmountable.

Curricula, student outcomes and competencies must be modified to encourage and support these international programs and initiatives. By making appropriate changes to the looking glass with which students view their academic careers and the methods by which faculty facilitate the development of those careers, the outlook should be encouraging. By understanding the strengths and limitations inherent to the exchange of ideas and practices between two countries of such broad distinctions, U.S. institutions of higher education can make the appropriate changes to ensure that American education adapts to the 21st century model.

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MEMS Education for Technology Students

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Abstract

Micro Electro Mechanical Systems (MEMS) or simply Microsystems are about tiny micro electro mechanical devices. These devices are finding applications in consumer products such as automobiles, communication devices and medical devices. Microsystems are finding rapid growth in a variety of applications and usage. This prompts the need for a well educated and trained work force to sustain the growth of this nascent technology. This paper explores the opportunities and ways to incorporate Microsystems curriculum in Engineering Technology programs.

Introduction

Micro Electro Mechanical Systems (MEMS) and Micro Systems Technology were developed in parallel with the semiconductor industry and share many of the manufacturing and design processes. Microsystems devices include micron-sized components smaller than the diameter of a human hair. These systems can sense, think, communicate and perform complex tasks. Established micro devices include inertial sensors (accelerometers) used in automotive navigation and safety, air bag deployment, anti-skid and anti-rollover systems. Ink jet print heads and micro-optical display systems are another example of micro fluidic and micro-optical (MOEMS), high production volume devices.

Even though many of the established products produced are based on surface micro-machining methods and utilize classic semiconductor fabrication technologies, MEMS fabrication techniques are also embracing methods and materials not typically found in semiconductor manufacturing including: micro based hot plastic embossing and molding, bio compatible materials for BioMEMS, bulk micromachining and LIGA (Lithographie, Galvanoformung und Abformung). This requires the technologist and engineer working in Microsystems to have a multidisciplinary, broad education while also being adept at modern manufacturing methods to be successful and sustain the current growth level of this emerging technology.

The continued growth in Microsystems or MEMS has prompted universities and colleges across the nation and globe to develop graduate-level research programs as well as introductory undergraduate courses in engineering and technology with topics including MEMS design and fabrication methods. A steady stream of highly skilled engineers and technologists produced in this field is critical for the United States to maintain its competitive lead in Microsystems technology.

One of the major problems with the adoption of MEMS related courses at the undergraduate curriculum is the need to cover a broad spectrum of introductory topics that are essential in understanding the essential concepts and principles. Also there is the need to have sufficient access to design, simulation and manufacturing of these MEMS devices to stimulate the interest in the students. If the students get excited at an early stage, then there is a good probability that they would pursue a career in MEMS related programs. Analysts at Lyon, France-based Yole Development (www.yole.fr) estimate the global market for MEMS devices at \$5.26 billion in 2006, growing to \$9.86 billion by 2012.

Dr. W. David Williams former director of Sandia's Microsystems Center, says "I honestly believe that [MEMS] are the new way to keep the country safe" [1]. Williams isn't alone. "The government has its hands on almost every area of [MEMS] research, from cars to optics," says Eric Pearson, director of the Applied Physical Sciences Laboratory at SRI International, a Silicon Valley group that has worked closely with the military for more than 30 years. "They're watching this area very closely [1]."

The government is spending nearly \$200 million per year on MEMS research through two agencies: Sandia and DARPA, the Defense Advanced Research Projects Agency, which is responsible for funding cutting-edge military technology. Unlike DARPA, which is only a funding operation, Sandia is a research lab, a maker of MEMS. The top MEMS product manufacturers with estimated annual sales of US \$200 million as per Yole Development are shown in Figure 1. The top players as can be seen from the figure are those with their strong presence in the inkjet printer manufacturing and optical displays.

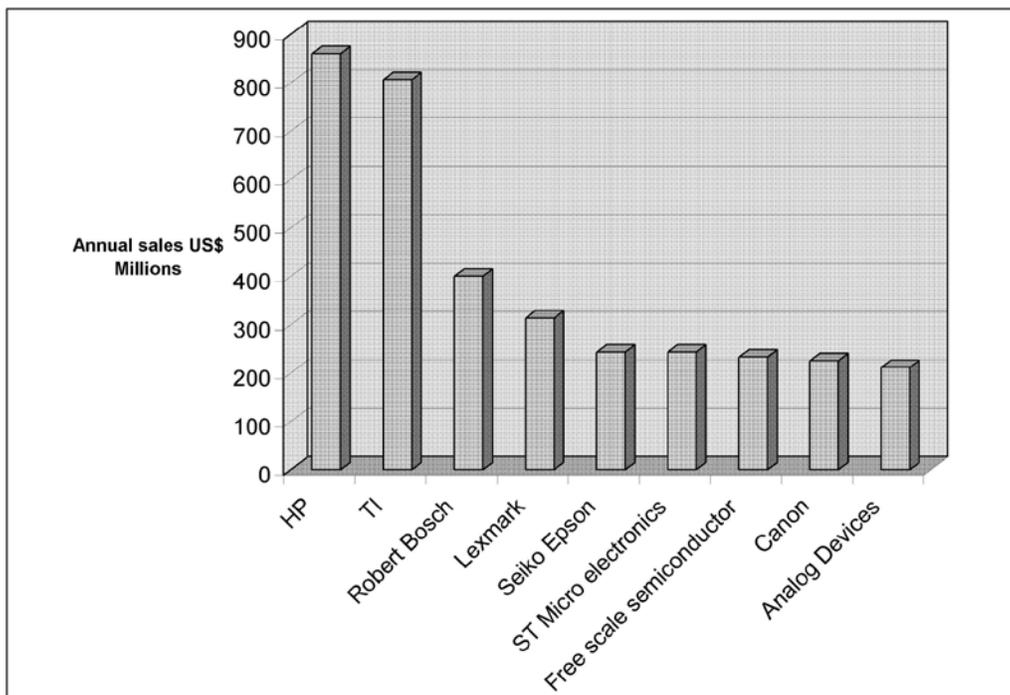


Figure 1. Top MEMS manufacturers in the world with annual sales above US\$ 200 millions (Redrawn with data from <http://www.i-micronews.com/upload/Micronews/images/top30prel.jpg>)

Core Technologies in MEMS

The continued growth in Microsystems or MEMS requires that the industry have access to labor force with a wide range of skills and knowledge in a variety of disciplines that are directly applicable to fabrication and design. There is a profound need for standardized source of educational materials and technological support including training for academia and industry so that these programs can be made more readily available. To this end, there is need to analyze and define the core competencies and curriculum requirements for this exciting technology in the applied engineering programs. Engineering technology programs are well suited for this because of their combined approach to the engineering fundamentals as well as the practical hands on approach.

Design and Simulation of MEMS

MEMS are designed by the creation of individual 2D layers and stacking them to create 3-D structures of varied complexity. In most cases, these MEMS devices are manufactured from rectangular or circular diaphragms whose thickness is constant and of the order of a few microns [2]. The development of high-performance diaphragm structures is of critical importance in the successful realization of these devices. In order to increase the sensitivity, the diaphragm thickness should be thin to maximize the load deflection response. On the other hand, a thin diaphragm under high pressure may result in large deflection and nonlinear effects that are not desirable. It is therefore important to characterize the relationship between diaphragm thickness, deflection, and sensitivity, both analytically and experimentally in order to establish the design guidelines for micro pressure sensors.

There are a number of commercial software packages available that provide designers with libraries to make use of proven designs. Many of these MEMS design tools provide students and designers with visualization capabilities for enabling rapid changes and review, so that the designs have a higher probability of resulting in functional working devices. It is also possible to use the conventional CAD systems to simulate the MEMS fabrication process to a limited extent. The Sandia National Laboratories University Alliance Program allows participating colleges (including two-year schools) to acquire the SUMMiT V software which enables the users to design to the Sandia MEMS surface micromachining SUMMiT V process. This software sits on top of AutoCAD and the perpetual 50-seat license costs only \$5k which makes it particularly attractive (see: <http://www.mems.sandia.gov/ua/>). Figure 2 shows the 2D and 3D views of a micro-designed gear and transmission. Note that the gear teeth are approximately 8 micrometers in width, about the size of a red blood cell.

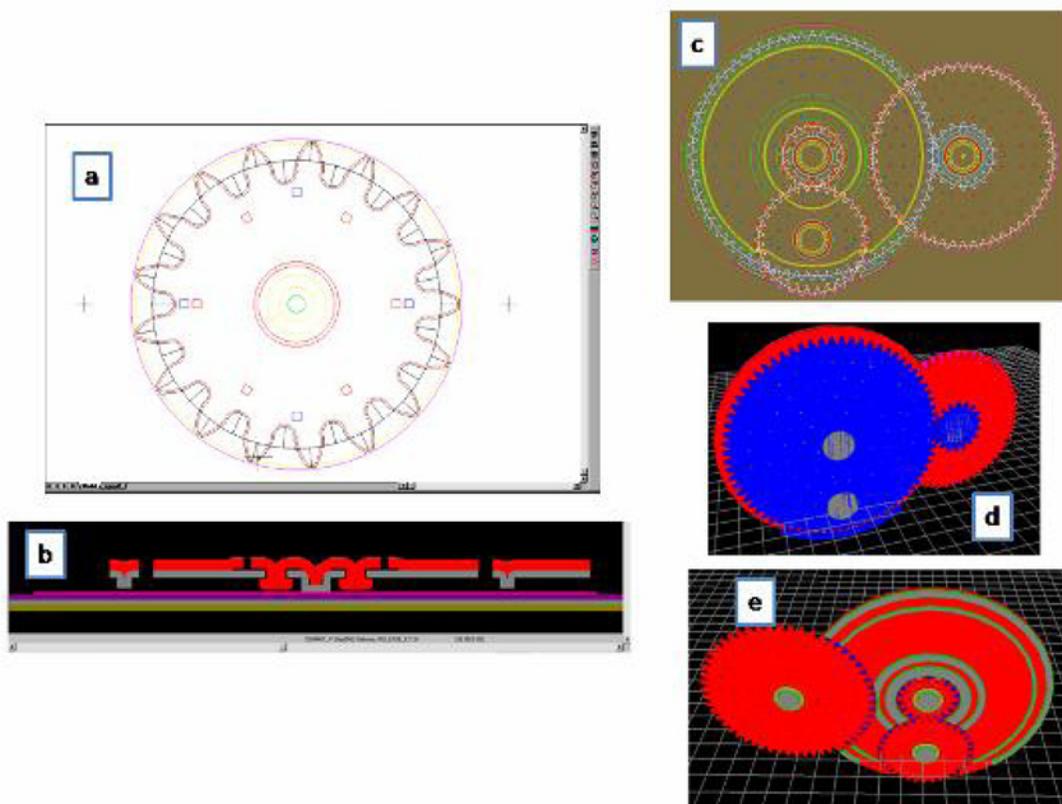


Figure 2. An example of visualization tools included in most design software, in this case the Sandia National Laboratories University Alliance SUMMiT V package. Parts (a) and (b) are screen images of a gear in 2D Layout and 2D Cross-sectional viewing modes. Part (c) through (d) show a gear transmission, (c) 2D Layout, (d) 3D visualization, top view and (e) 3D bottom view.

MEMS Fabrication

MEMS fabrication and packaging draws heavily from standard elements of semiconductor manufacturing methods. There are a large number of developments which have evolved in semiconductor manufacturing that has been leveraged in the MEMS fabrication. MEMS fabrication technology is not only about size and making use of silicon for building high-performance mechanical, small application devices, but, contrary to popular belief, these technologies are about the emergence of new manufacturing methods that allow for the manufacturing of complex electromechanical systems using batch fabrication techniques and coupling them with micro-electronics [3].

MEMS Testing

Since the early days of the IC industry, wafer-level testing has been possible using precision-controlled wafer probers to step from die to die on the wafer, making electrical contact using needle probes. Over time, the requirements to accomplish this testing have become more severe, requiring more sophisticated probers and probe cards. Testing MEMS devices requires the probing of not only electrical characteristics but also mechanical properties. In addition to voltage, current, resistance, capacitance and the like, the MEMS designer and fabricator needs to understand how to measure and characterize mechanical properties and responses including x, y, z deflection, stress, strain, velocity, acceleration and resonance.

Wafer level testing is currently done in characterization research and in production to avoid packaging bad parts, thus reducing cost. The testing of these devices requires MEMS-specific test strategies, equipment, and designs. Dynamic interference microscopy is utilized to accurately measure out of plane motion (z-axis) and strobe methods for x-y motion. Nano force measurement tools are also a common add-on allowing the research to measure strength of micro structures. Motion video is also a key tool employed.

Advanced MEMS Testing

Test feedback to the design and process engineer is critical for successful development and should include device dynamic behavior results, system parameter responses, and micro material properties. An essential part of a more effective micro device development is high-speed visualization of the dynamics of MEMS structures (www.bsac.edu). DARPA is funding the development of advanced technologies that enable up to 10 Gigabit-per-second data streams between end systems over a shared, wide-area network infrastructure. This project will extend the capabilities of the optical-characterization facilities available at the specified location for dynamic and static behavior of MEMS to be available to all users across the country through their use of the new Gbit/s SuperNet in a Virtual-Laboratory environment with SuperNet connection to advanced MEMS CAD and Simulation tools (Fig. 3).

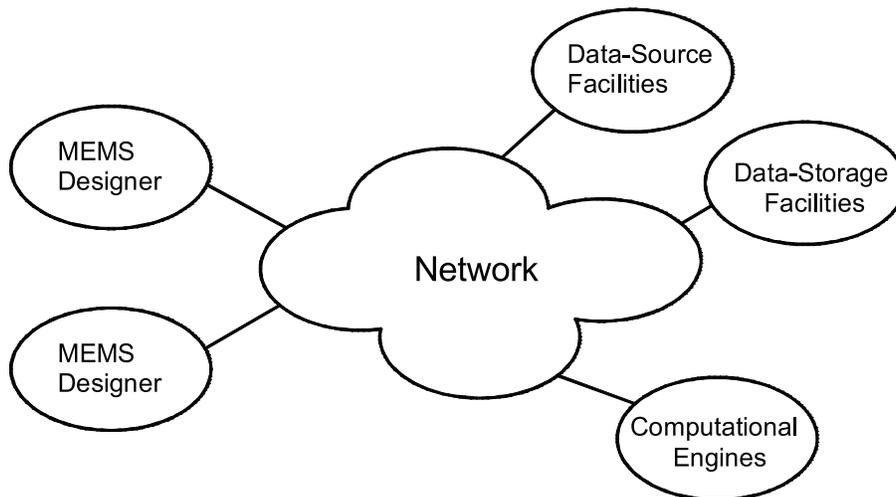


Fig. 3: Logic Arrangement of MEMS Facilities connected through the SuperNet. (Redrawn based on the graphic at: <http://www-bsac.eecs.berkeley.edu/projects/memstesting/>)

Current MEMS curriculum

The present state of Microsystems technology is comparable to the integrated circuit technology about three decades ago [4]. It is clearly going to be a dominant technology sought after by the universities and industries. Both commercial volume and patents on MEMS are growing at rates exceeding 20% annually. The educational components of MEMS technology, now in its early stages, must keep up with this expanding environment. Four courses on the production and applications of MEMS, which can form a specialization in MEMS are outlined.

MEMS Courses for Engineering Technology Programs

The proposed four course sequence of MEMS technology within the Engineering Technology program addresses the competency requirements of technicians and technologist graduates. The courses are designed to stimulate and sustain interest in the MEMS technology with the students as they learn to design and fabricate micro devices, as well as learning where they are used and how they work.

A High School graduate student can get a job as Equipment Operator or Technologists intern after completing two courses - Introduction to MEMS technology and MEMS fabricating methods. When these courses and the Advanced MEMS are coupled with standard Manufacturing/Mechanical/Electronics Technology core courses along with the required Math, Science and Communications classes, the students will be qualified for employment as technologists in MEMS-related industries. The Table 1 given below depicts the required competency levels of technologists so they can be successful at the technician level grade in MEMS industries. The Table 2 depicts the relationship between competencies and designations of a MEMS Engineer from an undergraduate Engineering technology program.

Infrastructure for Course Offerings

In order for the students to acquire a complete set of skills and understanding of MEMS fabrication and design, they need to be able to learn and experiment in realistic, hands-on cleanroom environments. One of the profound bottlenecks for offering the skill based MEMS courses is the need for a clean room. Establishment of a typical clean room with associated fabrication and testing facility requires capital costs of upwards of over a million dollars plus the continuous maintenance expense. As such, it is very difficult to establish a cleanroom in each of the participating universities. Already there are a number of universities that have established facilities, which are not being highly utilized. Hence a win-win situation is to have a group of colleges that can be associated with an established regional clean room so that the capital resources are optimized. This approach has been successfully demonstrated at Penn State in their Nanotechnology program.

Qualification	Add	Competency	Designation
High School Graduate	+	Introduction to MEMS MEMS Fabrication Methods	Equipment Operator
AAS Degree	+	Four MEMS courses	Technologist
Technologist	+	Diligence & Excellence	Sr. Technologist
Sr. Technologist	+	Technical Mastery	Lead Technologist
Sr. Technologist	+	Organization & People Skills	Production Supervisor

Table 1 Competency of Technologists.

Qualification	Add	Competency	Designation
Engineering Technology B.S. Degree Programs	+	Introduction to MEMS MEMS Fabrication Methods MEMS Design and Simulation Advanced MEMS	Engineer
Graduate Engineering Technology programs	+	Research	Research Engineer
Engineering Technology B.S. Degree Programs	+	MBA Program	Engineering Management

Table 2 Competency of Engineering Technologists.

Furthermore, most universities have been utilizing 3D CAD software such as AutoCAD, ProEngineer, Solidworks and Inventor, including FEA techniques in their curriculum. It would be possible to use these for the purpose of designing and simulating

MEMS devices. Also the actual MEMS specific design software should be available at low cost for the academic use. There exists another approach to providing hands on training to students with the MEMS fabrication technology without investing in a clean room. An air curtain with sustained laminar air flow can be used to keep a small area clean. Once a given fabrication step is completed, the wafer can be placed in a sealed carrier for transportation and storage. In this way, students can be exposed to myriad MEMS experiments without the need for a complete, fully functional clean room.

MEMS Curriculum

Four new undergraduate level MEMS courses are proposed: “Introduction to MEMS” for entry -level students, MEMS fabrication methods for juniors and the MEMS Design and Simulation and Advanced MEMS for senior undergraduate students. These courses are designed with a mix of theory and hands-on experiments. These courses build upon the technologies that are already part of the curriculum. Hence, it is possible that the students with these four courses, along with the capstone design project (if that can be oriented to MEMS for this set of students) will achieve reasonable proficiency in Microsystems fabrication and design. Should the student desire to further specialize, he or she can proceed to a graduate program which is already established at a number of universities. It has been observed from a survey that the students are interested in taking courses in emerging technologies such as MEMS.

Introduction to Micro-electromechanical Systems (MEMS)

Course objectives:

This is a survey course covering the exciting interdisciplinary field of MEMS. The nature of engineering at the micro scale, manufacturing and design techniques, micro device applications, MEMS commercialization issues, and future trends are thoroughly discussed. Applications and relevance to MEMS: sensors and actuators, micro fluidic-based printing and biomedical devices (BioMEMS), and optical-based telecommunication and display systems (MOEMS - Micro-Optical Electro Mechanical Systems) are explored. They will have a basic understanding of the breadth as to what MEMS are, how they are made and why they should care.

Course outcomes:

After completion of this course, students should be able to

- Describe current and emerging manufacturing techniques for MEMS;
- Describe examples of MEMS devices used in industries such as automotive, aerospace, biotechnology, display and fiber-optic communications;
- Describe the electronic, physical and chemical principles involved in the successful fabrication and operation of a wide variety of MEMS devices;
- Describe market forces that drive the development of MEMS devices and technology.

MEMS Fabrication Methods

Course objectives:

The objectives of this course are to go beyond the design stage in Micro-Electro-Mechanical Systems (MEMS) to provide students with a strong background in fabrication, testing and characterization of MEMS. The main focus is to understand the fundamental challenges and limitations involved in developing and testing devices found in MEMS. Various MEMS fabrication process will be discussed including surface micro-machining, bulk micromachining and LIGA. Simulation and hands-on laboratory experiments are key components of this course.

Course Outcomes:

Students should leave the course with the ability to

- Demonstrate a basic understanding of silicon electronic device and MEMS device fabrication processes including photolithography, thin film deposition as well as dry and wet etch methods.
- Demonstrate good laboratory safety and protocol procedures and laboratory notebook maintenance.
- Demonstrate hands on experience and working knowledge of microelectronics and MEMS processing steps and process modules.

MEMS Design and Simulation

Course objectives:

The objectives of this course are to understand the design process utilizing any of a variety MEMS design and simulation

tools available. The main focus is to understand the different processes that are essential for the successful operation of a MEMS device such as electrostatic, thermal and piezoelectric based actuator systems. A large number of small tutorial design exercises will be utilized in this course to hone the different design and simulation principles. A capstone design project can utilize many of the principles studied in the courses will be applied as an exercise which can also be continued with other courses to tie all the learned concepts together and bringing them to fruition. One such capstone could be participation in the Sandia National Laboratories University Alliance MEMS Design Competition held every spring (mems.sandia.gov/ua/contest.html).

Course outcomes:

Students will be able to

- Demonstrate a basic understanding of the various engineering principles in sensor and actuator design.
- Demonstrate hands on experience and working knowledge of the design tools used in MEMS design process.
- Demonstrate hands on experience and working knowledge of the design tools used in MEMS simulation process

Advanced MEMS

Course objectives:

The objectives of this course are to investigate the entire process of developing MEMS devices. Along the way, topics of discussion will include picking an appropriate application of the MEMS technology, designing a MEMS device, MEMS fabrication and packaging techniques, the challenging aspects of characterizing MEMS devices, and the unique physical environment that exists at the micron scale. Other discussions will address the existing MEMS market, the future of MEMS and the difficulties associated with establishing a successful MEMS business. The course will be taught through real world examples of existing MEMS implementations, drawing on both the successes and failures of past efforts to paint a realistic view of this exciting yet challenging new technology.

Course outcomes:

Students will be able to

- Understand MEMS fabrication constraints and typical process flows.
- Understand how to discriminate between "good" and "bad" designs.
- Appreciate the significance of package design on MEMS performance.
- Understand the challenges associated with "pulling it all together."
- Understand the current and future markets.

Conclusion

A minor in MEMS including a four course sequence for Engineering Technology students was presented. Specializing in the technology of the micro world will be advantageous to technology students in securing exciting jobs in all levels of MEMS manufacturing industries. Developing new programs and curriculum will provide the microsystems industry with a flexible set of educational resources and a core of trained human power while increasing the general public's awareness. This will also facilitate in the future creation of standardized curriculum, educational programs and industry validated certification.

Acknowledgements

This work is partially funded through a National Science Foundation Grant, DUE #0830384.

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Quality Systems Assessment Project

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Overview

A Quality Systems Assessment Project (QSAP) has been proposed as a prototype project within the Indiana State University (ISU) Ph.D. Consortium (www.indstate.edu/consortphd/). The ISU consortium was begun in the late 1990's and is composed of multiple participating institutions in several states. Multiple specializations represent the technical content of the consortium including human resources training and development, manufacturing, construction, digital communications, and quality systems. The initial focus of the QSAP is within the quality systems specialization (QSS). QSAP is positioned as a potential mechanism for systematically tying change, strategic planning and improvement together with leaders across the consortium, within the context of assessing and growing a broad-based institutional quality system.

It is commonly known that American industry uses tools such as lean and six sigma for assessment and improvement. But it is less obvious what this means in an educational environment, particularly a complex public university setting, or in the case of the Consortium with multiple university members (Bilke, et al, 2006). There is strong evidence (Bilke, et al, 2006; Miller, 2007; Maughan and Anderson, 2005) that educational environments and cultures must change and improve, in order to meet current challenges. This is increasingly true in the face of diminishing resources in states, new and complex demands from customers, new paradigms for delivery and other relationships among suppliers and increasing competitive pressures. This paper will examine several main aspects of the early prototypical QSAP work, with the intention of explaining the QSAP model after ten years of Consortium success, establishing the main attributes of the QSAP, suggesting structure of the associated research and main methodologies, and providing some early findings, analyses, and recommendations.

QSAP General Design Considerations

Several broad-based inter-related areas are offered for general consideration regarding design of the QSAP. These are areas thought to be important to a QSAP being developed and applied in a multi-university environment such as is the case in the ISU Consortium, and perhaps generically for other institutions and organizations with related attributes. The four areas offered for consideration include: 1) assessment, data and documentation; 2) standard operating procedures, SOP's; 3) lean sigma, continuous improvement; and 4) strategic planning. Viewed graphically in Figure 1, these are shown as an inter-related diagram which embodies equal portions of each area, and places the actual QSAP at the center.

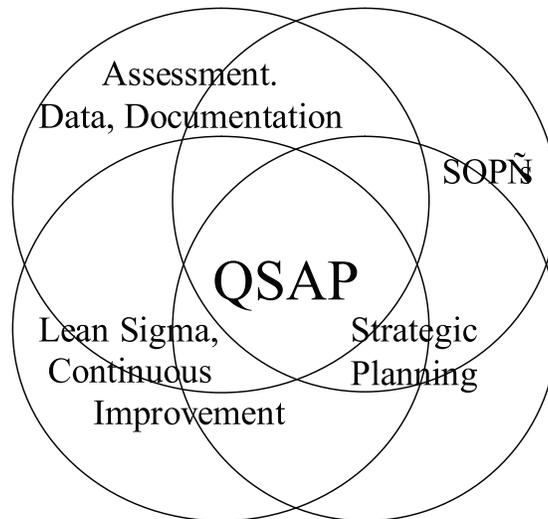


Figure 1. Core areas inter-related in QSAP.

Assessment, Data and Documentation

Higher education has a long history of using assessments (Miller, 2007). Assessment may be used to evaluate students, programs, departments, or entire universities. It may be used to ensure compliance, as with accreditation, or for the purpose of identifying improvement opportunities. From the perspective of the QSAP we are interested in evaluating a particular program for improvement opportunities, but with a twist: the program includes five different universities.

Common approaches to organizational or program assessment within higher education include various accreditation programs, and program review. Outside of higher education, approaches to assessment with a focus on quality, organizational performance, and continuous improvement include the Malcolm Baldrige National Quality Award, and certifications programs such as ISO 9000, or QS 9000. Certifications such as ISO 9000 or QS 9000, while they include elements for continuous improvement, are more focused on process documentation and management.

The Malcolm Baldrige National Quality Award criteria were developed in 1988 as a model for managing quality in a manufacturing organization. Over the ensuing years, the criteria have been revised and improved, and have evolved into a model for organizational performance for many types of organizations, including non-profits, healthcare, and education. Performance improvement frameworks such as Baldrige have influenced changes in accreditation standards to include continuous improvement requirements (Mattis & Sinn, n.d.). In 2003, criteria specifically for education were developed. These Baldrige criteria have been used successfully, as a basis for organizational improvement and performance in higher education (NIST, 2008a). Colleges and Universities have been recipients of the Baldrige National Quality Award, as well as state awards based on the same criteria. It is important however to focus on the benefits of the assessment process rather than the award. Because applicant information is confidential unless an applicant becomes a recipient, information is not available regarding how many higher education organizations are applying for national or state awards, or using the criteria for assessment and improvement without applying for awards. Elements of the Baldrige criteria, such as Leadership, Strategic Planning, Student Stakeholder and Market Focus, Measurement Analysis and Knowledge Management, and several results items may be useful in our assessment approach to the PhD consortium. Although the Baldrige process includes an extensive and time consuming application, there are also tools such as a Self-Analysis worksheet, and the Organizational profile, which can be used quickly to identify performance gaps and improvement opportunities (NIST, 2008b).

An assessment approach designed specifically for organizations with no existing formal quality system is the Quality Systems Development Roadmap (Olson, 2006). This model includes a tool for assessing an organizations strategy and readiness for the implementation of a formal quality system. As a part of preliminary work on this Consortium project, the beginning of a program assessment model, focusing on curriculum and courses, has been developed (Sinn, 2008). A successful assessment of the Consortium will require input from several sources, including strategic planning, advisory

committees, defined program outcomes, and from customers and stakeholders. This focus on meeting customer expectations is central to a quality approach in higher education as it is in other organizations (Maughan, 2005; NIST, 2008a). While most of these inputs are available, it will be necessary to gather data from customers and stakeholders of the consortium related to and aligned with the information from the other sources. This additional data will ensure that information from all perspectives will be included in the assessment, and the most valuable improvement opportunities for the consortium program are identified. Gathering data that reflects the voice of these important constituencies is only the beginning of essential data collection efforts. As we begin to examine core processes of the Consortium, additional data will be needed for our improvement efforts.

Standard operating procedures (SOPs)

As a core component of the QSAP general design considerations shown in Figure 1, the standard operating procedures (SOPs) fulfill a number of pervasive needs found in major quality, organizational and process improvement systems. The SOPs form the basis for implementation of the quality system, providing steps to follow in disciplined ways to accomplish all functions of the program. For the broad purposes of the QSAP, these ‘SOPs’ may take different forms. This includes written work instructions, flow charts, examples, process maps, and other procedural documentation which can be accessed and used by all participants in the consortium.

SOPs would include all procedures required to function in the Consortium, from start to finish for students, faculty and staff, enabling and facilitating communication and conduct of all related activities (Bilke, et al, 2006). Table 1 provides examples of typical SOPs that have been documented for the PhD Consortium. It should be noted that the same SOP would typically have importance to the PhD student or candidate, and other major stakeholders in the Consortium.-

In a similar manner, more specific QSAP SOPs have been and will be developed, and will evolve. The overarching - and continually evolving - SOP is the Quality System Assessment Project (QSAP) (Sinn, 2008) manuscript. This document has evolved over a number of years, and draws from several prior documents (Bailey, Bilke, Xia, Rodchua, and Sinn, 2006; Olson, Radziwill, Lippert, Vollmar, Mattis, Van Dewark, and Sinn, 2006; Sinn, 2008: Sinn & Woolsey, 2008)), and Table 2 provides a brief project timeline with major activities. The QSAP has effectively completed Phase I, Year 1, Objective 1, which sets the stage for the project and anticipated research.

<u>Level and/or type of SOP</u>	<u>Format of SOP</u>	<u>Typical SOP developer</u>	<u>Typical SOP user</u>
<i>Consortium level</i>			
Overarching Consortium Website at ISU http://www.indstate.edu/consortphd/	Multiple page university website with documents	Consortium faculty and ISU website developer	Current and perspective students; faculty
PhD in Technology Management Flow Process	Flowchart in Word format	Consortium Program Staff	Current and perspective students; faculty
Program Forms and Policy Statements http://www.indstate.edu/consortphd/program/forms.html	Word or Excel documents	Consortium Program Staff	Current and perspective students; faculty
Consortium Course Catalog	Webpage or website	Consortium faculty and ISU website developer	Current and perspective students; faculty
<u>Level and/or type of SOP</u>	<u>Format of SOP</u>	<u>Typical SOP developer</u>	<u>Typical SOP user</u>
<i>Individual University</i>			
Graduate school application procedure	Word document or webpage	Grad School and university website developer	Perspective students

Table 1 continued on next page

Library and Interlibrary Loan procedures	Word document or webpage	university website developer	Current students and faculty
Web-based course platform (in PhD Consortium, this is Blackboard)	Course specific Blackboard website	Blackboard website developer	Current students and instructor(s)
<i>Department housing Consortium PhD</i>			
Faculty websites	Webpage or website	Consortium faculty and ISU website developer	Current and perspective students
Course syllabus	Word document or webpage	Consortium faculty and university website developer	Current students
<i>Student</i>			
Program of Study (POS)	Word document or website	Consortium	Student, Consortium and faculty
Portfolio	Word or PowerPoint document, Webpage or website	student	Student(s) and POS Committee members
Dissertation Guidelines	Word or PDF file	Consortium faculty and university website developer	Current students and faculty

Table 1: Example of Typical SOPs in the PhD Consortium.

Phase I, Year 1	Objective 1. Preparations for the research, setting the stage for the project
	Objective 2. Assessment of existing systems.
	Objective 3. Development of a QSS quality system for the ISU Consortium.
Phase II, Years 2+	Objective 4. Data and documentation for analysis.
	Objective 5. Grow the systems
	Objective 6. Evaluate all and communicate broadly about the systems.

Table 2: QSAP Timeline With Major Activities

Lean sigma, continuous improvement (LSCI)

In every recognized quality system methodology (ISO 9000, Baldrige, Academic Quality Improvement Process, TS-16949, AS-9100) there is a requirement for continuous improvement of the quality system. None of the methodologies are prescriptive. The improvement may be incremental (evolutionary) or it may be improvement of a breakthrough nature (revolutionary). As defined in the context of this paper a process is the series of events by which work gets done. This is not limited to manufacturing work. Any work process is a culmination of the steps or actions directed to some end - which in this case is the completion of some task defined as work. In any process, whether it is manufacturing related, administrative, financial, medical or academic, there are opportunities to identify and reduce waste. The Quality System Assessment Project (QSAP) also requires continuous improvement at Indiana State University and the other consortium universities, for processes related to the consortium.

In the ISU consortium program there are five universities that contribute to the consortium. With five different universities come five different operating and administrative systems. The opportunity to significantly reduce waste and complexity in the PhD Consortium suggests numerous projects in a 'target rich' environment. There is waste in

redundancy, complexity, rework and queue time. Universities are finding that with decreased funding opportunities from local, state and federal sources and the new competition for students among traditional and non-traditional institutions that the reduction of complexity, redundancy and rework (process waste) translate into more effective value added processes which translate into money saved for the organization. The Quality System Assessment Project recognizes the value of implementing continuous improvement and waste reduction processes into the business model for these universities. This would ensure that these institutions have the opportunity to save money by applying process improvement and waste reduction projects as an integral and prescriptive part of the QSAP. Table 3 looks at Eleven Deadly Wastes associated with Lean, and considers the implications for the QSAP. Combining lean and six sigma methodologies is one answer to the continuous improvement mandate in the QSAP. Note that the entire University System of Georgia is currently implementing Lean Six Sigma

1

<u>11 Deadly Wastes</u>	<u>What are they?</u>	<u>What are their results?</u>	<u>Implications or considerations for QSAP</u>
Defects	Errors and mistakes, wrong forms, wrong departments, wrong people	Many times found by the customer when something does/ doesn't get done	PhD-related course is dropped by participant university. Students are not enrolled on time. Mistakes in administrative functions cause students to scramble.
Overproduction	Overproduction can cause disruptions in material flow	Working overtime to send work to the next department in "waves" may bury the next dept.	Forms are printed and then changes made causing the forms to be used up before they are corrected or discarded.
Queue Time	Time spent waiting for other people to "give permission" complete a task or get more information or simply waiting in a file or "in basket"	Product doesn't get to the customer on time. Delays result in misplaced work and could lead to redundancy.	Waiting for signatures or decisions to be made slows down and confounds the academic process. In many cases decision by committee causes excessive queue time waste.
Transportation	"Processing" may not be in the same building or on the same campus.	Cost of gas, handling, work may be lost or misplaced or could go to the wrong department	Transportation time between SOT and Grad School during dissertation process. Paperwork recovery - transcripts need to be pulled from all consortium members prior to prelims.
Processing waste	Current process is ineffective	Rework or ineffectiveness may result in higher processing costs	Several office professionals doing similar tasks, university coordinators do not share best practices.
<u>11 Deadly Wastes</u>	<u>What are they?</u>	<u>What are their results?</u>	<u>Implications or considerations for QSAP</u>
Inventory	Too much inventory ties up resources.	Money used to tie up inventory could be used for other things.	Can consortium universities "share" resources? Are there direct buy and consigned inventory opportunities for supplies within/among the consortium universities? Is there a national office supply chain that would provide preferential pricing to a 5 university consortium?

Table 3 continued on next page

Waste of Motion	Is everything close at hand or do employees have to walk, stretch or fetch something to do work?	Repetitive motion injuries wastes time and efforts	Workplace organization (5S) should be a standard in QSAP. Consortium members need to understand and implement 5S workplace organization principles.
Talent	Are the right people in the right jobs?	Talent could leave or not be effective if under or over utilized	Universities sometimes overlook internal talent when implementing processes like QSAP. In many cases, professors are teaching Lean Sigma or like methodologies and even consulting these methodologies but universities overlook these talented people when implementing improvements causing frustration.
Complexity	Are the work instructions clear?	Time could be wasted clarifying work instructions or critical steps could be omitted if too complicated.	Are academic procedures clear and concise across the curriculum? Have the consortium members reviewed best practices to navigate the work process and defined procedures for students?
Redundancy	Many people are doing the same thing sometimes the same way.	Wasted time, talent and redundant efforts cost money.	Several departments doing similar tasks. Registration at 5 universities, counseling at 5 universities etc.
Communication	No enough or too much or bad communication.	Errors, mistakes, delayed or premature action	Does everyone understand the “vision” of the consortium? Is everyone that interacts with the consortium on the same page? Are communications clear among and between all consortium universities?

Table 3: Lean’s Eleven Deadly Wastes and QSAP

As defined, lean is the identification and elimination of waste. Six Sigma is a method and a tool by which variation, defects and waste can be systematically identified, measured, eliminated and improvements sustained. We have noted many opportunities in the current consortium processes where waste may exist and should be eliminated. Application of a lean six sigma project to an identified waste in the process could payoff handsomely for the consortium. Capturing the costs and savings would be a matter of negotiation between the institutions. It is not uncommon for a six sigma project to return an average of \$230,000 per project in a target rich environment (Mikel, 2000). The steps required to commission such a project include: 1) mapping the current value stream with the value stream is defined as the process by which value is derived by the organization (i.e., work); 2) identifying potential sources of waste within the current value stream; 3) targeting the waste to be reduced (i.e., define the project); 4) determine the amount of waste or potential saving (measure); 5) review the process in detail (analyze); 6) make and implement recommendations measuring the delta in waste value pre and post improvement (improve); and 7) sustain the gain (control). Table 4 looks at the generic lean six sigma components of a process, and considers the implications for the QSAP. Note that other benefits to stakeholders include customer service and satisfaction. This can create growth opportunities and improve graduation and retention rates, with graduation and retention being key measures for higher education.

<u>Six Sigma Attribute</u>	<u>Characteristic of Six Sigma Attribute</u>	<u>How to Accomplish</u>	<u>Complimentary Lean activity</u>	<u>Implications for QSAP</u>
Define	Define the process and the project	Use process mapping	Using the process map identify all process steps.	With all of the processes defined, QSAP methodologies could be spread across each process.
Measure	Determine step timing, activity costs, flow distances, process parameters	Measurement	Determine current time and develop takt time for all steps	Measurement implications for QSAP will highlight where operating discipline is not employed at the process level. Weaknesses in the system are brought to light and QSAP can be used to address the weaknesses.
Analyze	Analyze every measurement for waste, value and opportunity	Deep Dive the data	Determine the delta and analyze root cause.	Systemic analysis of each process related to the consortium is required to meet the improvement criteria in the QSAP.
Improve	Target the high waste measurements and develop a process to mitigate	Try Something - the opposite of trying something/ anything is analysis paralysis	Understand and develop and implement improvement strategies for each step of the work process.	QSAP calls for systemic improvement as well as benefiting the universities that it serves. Improving the processes, eliminating waste, improves the financial status of each university.
Control	Ensure process discipline and that the organization does not slip back to the old way/habit	Process discipline, leadership, visual management/ visible management	Through management audits and visual management ensure that the gains are sustained.	Control resets the baseline for continuous improvement as prescribed by the QSAP. The control process ensures operating discipline among the universities and ensures a consistent process is being followed eliminating wasteful behavior and assuring consistency for students and staff.

Table 4: Lean Six Sigma Components and QSAP

Institutions are reluctant to apply the tools for continuous improvement for a number of reasons. Some organizations do not believe that they have the requisite knowledge to apply the tools. Some institutions do not have the discipline to change. Some do not believe that the tools will work at their institution or that they are different somehow. Lean and Six Sigma tools have been implemented at a number of administrative, service, healthcare and financial institutions to great success. Generalization of these continuous improvement tools has been proven to be effective from manufacturing to service organizations committed to continuous improvement. The biggest barrier to success is the culture that believes that it will not work or that will not change. Continuous improvement as an integral part of QSAP can be successfully achieved through the use of Lean Six Sigma methodology. Integration with the continuous improvement methodologies developed by a robust Lean Six Sigma process in the QSAP is a strategy for success for the consortium.

Strategic Planning for Change and Improvement

Strategic planning has always been part of the vision-determining mechanism and guide for the future as the ISU Consortium has emerged as a leader in granting technology management-focused doctoral degrees over the past 10 years. What is suggested within the QSAP proposal is that strategic planning must become increasingly systematized as a fundamental methodology for assessing and determining the direction of work to be pursued for improvements and changes. This is anticipated to lead to an increasingly robust consortia arrangement and mechanism for offering doctoral degrees.

Strategic planning is generally tied to change and improvement, based on a vision for the future. The future and vision being discussed in this case are tied to systems for assessing directions related to change and improvement within the context of a broader quality system. Although data has been collected by individual Consortium universities, related Consortium courses, to date there is little substantive data/information which has been collected. The QSAP is the first serious attempt at comprehensive data collection. As the ISU Consortium has evolved, there have been changes and improvements, but they have been isolate rather than systematic. Thus, it bears underscoring to indicate that data must be collected and documented in ways which are appropriate to the mission of continuous improvement.

With the development and deployment of QSAP, various lean six sigma projects - with enhanced documentation as standard procedures - will be intentionally undertaken, primarily related to change and improvement. Strategically, many of the early recommendations for changes could become new and improved systems for how to operate and manage the consortium, including improvements in recruitment and tracking of students; recommendations for changes in curriculum based on student and faculty satisfaction; and other data, and all other major elements of faculty and student work, including standard procedures for processes inherent in the approval of student programs, dissertation committees, comprehensive examinations.

Strategic planning affords a systematic approach to setting goals for the future, determining appropriate measures for success, and planning for needed resources. A practical expression of strategic planning within the Consortium has been the Quality Systems Specialization Faculty meetings held annually (or near annually) for the purpose to review and updates of courses and curriculum discussion of the role of the five Consortium specializations beyond the offering of courses and directing research. Strategic adjustments have been made within the Consortium university members, as one initial university withdrew (University of Wisconsin, Stout), and other universities consider joining the Consortium. As well as setting strategic goals, measures of success, or metrics, will be determined increasingly through QSAP and related initiatives. Defining how to measure success, as well as what the measures should look like will be increasingly important as outcomes assessment is pursued. The identification and validation of outcomes, related measurement, data collection systems and analysis for potential ways to add value are expected to continue through QSAP and related initiatives.

One of the very possible outcomes from a QSAP initiative, as described in this proposal, is that changes may be proposed to the Consortium which are not driven only by the institution which is charged with maintaining the quality and integrity of the degree itself. What was inherently a good and necessary consortia design for all original activities of the degree at the outset could likely be found to require new and different changes, as improvements, to innovatively meet demands and challenges of the future.

Strategically, this may relate to governance of the degree, decision-making among the five institutions, what specializations should constitute the degree, how faculty are selected to be part of specializations, and other shared responsibilities and authority inherent in the consortium. Given the innovative nature of the consortium, and existing positive relationships among the member institutions, innovative relationships for change among and between faculty and administration, for shared governance and decision-making, could be strategically anticipated.

Development of processes and systems for implementation of strategic initiatives will be an additional important area of activity over the longer term. Use of student teams in various courses, particularly QS courses are anticipated to be appropriate and helpful within the QSAP initiative, to bring about change and improvement. Defining what constitute appropriate and necessary strategies for implementation, then organizing and managing to implement them, will be a continual project driven need and agenda within QSAP.

Summary

In the current global environment, presents challenges to every organization, and no organization can afford to rest on its laurels. In higher education, those challenges include diminished funding from government, an increasingly diverse student population and related access issues, increasing pressures for accountability, and growing competition from the private sector and from abroad. Effectively addressing these global challenges will require a proactive, strategic and systematic approach. The Quality Systems Assessment Project (QSAP) provides a model for the PhD Consortium, lead by Indiana State University, to successfully meet these challenges.

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Setting the Foundation: Rekindling Interest in Science, Technology, Engineering, and Mathematics (STEM) for Promising Students

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Introduction

Scientific and Technological disciplines serve as a premise of a globalized workforce. Across the country, there has been a major decline in promising students entering into the Science, Technology, Engineering, and Mathematics (STEM) areas. The American College Testing (ACT) Organization (2006) reported that the interest in STEM areas had a steady decline from 4.5% to 2.9% within a five year period.

There is little known about the reasons for this decline. The saturation of technology in most fields means that all students, not just those who plan to pursue a STEM profession will require a solid foundation in STEM to be productive members of the workforce. When employers were asked to identify job applicants' common deficiencies, most industries reported a lack of mathematics, computer, and problem-solving skills. The United States is also rapidly losing its competitive edge within the STEM fields as our students fail to keep up with their international peers.

The Trends in International Math and Science Study (TIMSS) investigates the performance of students in math and science across the world. They are creating benchmarks that students in Mississippi continue to fail to achieve. The focus based on the TIMSS report is breath verses depth. This means instructions tend to teach everything at once instead of giving the students the depth of knowledge required to master concepts which are important for academic survival. Students are taught concepts for mastery and re-taught throughout the year prior to the exams. This is done in preparation for the exams. According to the Program for International Student Assessment (PISA), Mississippi students are far below the national standards in math. Thirty percent of students score below the basic in Mississippi compared to 19% in the remaining states average score. Mississippi continues this trend on each level. While Mississippi does have a higher percentage of time spent on math homework compared to some of the other states, this is not reflected in achievement scores.

Mississippi Educational Statistics

The Mississippi Curriculum Test administers standardized tests to students in grades 2-8 to observe their levels of achievement in reading, writing, and math. Students are tested on items they learned in the beginning of the year up until weeks before the exam. It is impossible to believe that students will have high scores on tests; because of the rushed curriculum format. Table 1 represents the math scores of students in the recent school year. There is a dramatic decline in test scores percentages in proficient and advanced from 3rd - 8th grade. The researchers have observed that fractions are first exposed to students in the 3rd grade. This is very confusing and new to students. It seems as though when they finally began to feel confident about math skills, they are given a curve ball. Fractions are the beginning of a mathematic breakdown that affects students throughout their academic careers. This damages their confidence to excel in math because as they continue to the next level of math, they will encounter fractions and inevitably there will be set backs. Reinforcement activities are the keys to overcoming fractions. This will greatly increase the levels of confidence in students and encourage them to embrace learning all concepts of the STEM arena.

Mississippi Curriculum Test (MCT)						
Grade Level	Number Tested	Mean Scale Score	% Minimal	% Basic	% Proficient	% Advanced
Mathematics						
2	38197	454.8	2.9	7.7	48.8	40.6
3	36910	503.3	2.3	6.6	48.3	42.8
4	36464	526.1	6.3	12.5	41.7	39.6
5	36474	545.1	11.6	16.3	41.3	30.8
6	37573	565.7	16.2	14.1	29.2	40.4
7	38484	576.2	21.9	15.0	30.4	32.7
8	37643	587.8	21.6	24.6	29.5	24.3

Note: Minimum N-count for reporting is 10 students.

Source: Mississippi Department of Education 2006/2007 School Year
Table 1. Math Scores of Students in Recent School Year

Low Teacher Interest and Motivation

The teacher profession is enduring a shortage in regular educational disciplines. This really holds true to teaching the sciences. There are two issues against teachers pursuing educational careers in the sciences. Teacher salaries compared to technical career salaries are completely diverse. Coincidentally, most STEM teachers leave education to pursue careers in other technical fields. College students in the STEM are not encouraged to become teachers. They are persuaded to pursue fields that are technical in nature. This would be an insignificant problem but it decreases the amount of teachers that can produce promising students in technical areas. There is not a great emphasis on STEM teaching. The researchers believe it is still being developed and many educators do not want to take on the challenge of being trained in the area. There is a constant need for teachers to be trained yearly. They have to be one step ahead of STEM developments, in order to do this they must be current. Society does not automatically cater to the needs of STEM students. It is usually the last subjects to be brought to the forefront.

When administrators speak of education, STEM is usually an after thought. Society persistently stresses reading, writing, and math. STEM is considered a headache. The hope of society is that along the way, students will learn all sciences collectively. It is this relaxed thinking that is creating a problem for STEM advancements. STEM is one of the most observed topics but it baffles highly educated minds. More children would be better equipped if they become familiar with STEM on the elementary level. STEM research can be quite an expense to schools. Many schools cannot afford remedial assistance for STEM students. Thus, they do not stress the need for new STEM teachers. The researchers believe there may never be an abundance of STEM teachers because in some regions they are not greatly needed. In order for students to develop solid skills, teachers must equally have excellent foundations to facilitate learning.

Nationally, the lack of instruction does affect the success of STEM students. A shortage of STEM teachers in the United States has been directly linked to the low quality of STEM education in this country. The United States faces a critical shortage of highly qualified math and science teachers; projected to reach 283,000 by 2015. The National Science Foundation concluded that of all the graduating STEM students only 4.1% go on to choose teaching as a profession. Most teachers did not want to teach in the STEM field. Other teachers are thrown into the world of STEM because of the shortage of teachers in this field. Subsequently, there is a major decline in the percentage of teachers that even obtain a degree in the STEM areas as represented in table 2. This is a leading reason as to why students are lacking skills in high school technical practices. Teachers are not properly being prepared to instruct students in the sciences. This is critical because students need consistency. Scientific teachers must be well versed and trained to effectively instruct the sciences. There can be no room for hesitation from teachers when motivating students to excel in STEM. The environment of a student creates his/her outlook for self-concept.

	Middle School	High School
English	44.8%	13.3%
Foreign language	27.2%	28.3%
Mathematics	51.5%	14.5%
Science	40.0%	11.2%
Social science	29.6%	10.5%
ESL/bilingual education	57.6%	59.4%
Arts and music	6.8%	6.1%
Physical health education	12.6%	9.5%

Source: U.S. Department of Education, National Center for Education Statistics, *Qualifications of the Public School Teacher Workforce: Prevalence of Out-of-Field Teaching 1987-88 to 1999-2000*, NCES 2002-603, May 2002.

Table 2. Percentage of Middle and High School Teachers Lacking a Major or Minor in Subject Taught, 1999-2000

Creating a Conducive Learning Environment

Key elements in a student’s environment are parents and teachers. As a student enters middle school, peer influence becomes more of a factor. Self perception in part determines the extent of motivation a child has towards achieving. Most studies support an association between students’ motivation and socializing agents. Middle school is the time for a child to begin preparing for a career. The selection of a rigorous math track in high school will depend on how a student perceives his or her math ability. Successful completion of advanced STEM topics in high school by students will depend upon achievement in grades sixth through ninth. During the high school years, some students will need tutoring to maintain a grade average of “B” or higher in math courses. The information which will be analyzed statistically by TIMSS could help shape future STEM studies by agents, as it relates to under achieving students.

The major areas of avoidance are biology, engineering, and mathematics. The engineering topics are pivotal points of students in higher education. It is stressed that students must be heavily encouraged to excel in this area. The material for math and engineering are categorized by grade levels to ensure students develop these skills gradually. For example, since statistics is a topic of seventh grade math in the Jackson Public School System (JPS), topics from basic statistics such as developing stem leaf plots are the focal point of learning in most middle schools. For grades tenth and eleventh, statistics topics must include regression and correlation interpretation. As a part of resources, slower learners should be tutored on an individual level.

Reinforcing STEM Skills

Rigorous investigating is stressed in out-of-classroom assistance all but vanishes after the eighth grade. This could be another factor in the decline of STEM in higher education. The activities supported by the education leaders will provide focus on something other than routine basic skills. The investigators further assert that non-academic courses lack rigor and rich content for the mostly minority and low-income students in remediation environments. Help with basic skills is described as having a stigma. Strengthening students in STEM will entice and provide the students with activities which are not remediation, in nature. “Dabbing Down” content may generate a vicious cycle which causes a negative outlook by the students. The student tends to give up out of frustration, boredom, or low self concepts. When educators become frustrated with slower learners there is simply no life inflected into classroom teaching or there is a stigma among under achievers needing help. Students become disengaged because schools are perceived as boring or irrelevant. The belief causes disengagement with school in participants among middle school youth and high school youth.

The most important goals on the minds of educators should be to raise and sustain achievement in math, facilitate more student participants into advanced high school math courses needed to perform successfully in STEM disciplines upon entering college, increase the number of students earning scholarships, and provide statistical analysis so that educators, counselors, state officials and national officials will acquire a valid analysis of the promising students. To

ensure these goals are met, administrators must make students, teachers, (i.e. elementary level), and parents aware of the math (STEM) needed to successfully become scientists or engineers. They must also provide positive images of today's scientists for the students. Lastly, they need to expose the students to applications of the math which they study. The fields covered will be various types of engineering, physics, scientific topics, and math (STEM). The formal part will improve the students' math skills.

A Changing Workforce

There is a wealth of opportunities available for those interested in STEM. To be competitive in the global economy, companies need to develop innovative, high value added products and services, and its nonprofit and governmental institutions must continue to improve productivity by using technology based tools. Engineers, scientists and technology specialists are the critical personnel needed to make this happen. The societal impact encourages science, technology, engineering and math (STEM) preparedness. The rationale is personal pride, developed by enriching one's environment, stimulates the individual in a positive manner. The dismay of learning that biology majors have to complete college math with a "C" or better through calculus is frequently expressed by students entering college. Moreover, the amount of students enrolled in the STEM area, are significantly smaller than all disciplines in the United States as depicted in table 3. The positive side is that there has been a constant increase in the field. College students are enrolling in these technical courses. Many become disenchanted at the first sign of trouble and switch to a liberal major. Once again, this is where professors need to motivate students to stay with a technical field. Students must be able to comprehend topics that they are not comfortable with exploring. Students should no longer be allowed to memorize objectives and forget them once a test has been administered. They need to learn them and apply them to real world situations. It is excellent to speak about knowledge intelligently but how will they use it to create a better world? There is no need of knowing the Pythagorean Theorem unless you can then apply to it constructing designs useful to a successful engineering firm. Very detailed tutorial and laboratory sessions should be offered during leisure time for students. Colleges need to create an environment that puts students at ease about accepting assistance for their academic troubles.

Academic year ending	Bachelor's		
	All degrees	S&E degrees	% S&E degrees
2001	1,257,648	400,206	31.8
2002	1,305,730	415,611	31.8
2003	1,359,843	439,434	32.3
2004	1,407,009	454,978	32.3

Source: National Science Foundation

Table 3. Degrees awarded in all fields and in science and engineering: 2001-2004

Most literature indicates there is a need for middle school students to experience career exploration. The writings further assert conducting career exploration activities is a challenge for middle school counselors. With more women and minorities seeking jobs, there have been changes in the economic, political, and social environments. These changes have altered requirements for preparation to enter the world of work. Parents need to be informed about STEM requirements. Middle school and high school students will only obtain good jobs if they have good reading skills, develop a written resume, be able to fill out a job application, and conduct a well planned interview. Notice that most employers never indicated a need for good math skills. This can be misleading especially in the technical arena. There is an increased amount of companies that administer math tests before hiring. This further stresses the alarming need of evolution in the STEM areas.

STEM occupations are becoming more abundant as society continues to demand a need for a more technically advanced society. College Students are obtaining these positions but there is stagnation when it comes to careers in math and statistics. The U. S. Department of Education (2004) recognized that the number of bachelor's degrees awarded in

STEM subjects has been increasing in the past few years after years of a slight decline. This is an indication that college students are making a slight turn toward STEM careers. The researchers conclude that their confidence levels are somewhat low because they feel they are not prepared to function in high performing technical careers. To overcome these hurdle students must be provided with internship opportunities that guide them into the technical workforce. College professors need to be able to identify companies that encourage promising college students to work with seasoned professionals. The best remedy is to offer students hand-on experiences that can sharpen and extend their classroom activities.

The greatest benefit of pursuing STEM occupations is the increased salary scale. Holistically, STEM professionals earn about 70 % more than the national average. Society recognizes that students deriving from STEM backgrounds have slightly better critical than skills than those of average workers. This comes from prolonged exposure to fields that require students to develop technical and mechanical skills. These students are the future builders of society and are destined to reshape society as it evolves. Engineers will develop state-of-the-art buildings, mathematicians will solve complex equations to provide formations for construction, and natural scientist/chemist will find cures for deadly diseases. The sciences are a major part of creating a world that will sustain humanity.

Conclusion

STEM has been a constant focus for society. It creates students that are able to compete with student, globally. It is the driving force in developing a society that can prepare for the changes of tomorrow beginning today. There is a constant need for educators to understand the complexities of STEM. It impacts students' academic success for the rest of their lives. It can become a hindrance or the keys to limitless success for most students. In order for the national to conquer this phenomenon stakeholders must congregate and brainstorm ideas that will give students consistency. Students must begin in elementary school focusing on STEM achievement and carrying these goals with them through their educational endeavors. Educators must knock down the walls of educational doubt and give student strategies on of overcoming frustration related to mastering STEM objectives. Students are only promising if educators allow them to fully grasp the concept of STEM areas. It is unacceptable to produce students that are not prepared to empower and change society for the better. There is a wealth of opportunities available for those interested in STEM. To be competitive in the global economy, companies need to develop innovative, high value added products and services, and its nonprofit and governmental institutions must continue to improve productivity by using technology based tools. Engineers, scientists and technology specialists are the critical personnel needed to make this happen. The societal impact encourages science, technology, engineering and math (STEM) preparedness.

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Construction



Globalization of Technology

Imagine the Possibilities!

Adding Green to the Curriculum: An Examination of Integrating Green and Sustainable Building Practices into the Construction Curriculum from Customers' Viewpoints

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Introduction

Green, or sustainable, construction has gone from relative obscurity only a decade ago to becoming a significant issue and approach in virtually every market segment of the industry today. Glavinich (2008) defines green construction as “the planning and managing a construction project in accordance with the contract documents in order to minimize the impact of the construction process on the environment” (p. 5).

According to Srinivas at the Global Development Research Center (GDRC), green construction is “a way for the building industry to move towards achieving sustainable development, taking into account environmental, socio-economic and cultural issues. Specifically, it involves issues such as design and management of buildings, materials and building performance, energy and resource consumption - within the larger orbit of urban development and management” (n.d., ¶ 4). More recently, the importance of green/sustainable construction has grown. It is said to be “changing the way buildings are designed and built” (Nobe and Dunbar, 2004) and has even been described as a “megatrend” (Christen, 2004).

Various organizations, from the United Nations to contractor associations, have called for green/sustainable practices to be integrated into the construction management curriculum, and various approaches have been tried at different institutions. However, current curricula are already strained with existing subjects and topics and instructors and administrators are aware of the difficulties of integrating additional material into them. This situation is exacerbated when the familiarity of the students with the topics is unknown and administrators are unsure of the best instructional approach to use. By examining the viewpoints of current students and recent graduates of the program through surveys, the researchers were able to document these perceptions and use them in considering various educational approaches for including green/sustainable practices in the construction curriculum. Specifically, the researchers were able to make recommendations regarding stand-alone courses versus integrating these topics into existing courses, course contents, and which semesters to offer the course.

Curricular Approaches

When considering the introduction of any new topic into a program, faculty have several different options that must be evaluated. These options include whether the topic should be mandatory or elective, if it should be included in an existing course or courses or have its own course, and which semester or semesters it should be offered. While each program will have its own approach and administrative requirements, some of the advantages and disadvantages of each are offered here for consideration with specific regard to green/sustainable construction.

Although many entities are calling for the green construction to be included in the curriculum, it is not currently a requirement for any of the major accrediting bodies for construction programs. This leaves the decision as to whether or how to make it a mandatory part of the program up to the respective institutions. Programs that might want to emphasize their commitment to this approach, take a leadership role in promoting its use, and perhaps even define their program by its inclusion might therefore decide to make the topic a mandatory part of their curricula. This has the added advantage of quantifying exactly how many students will be introduced to the material (all of them) and simplifies course loading.

However, there are some potential drawbacks to this approach. First, most construction curricula already have many other competing topics that are deserving of course time. With most programs already constrained by accreditation and other requirements, the decision to add material on green construction likely would result in something else having to be eliminated or a reduction in the number of electives as well as limiting student choice. Additionally, its relative newness often means that current faculty do not have experience, expertise, or credentialing in green/sustainable construction, and new faculty are in short supply. This might constrain the option of seamlessly integrating green/sustainable construction into existing courses without the expenditure of considerable resources and the potential of faculty backlash against it. Finally, the actual process of changing any program's curriculum usually takes a considerable amount of time and simply could not be implemented immediately even if so desired. For example, the process of changing the required courses at the researchers' institution can only be done every three years when a new course catalog is published. These drawbacks often indicate that voluntary integration and/or elective courses are the normal course for programs to include green and sustainable construction into their curricula, even if only done as an interim step as they move towards mandatory requirements.

The next consideration is whether to integrate green/sustainable construction into a current course or courses, whether to offer its own course, or both. Naturally, its inclusion into existing courses could produce a more holistic approach, for example allowing students to examine and compare the material, construction, and life cycle costs in estimating and finance courses. This also demonstrates a commitment to green/sustainable construction that its use should be both inclusive and pervasive rather than a separate topic. However, the scope of the topic means that its inclusion in other courses devoted primarily to other topics will necessarily result in it receiving only secondary coverage. If preparation for a credentialing process, such as the Leadership in Energy and Environmental Design - Accredited Professional (LEED-AP) exam, is a goal then inclusion in existing courses will likely not result in a high pass rate.

Offering an elective course devoted exclusively to green construction allows fuller coverage of the topic and better preparation for an accrediting exam, if that is a goal. However, treating it as a separate topic might not fully demonstrate its integration and limits exposure to only those students who take the course. This approach will also draw limited resources (including faculty loading) away from other topics and may draw students away from other elective courses. Naturally, a combination of integration and a separate course offering exaggerates both the advantages and disadvantages, with better coverage and integration but also more demands on resources.

Finally, if a separate course is offered, the decision must be made as to which semester or semesters it will be offered. While this is often decided based upon faculty loading alone, student input should also be considered. Certain programs have heavier regular schedules in certain semesters that faculty should consider, including those of other programs outside construction if a substantial population of minors takes construction courses. While it might be most convenient for students to simply offer it every semester, administration might require a certain baseline enrollment with resultant class cancellations and rescheduling if classes do not fill.

With these considerations, the researchers decided to survey student and recent graduate interest to better evaluate the interest in green/sustainable construction. This was then used to make better decisions regarding curricular approaches, request appropriate resources for these approaches, and accommodate learner wants and needs.

Methodology

A survey is used to collect quantitative information from a population. The customer survey is a standard tool in many fields to provide input on changes under consideration, and can provide valuable feedback about perceived needs and desired approaches. Surveys are one of the most common data collection techniques in adult education, although not specifically for student input on curriculum issues (Merriam and Simpson, 2000). Surveys offer the opportunity for learners to provide their own input and perspective on topics and allow them to more fully participate in the process.

A simple, straightforward, anonymous survey instrument was developed to survey students currently in the program. This survey was then administered in every construction course offered in that semester, from freshman through senior-level. Participation was voluntary but requested, with the intent clearly explained by the instructors of each class. A cover page was included reiterating the voluntary aspect and the intent of the study, as well as indicating that it should only be taken once, even if offered in multiple courses for any individual student. By surveying all the students taking construction courses in a semester, virtually all of the construction management majors were offered the opportunity

to participate, as well as students from other programs who were minoring in construction or just taking a particular course.

The responses from the students were imported into a statistics program (SYSTAT V12) and were converted into categorical data. Descriptive statistics were first obtained and plotted to characterize the responses. Then multinomial logistic regression analyses were conducted to identify the most important factor(s) that affects the responses (whether or not the green course should be included in the existing construction management curriculum, how, and when, etc.).

Since the program at the researchers' institution is relatively new and does not have a large alumni population, it was not expected that statistically significant results would be able to be obtained with a similar survey of recent graduates. Therefore, students who had taken the capstone construction course the previous spring and who were known to have graduated and were working in the industry were selected for telephone interviews. This qualitative approach offered the opportunity to explore the current use of green construction by the program's graduates in greater depth and provided a more complete picture of the interest by organizations employing the program's graduates.

Results

The survey was administered to all the 147 students taking construction management courses in the Spring 2008 semester. The total number of the students who took the survey was 111, making the respondent rate close to 76% and providing a sufficient amount of data from which useful conclusions about the feasibility of offering a green/sustainable construction course could be drawn. Respondents' major and academic classification were displayed in Figure 1. 77% (85) students were construction management (CM) majors. It is interesting to note that for all the CM students there were more seniors and juniors than sophomores and freshman. This indicates that the survey results might be more affected by the input from senior and junior construction management students.

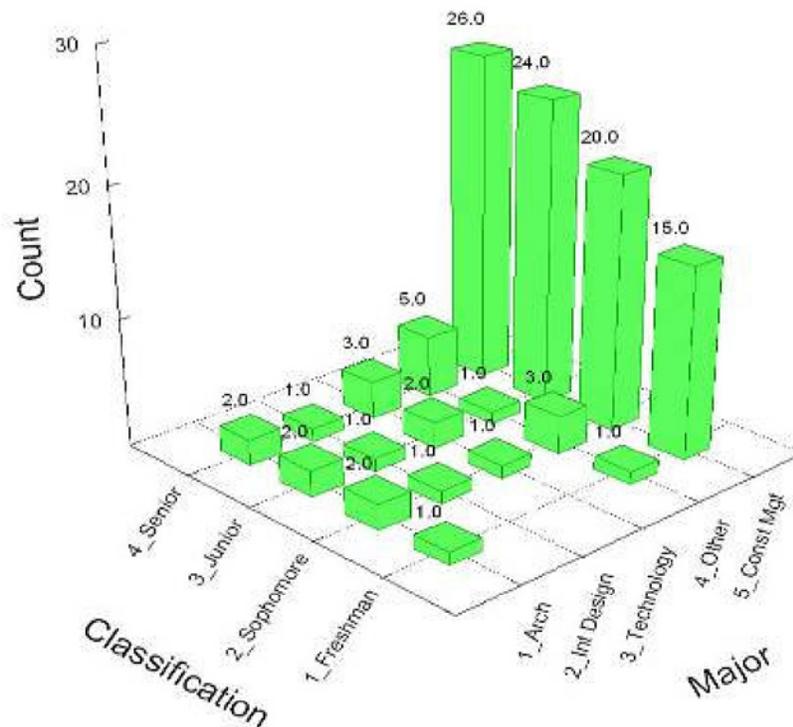


Figure 1

82% of the students had heard about green construction prior to taking the survey, with still a substantial amount (18%) who had not. The biggest surprise was to find that out of the four (4) students who had not heard about green construction, three (3) were CM majors (Figure 2). This indicates that the existing CM curriculum has not addressed

green construction sufficiently as other programs have. On the other hand, CM students' awareness of green construction increases proportionally with their classification (Figure 3).

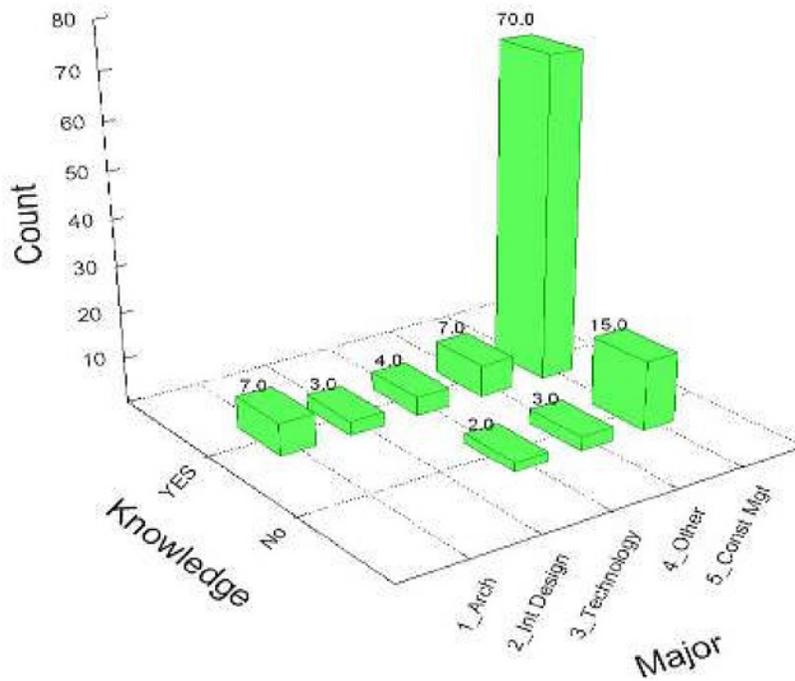


Figure 2

Awareness of Green Construction

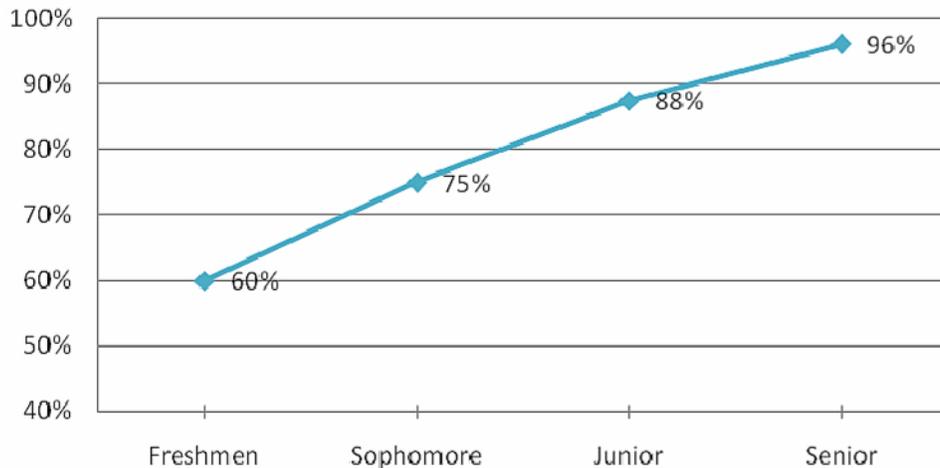


Figure 3

81% of the students agreed to include green construction subjects in the construction management curriculum, 5% were neutral, and 11% did not have enough knowledge about the topic. 3% of the students disagreed, which included two (2)

construction management students (one sophomore and one freshman) and one (1) student from other majors (Figure 4). Looking at the knowledge of green construction, it was not surprising to find that the two construction management students were not aware of the subjects prior to this survey. As expected, all the students majoring in architecture and interior design were in favor of the inclusion since both programs have offered green courses in their respective programs already.

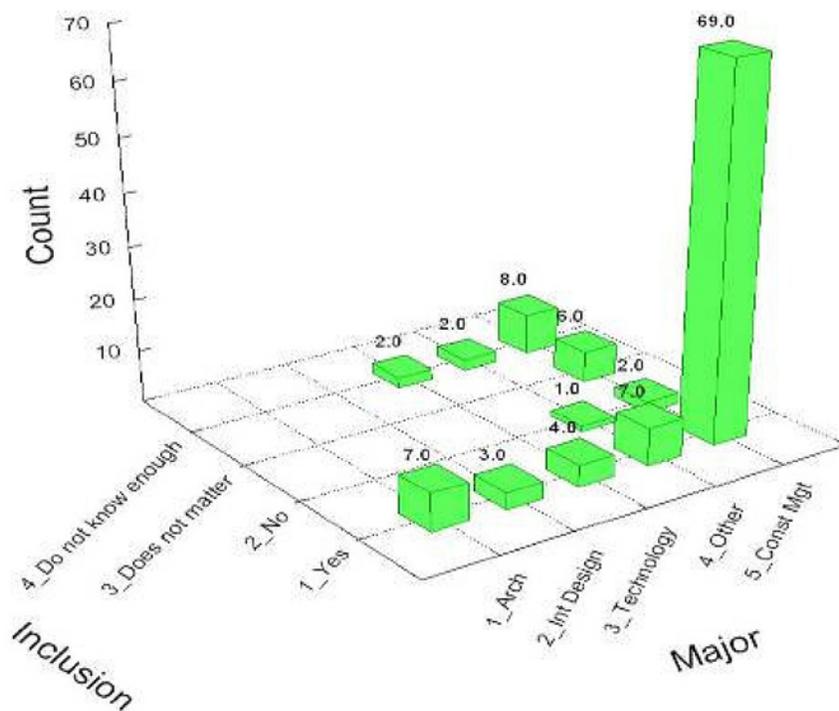


Figure 4

82% of the students thought green construction should be either integrated or newly developed or both into and for the existing curriculum. Eight (8) CM students did not answer this question because their responses to the previous question were either neutral or negative (Figure 5). 57% of the students would like the course to be offered in both Spring and Fall semesters, 13% preferred Fall semesters and 13% Spring semesters, and 17% did not answer the question (Figure 6).

Overall, a total of 79% of the students would like to take the elective which indicates a well-established interest (Figure 7). Among those who were interested in the elective, 76% were construction management students stating the fact that the green course should be included in the existing construction management curriculum. Also, among those who were “very likely” to take the elective, most of them were juniors and seniors, which might relate to their awareness of green construction subjects. 39% of the students were “very interested” in taking the LEED-AP exam, 16% “interested”, and 15% somewhat interested”. Overall, a total of 70% of the students were interested in taking the LEED-AP exam (Figure 8).

Qualitative data was obtained from recent graduate students using telephone interviews to capture additional, richer detail and because the program does not have enough graduates to make statistical analysis feasible. Although anecdotal, all recent graduates interviewed were aware of green and sustainable construction and felt that it was an important trend. Of 22 graduates who had taken the capstone course in the spring of 2007, two had already obtained their LEED-AP certification and another was working towards it. All mentioned how their employers supported their accreditation and even offered financial incentives, from reimbursement of examination fees to cash bonuses for successful completion. They were unanimous in feeling that a separate course in green construction would be a useful course and that it would give program graduates a competitive edge and help them advance more quickly.

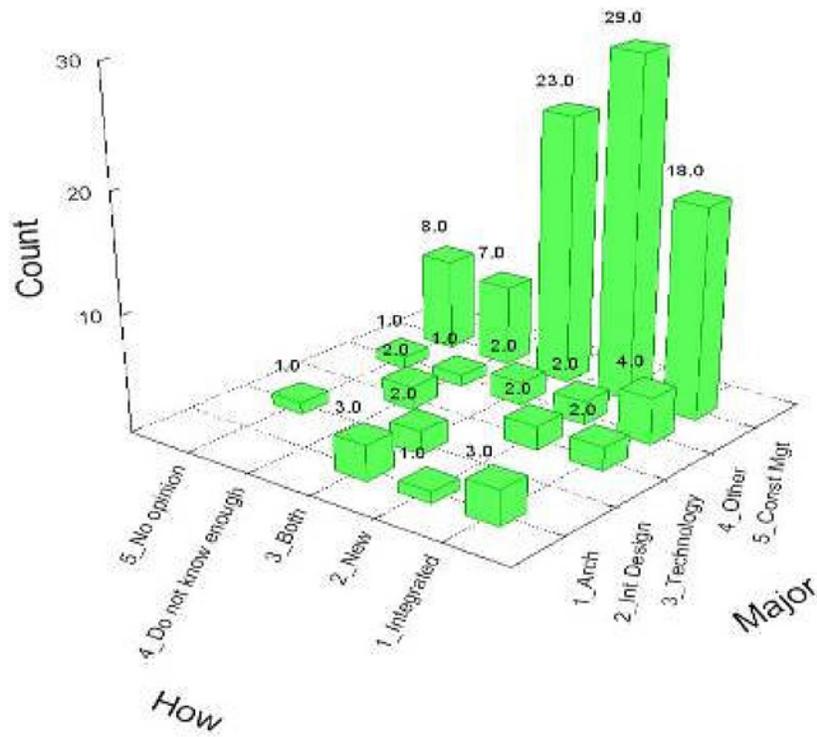


Figure 5

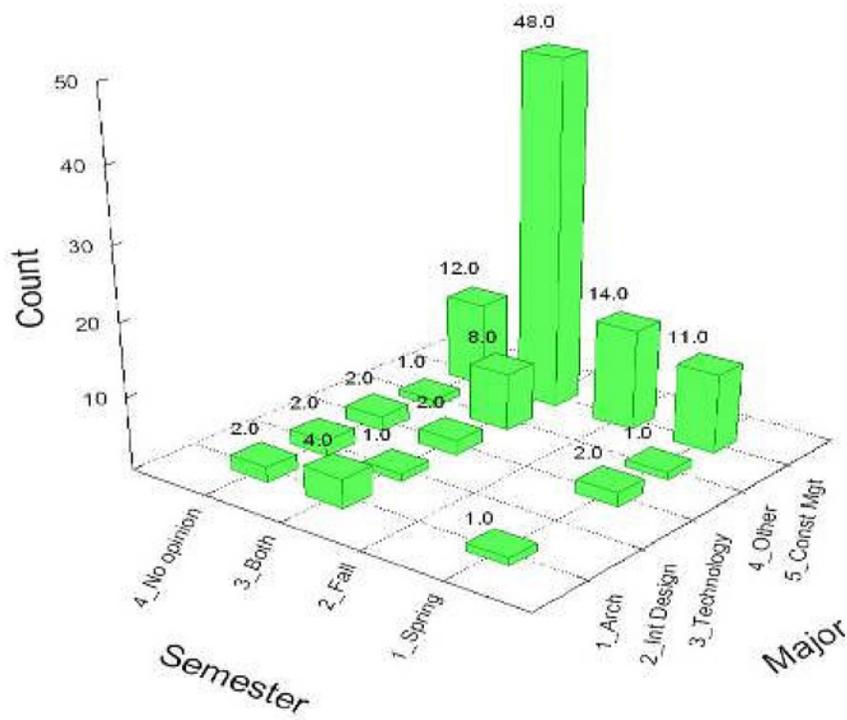


Figure 6

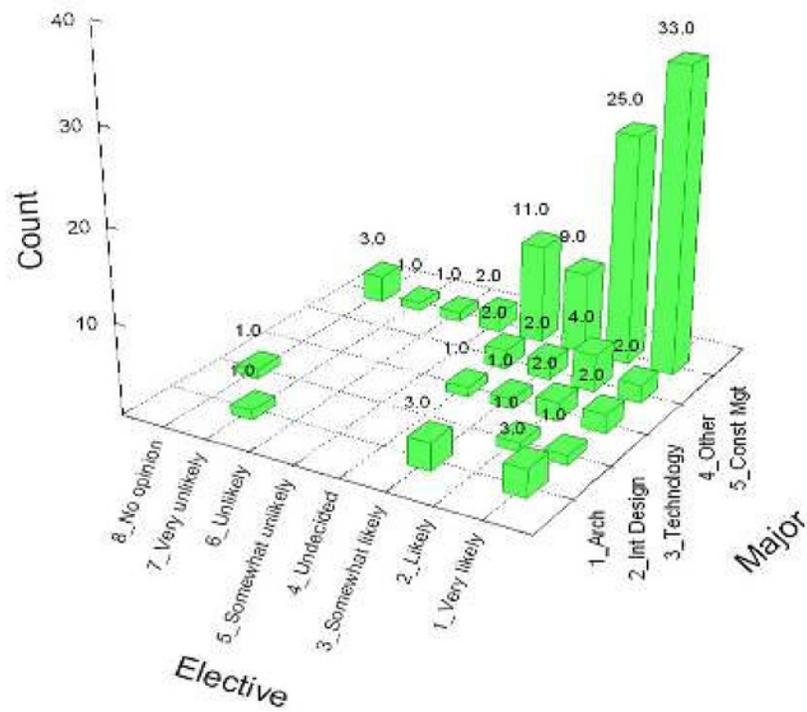


Figure 7

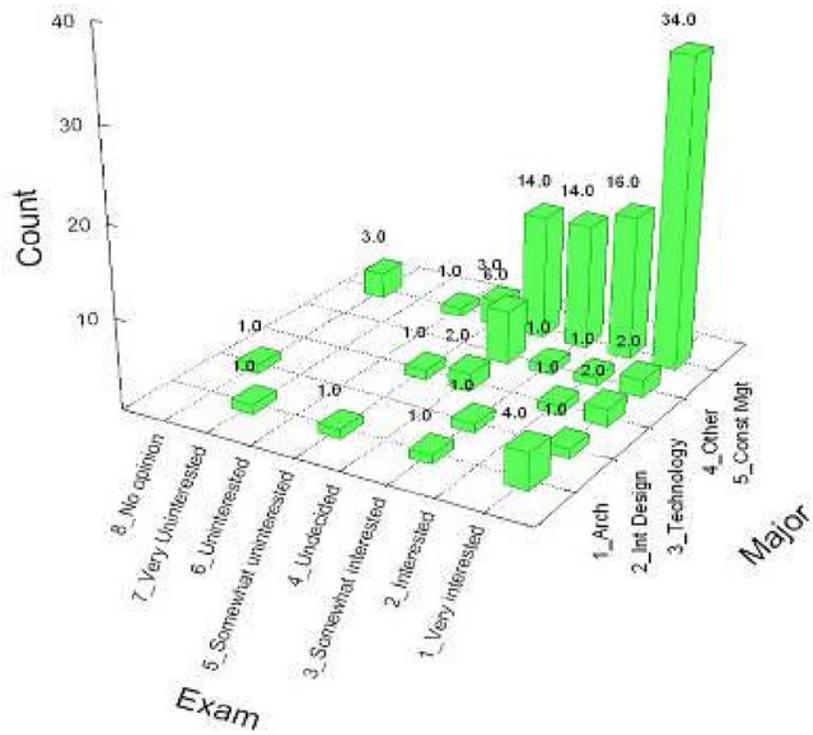


Figure 8

Statistical analyses

In addition to analyzing the summary statistics of the survey, it is interesting to see if some of the factors are more important than others in effecting how students in different categories responded the questions. For example, which one(s) of the following three factors, major, classification, and knowledge about green construction, would prominently influence a student's decision regarding questions #5 through #9 in the survey:

- #5. If green construction should be included in the curriculum;
- #6. If the green course should be a new or an integrated course;
- #7. What semester s/he prefers the course to be offered;
- #8. If the student would like to take the course as an elective; and
- #9. If the student would like to take the LEED-AP exam.

In statistical analyses, the three abovementioned factors are considered independent variables. Each of the factors has several levels, for example, Architecture/Interior Design/Construction Management for "major", freshmen/sophomore/junior/senior for "classification", and yes/no for "knowledge". Since these levels are better described in text strings than numerical numbers, the three factors are defined as categorical independents.

The responses to questions #5 through #9 are dependent variables. For the same reason as the independent variables, these responses are categorical dependents. Logistic regression technique handles categorical dependents. If the categorical dependent has more than two levels, multinomial logistic regression should be used, which is the case for this study. Five (5) initial full models and five (5) simplified models with simple terms and interaction terms were written as:

Full model #1: RESPONSES to #5 ~ MAJOR + CLASSIFICATION + KNOWLEDGE + MAJOR* CLASSIFICATION + MAJOR*KNOWLEDGE + CLASSIFICATION*KNOWLEDGE + MAJOR*CLASSIFICATION*KNOWLEDGE

Full model #2: RESPONSES to #6 ~ MAJOR + CLASSIFICATION + KNOWLEDGE + MAJOR* CLASSIFICATION + MAJOR*KNOWLEDGE + CLASSIFICATION*KNOWLEDGE + MAJOR*CLASSIFICATION*KNOWLEDGE

Simplified model #1: RESPONSES to #5 ~ KNOWLEDGE + MAJOR*CLASSIFICATION

Simplified model #2: RESPONSES to #6 ~ KNOWLEDGE + MAJOR*CLASSIFICATION

Then stepwise procedures were applied to identify the "best model". The estimates of the factors were analyzed to obtain the following findings:

- As expected, knowledge of the green construction plays an important role in students' decisions.
 - Students who had heard of green construction practices were 30 times more likely than those had not to include green construction subjects in the CM curriculum.
 - Knowledgeable students were 29 times more likely to have an integrated green course, 14 times more likely to have a new course, and 32 times more likely to have either an integrated or a new course than those had not to include green construction subjects.
- Other two independent variables, major and classification, turned out to be non-significant factors. This was despite the fact that "major" was an important factor in the initial descriptive analysis. However, this counterintuitive conclusion was not a surprise when the total number of the students in each major (85, 10, 7, 6, and 3) were not "balanced."
- The goodness-of-fit of models for questions #7, #8, and #9 were not satisfactory. Therefore, no conclusions were drawn regarding which semesters to offer the course, should the course be an elective, and if students would like to take the LEED-AP exam. However, the initial descriptive analysis provided useful conclusions to these questions.

Conclusions and Recommendations

To study the best way to include green construction subjects in the existing construction management curriculum, a survey was administered to 147 students. 111 students responded, with the survey yielding a respondent rate of 76%. After statistics analyses of the collected data, the following conclusions were drawn:

- There was a well-established interest in green/sustainable construction. 81% of the students would like to

include the subject into the construction management curriculum, 79% of the students indicated they would take the course as an elective, and 70% of student would be interested in preparing for the LEED-AP exam.

- Qualitative data from recent graduates confirms that there is a growing interest in green/sustainable construction and that LEED-AP accreditation is valued by employers.
- Earlier exposure of the green construction concept is imperative in rolling out and retaining the course. Students who had heard about green construction practices were 30 times more likely to include green construction subjects in the construction management curriculum. Knowledgeable students were 29 times more likely to be interested in taking an integrated green course, 14 times more likely to be interested in taking a new course, and 32 times more likely to be interested in taking either an integrated or a new course than those had not to include green construction subjects. This indicates the importance of introducing the green construction in entry level courses.
- Careful consideration of how often the course should be offered is necessary. Even though 57% of the students would like the course to be offered in both Spring and Fall semesters, most likely it will be offered in the Spring semester only. Several factors were considered: firstly, all other majors, except Construction Management, were interested in taking the course in Spring; secondly, the enrollment might be an issue because CM is still a fairly young program; lastly, the faculty workloads will have some significant changes if the course is offered in both semesters.
- The course should prepare students for the LEED-AP exam. 70% of the students were interested in taking the exam. It is expected more students will be interested in taking this class if the course description states that taking this course helps them to prepare the LEED-AP exam.

Some recommendations were also made from this study:

- More information could be collected in future surveys. For example, the gender, SAT/ACT scores, and the current GPA of the student. These factors could be influencing parameters.
- A better Design of Experiment (DOE) could be conducted. The obvious differences of sample sizes in different categories might have caused the poor goodness-of-fit of the regression models and the counterintuitive conclusion. A better DOE might be the solution to these issues.

This investigation, using a simple survey instrument and telephone interviews, established student and industry interest in green/sustainable construction. This interest was quantified and assisted the researchers select the appropriate offering for the topic as well as providing justification for requesting appropriate resources from their administration. This methodology can be used to understand the perspectives on green and sustainable practices being integrated into the construction curriculum from two key customer viewpoints: current students and recent graduates now working in industry. The customer survey model presented can be used to gauge student interest and industry need for integrating new topics and selecting the best instructional approach into any industrial technology course.

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Imagine the Possibilities!

Web 2.0 at Work: Managing Knowledge in a Collaborative Web Environment for Product Realization

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Abstract

For decades, the manufacturing industry has been hampered by silos of systems and processes that were isolated geographically or within organizational departments hindering collaboration across the value chain. In the quest to collaborate, it has become essential to reduce information overload to capture and replicate best practices, leveraging existing investments, and maximizing their use in a collaborative knowledge environment and exploiting multiple and disparate knowledge resources. Web 2.0 principles and techniques allow for an integrated support framework that has facilitated the organizing, disseminating, sharing, storing, and interpretation of data, information, and knowledge. Manufacturing 2.0 is based on Web 2.0 which is the open, programmable, collaborative and amassable Web. The consistent capturing and reusing of intellectual assets is a critical endeavor within organizations that value information and knowledge-sharing.

Introduction

The turn of century brought to the fore and the attention of the global manufacturing community, issues of global enterprise collaboration and intellectual capital management (Masson, Jacobson, & Smith, 2007). For decades, the manufacturing industry has been hampered by silos of systems and processes that were isolated geographically or within organizational departments hindering collaboration across the value chain. Enterprise applications that had been force-fitted into manufacturing operations had not only been costly and risky, but also counterproductive. The force-fitting of applications resulted in the creation of systems that were not only complex but hampered agility, efficiency, and effectiveness; defeating the original intent of the collaborative efforts.

Most global enterprise applications utilize Web 1.0 technologies which tend to have rigid manufacturing execution systems (MES) architectures that are difficult to scale for multisite rollouts. These applications also tend to have inflexible enterprise resource planning (ERP) business processes that do not mesh easily with manufacturing operations (Masson, Jacobson, & Smith, 2007). ERP and MES have been shown to have difficulties coping with constant reconfiguration and requirements to support manufacturing initiatives and have functional inadequacies when confronted by multiple manufacturing approaches such as Lean Manufacturing, Six Sigma, Product Lifecycle Management (PLM), among others. The implementation of MES applications and the adaption of ERP to manufacturing has been challenging to the manufacturing industry as these require increasingly scarce engineering skills and domain knowledge that many businesses lack (AMR Research 2007).

The complexity and cost of MES operations and traditional hard-wired automation approaches have created an automation ceiling, making it difficult to obtain a return on investment of the manufacturing software (AMR Research, 2007). The urgency for the industry is to support the growing demand for manufacturing systems that enable demand-driven manufacturing. This has necessitated manufacturing organizations to rethink the application architectures, delivery, and supporting business models from technology providers, consumers, and services firms that help deliver complete applications to manufacturing companies to support operations across integrated manufacturing operations (Masson, Jacobson, & Smith, 2007). The production and use of knowledge is a collective and collaborative endeavor requiring communication among team members that can be challenging and costly. The consistent capture and reuse

of intellectual assets is a critical endeavor in organizations that consider information-sharing vital to its competitive advantage. Driven by Web 2.0 technologies which allow for an integrated support framework that facilitate the organizing, disseminating, storing and interpreting of knowledge, the next generation of manufacturing dubbed Manufacturing 2.0 is seen as the solution to many of these woes.

Web 2.0: Managing Knowledge and Intellectual Capital

Web 2.0, an improved form of World Wide Web, is the new generation of the Web that offers a two-way communication with the user. Web 2.0 is considered more of a conceptual perspective or paradigm rather than a specific technology. It refers to a set of principles and practices that tie together a system of sites that demonstrate some or all of those principles, at a varying distance from that core (O'Reilly, 2005). Unlike Web 1.0, it characteristically allows "Two-way Apps," that involves both reading and writing (Kroski, 2006). It is a set of social, economic, and technology trends that collectively form the basis for the next generation of the Internet - a more mature, distinct medium characterized by user participation, openness, and network effects (Barros, 2008).

A distinctive feature of Web 2.0, is an understanding that humans are very good at certain activities, computers are really good at others, and groups or teams of people are good at yet other things. Therefore, creating systems that combine individual and machine capabilities makes very good sense (Pang, 2007). Through human-machine interface, the collective intelligence generated is more powerful than artificial intelligence or software that try to mimic human capabilities.

Highly complex manufacturing machines are always expensive and are extremely specialized. A change in design or technology can turn a machine into an albatross overnight. Simple tools coupled with the sensing, judging and tactile abilities of people have been found to be often more desirable than complex machinery. It is very difficult to make a machine that has the same capabilities as the human being for at least for the same cost and flexibility. (Leslie, 2001). A similar kind of relationship between human and machine, which recognizes that symbiotic systems tends do better work, more cheaply, than ones that try to cut humans out of the loop. (Pang, 2007). Web 2.0, in essence, allows the symbiotic systems to emerge and develop.

Web 2.0 leverages a group of technologies and tools including Weblogs, Wikis, Podcasts, RSS Feeds, among others that are social, writeable, personalized, and interactive. It goes beyond the page metaphor of Web 1.0 to deliver rich user experiences. The latest rich user experience platforms include Ajax, Adobe's AIR, Microsoft's Silverlight, and Sun's JavaFx with a consideration of how to take advantage of their individual strengths to create new, highly compelling user experiences not previously possible (Hinchcliffe, & Fandel, 2008). These applications make the most of the intrinsic advantages of the Web 2.0 platform. These social software facilitate collaboration and encourage community formation creating a network effect through "architecture of participation." They deliver software as a continually-updated service that improves as more people use it, consuming and remixing data from multiple sources, including individual users, creating network effects through an "architecture of participation" (O'Reilly, 2006).

Knowledge capture can be viewed as mainly a social process and collaboration technologies have been shown to facilitate knowledge sharing among users across by geographical boundaries. Knowledge management is the explicit and systematic management of organizational knowledge and associated processes of creation, organization, diffusion, use, and reuse (Skyrme, 1997). It consists of a range of techniques, procedures, and practices used by corporate organizations to identify, create, represent, and disseminate knowledge including data, information, facts, and procedures, for exploitation, awareness and learning. Web 2.0 is the ideal forum for integrating the different technological modules as the common communication platform (Gunasinghe & Kelly, 2005). A fundamental feature of Web 2.0 is that it can deliver and allow users to control interactive applications entirely through a web-based browser. Web 2.0's two-way conversations provide instant feedback, rapid evolution of offerings through co-innovating with the people actually using the products (Hinchcliffe, 2006). The content on Web 2.0 is user-generated allowing for content reviews and revisions, and feedback. Web 2.0 is able to deliver applications as a continually-updated services that gets better the more people use by allowing users contribute and letting others see and respond to those contributions (Yaneske & Bingham, 2006). The ubiquity of the Web 2.0 has made it an excellent medium for knowledge sharing in dispersed and collaborative environments. At its core, Web 2.0 is about harnessing collective intelligence and all other principles support this concept. The use of Web 2.0 social and community techniques, enterprise can help foster global communities of people.

Web 2.0 for the Manufacturing Enterprise

Since businesses are typically vastly outnumbered by their customers and potential customers, product development would be greatly enhanced by providing the teams with techniques that can collectively harness the collective intelligence and creativity of the teams. Using the Web 2.0 techniques and technologies that have emerged in just the last few years, businesses are now able to provide their product development teams with the tools and motivation to tweak, tune, refine, and contribute to its products and services (Hinchcliffe, 2007).

Manufacturing 2.0 is a conceptual model for achieving demand-driven product development and manufacturing through collaboration (AMR Research, 2007). Manufacturing 2.0 is more a state of mind than a technology that can be purchased. As such, many businesses still need to educate their employees on the techniques and best practices of Manufacturing 2.0 and social media. Manufacturing 2.0 lets companies collaborate across design, manufacturing, and supply chain functions, internally and externally by cutting through traditional departmental silos enabling the manufacturing community to achieve higher levels of collaboration across the manufacturing value chain (AMR Research, 2007). By leveraging mass user contributions, providing open architectures for others to build on as they like, and handing control over key product decisions directly to users, allows for the co-creation of better and cost-effective products faster. The main justification for Manufacturing 2.0 is that satisfied customers.

Manufacturing 2.0 employs Web 2.0 and Enterprise 2.0 technologies and constructs such as blogs, instant messaging, mashups, search, tagging, wikis, and cool, always-connected mobile devices allowing for user-focused interfaces streamlining activities also taking advantage of the intellectual capital at the company's disposal, reconfiguration, and software maintenance (Masson, Jacobson, & Smith, 2007). Furthermore, it uses manufacturing architectures that build on existing structures by using manufacturing service oriented architecture (SOA) instead of replacing them with new less agile applications.

Mainly web-based, most successful Manufacturing 2.0 applications can be used almost entirely through a Web browser. This is commonly referred to as "network is the platform" (O'Reilly, 2005). The network is no longer just infrastructure or bandwidth but is emerging as a secure platform for delivering the customized experiences such as delivering new services as a carrier, boosting productivity for businesses, or consumers looking for real-time, personalized entertainment and services (Carless, 2006). Users usually own their data on the site and can modify it at their convenience. An "architecture of participation" that allows users to add value to the application as they use it. While it is characteristic for Web 2.0 to avoid "walled gardens," in other words, it should be easy to get data in and out of the system, within the manufacturing context it has become necessary to create some walled gardens. Manufacturing 2.0 is based on Web 2.0 philosophies, principles, technologies, and practices which is the open, programmable, collaborative and amassable Web, resulting in the Web everywhere, the ubiquitous Web (Ortiz, 2006). Figure 1, below, illustrates the path of these aforementioned characteristics in relation to product development and related participants to the core essence of Manufacturing 2.0.

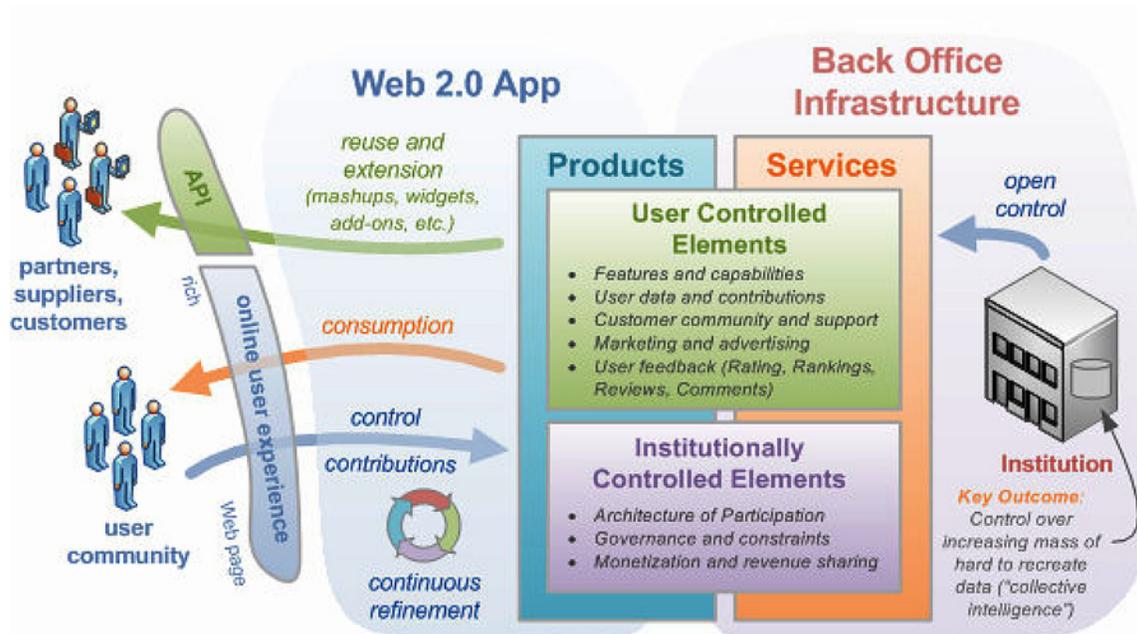


Fig. 1: Manufacturing 2.0 for Product Development Model
 (Source: http://web2.wsj2.com/product_development_20.htm)

In Manufacturing 2.0, the concept of “Web as platform” (O’Reilly, 2005) is fully embraced as Figure 1 illustrates. In this context, the web is a platform for business and communication. This is where the scale, new tools, and business models of Web 2.0 have been incorporated, giving the manufacturing industry the potential to provide our customers with better, rich products, much more quickly, and with more of what they want (Hinchcliffe, 2007). Another feature in the Manufacturing 2.0 model, is that there is innovation in assembly, whereby the web has become a massive source of small pieces of data and services, loosely joined, increasing the recombinant possibilities and unintended uses of systems and information. Users enjoy rich experiences enabling interaction and immersion in innovative new ways. Manufacturing 2.0 software are above the level of a single device allowing for both user- and institutionally controlled elements. Because of the continuous refinement in the Web 2.0 environment, software are in a perpetual beta state, software releases are disappearing and continuous change is becoming the norm (Hinchcliffe, 2006).

Manufacturing 2.0 leverages the “Long Tail,” a phrase first coined by Chris Anderson (2004). It refers to the mass servicing of micro-markets cost effectively on the Web. The Long Tail is a potential market and, the distribution and sales channel opportunities created by the Internet often enable businesses to tap that market successfully (Anderson, 2004). As with other Web 2.0 platforms, Manufacturing 2.0 utilizes simple, inexpensive lightweight software and business models that are cost effectively scalable (Hinchcliffe, 2007).

Product Realization in a Collaborative Web: PLM 2.0

The concept of Product Lifecycle Management (PLM) emerged in the 1990’s with the aim of moving beyond engineering aspects of a product and providing a shared platform for the creation, organization and dissemination of product related information (cradle to the grave) across the extended enterprise (Ameri1 & Dutta 2005). The main phases of PLM are: Plan, Design, Build, and Service (Stark, 2004). The first phase of PLM is the Planning or Conceptualization in which the ideas are generated and defined. During the Design phase, the detailed design and development of the product begins. It also involves prototype testing and pilot release. Once the design of the product’s components is complete the method of manufacturing is defined and the product built. The final phase of the lifecycle involves service and support of the product (Stark, 2004). It also includes consideration of end of life issues. This involves determining reuse, recycling or disposal of the product.

At the core of PLM is knowledge management, a process that supports capture, organization, and reuse of knowledge throughout the product lifecycle as such fills the gap between business processes and product development processes. The knowledge lifecycle is continuous and the optimization of these knowledge management processes generates the creation of new knowledge and innovation, is probably the most important knowledge process for achieving competitive advantage (Leitch & Rosen 2001). The process starts with planning including the identification and analysis of requirements ending with the disposal or recycling of the product.

The basics of PLM allow for the creation of a knowledge/information core that promotes innovation incubation based on the product and process changes. Knowledge becomes a corporate asset and establishes strong brand identification and value (Roberts & Almquist 2003). Driving knowledge core are the knowledge workers. Through collaborative efforts they stabilize and standardize the process. The extent to which knowledge workers are able to share and transfer knowledge will determine how successful knowledge management processes are. It therefore makes sense for manufacturing to take advantage of this new and emerging technology.

In 2008, following the revolution around Web 2.0, PLM 2.0 was introduced by Dassault Systemes (DS), a France-based provider of 3D and product lifecycle management (PLM) services (Vyas, 2008). PLM 2.0, just like Web 2.0 and Manufacturing 2.0, is more than a technology, it is a philosophy where PLM applications are Web 2.0-based. PLM 2.0 is about the reuse of Web 2.0 like terminology and concepts in the domain of PLM. The applications focus on online collaboration, collective intelligence and online communities. PLM expands to new usages like crowdsourcing which is basically the outsourcing of a task or job to an undefined, generally large group of people, in the form of an open call and real world web, extending the reach PLM outside the enterprise (Howe, 2008). In the PLM 2.0 environment, PLM business processes can easily be activated, configured and used, with online access.

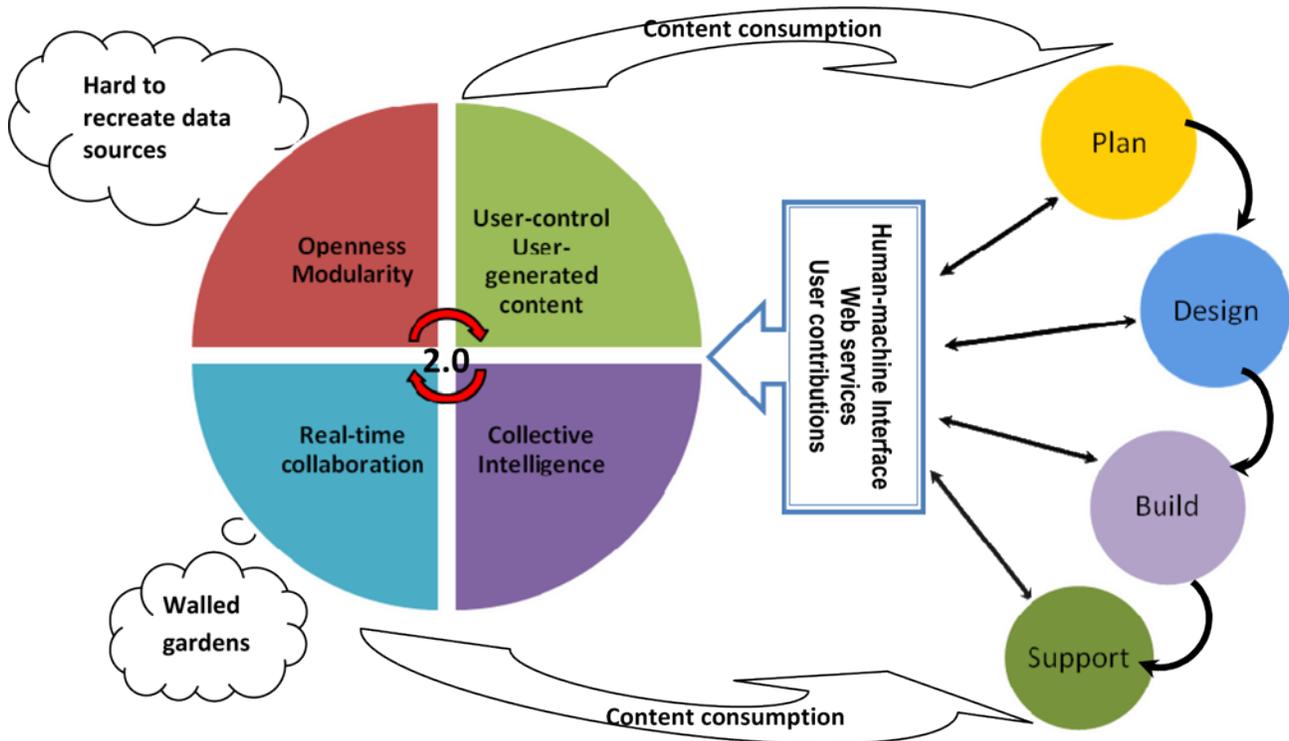


Figure 2: A Model of PLM 2.0

The model shows how PLM 2.0 facilitates knowledge management and collaboration. The basic PLM phases are fully integrated into the system. Information, data, and knowledge are shared and accessible through the human-machine interface. This allows for fast or expanded adoption of new products, technologies or ideas as part of an overall communication strategy. PLM 2.0's data and metadata are user-controlled and user-generated; while the interface is its own (Koivunen, 2005). This results in the development of collective intelligence. The collaboration helps locate expertise and seed new communities of practice also improving cross-functional knowledge-sharing. PLM 2.0 effectively builds well-structured global teams that are and facilitates the management of distributed teams (Bardhan, 2007).

Another feature of PLM 2.0, is that it seeks to own a unique, hard to recreate source of data. This is an important element in the manufacturing industry as companies are able to have their own intellectual property, setting them apart competitively. Users control their own data hence enhancing the core data. Although PLM 2.0 embraces openness, whereby the industry provides open, transparent access to their applications and content to partners, suppliers, customers, developers and others, through necessity, some walled gardens have been created. This allows organizations to make some rights reserved, not all design data for reuse and outsource or supply data access management (Hazlett, 2007; MAAWG, 2007). Modularity another critical characteristic of PLM 2.0, is composed of components or modules that are designed to link and integrate with others, together building a whole that is greater than the sum of its parts (Graziadio & Zilbovicius, 2003). Other benefits of PLM 2.0 to manufacturing, include allowing for strategic decision-making across leadership teams and helping the leadership to identify how to structure teams for innovation (Hinchcliffe, 2007). PLM 2.0 also helps the management of post-merger integration facilitating the many acquisitions and mergers in today's global economy.

Conclusion

Increasingly, organizations are looking to foster collaboration and sharing. In this quest to collaborate it becomes essential to reduce information overload to capture and replicate best practices. Web 2.0 has allowed companies to more effectively leverage existing investments and maximize their use in a collaborative knowledge environment and exploit multiple and disparate knowledge resources. The production and use of knowledge is a collective enterprise and communication between participants has been for decades the bottleneck. Some of the costs of this bottleneck are duplicated work, misdirected work, slower progress, and suboptimal decisions for lack of knowledge that is actually available. Web 2.0 techniques and principles have allowed for an integrated support framework that has facilitated the organizing, disseminating, sharing, storing, and interpretation of data, information, and knowledge. Manufacturing 2.0 is based on Web 2.0 philosophies, principles, technologies, and practices which is the open, programmable, collaborative and amassable. The consistent capturing and reusing of intellectual assets is a critical endeavor within organizations that value information and knowledge-sharing.

The greatest benefit of collaboration has been in the free transfer of information and knowledge within a company and its extended supply chain (Nucleus Research, 2005). As the field of Web 2.0 and all its spinoffs including Enterprise 2.0, Manufacturing 2.0 and PLM. 2.0, develops and becomes more widespread and sophisticated with varied experiences with different approaches to Web 2.0, additional critical pieces of the concept will continue to be revealed, and that it will become clearer how all the pieces fit together to create a rich picture of social and intellectual capital within organizations (Thomas et al 2001). As Web 2.0 becomes more centered in virtual relationships and spaces both within and across organizations, creating and maintaining knowledge and its social context will become more imperative. Effective knowledge management makes knowledge more accessible and available to the right people resulting in less duplicated work, misdirected work, increased productivity, and more effective and efficient decisions making mechanisms.

Proponents of Web 2.0 and Manufacturing 2.0 believe an added advantage of the technology is that it will engage younger generations in manufacturing as well as enhance software usability and collaboration. As an event-driven, supply network collaboration platforms (Masson, Jacobson, & Smith, 2007). The Manufacturing 2.0 platform allows for the convergence of product data management and process development models for rapid development of new products and manufacturing processes to accelerate time to market.

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Electrical, Electronics
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Globalization of Technology

Imagine the Possibilities!

Development of a Training System Integrating RFID Technology with a PLC

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Introduction

The industrial technology educator is constantly challenged to maintain a rigorous curriculum that reflects the modern state of industrial technology for which he or she prepares their students to enter. This challenge is often coupled with a limited budget for laboratory equipment and the need to make new equipment compatible with existing equipment. The College of Technology at Indiana State University has several laboratories in which part identification, inventory control, and Supervisory Control and Data Acquisition (SCADA) processes are taught. In the past, traditional Bar Coding technology was utilized in the teaching of courses using these laboratories.

In the summer of 2007, the authors, who are faculty in the Department of Electronics, Computer, and Mechanical Engineering Technology at ISU, began investigating a means of introducing Radio Frequency Identification (RFID) technology into the curriculum to replace Bar Code technology. Bar Coding is rapidly being supplanted by RFID. It was decided to develop a training apparatus which could be used by students to learn the operating principles of RFID, and apply those principles to industrial processes and situations through integration with existing laboratory equipment by means of a standard programmable logic controller (PLC). This paper provides an overview of the results of that effort.

Need

RFID is an area of technology that combines the fields of electricity, electronics, and computer technology in one application. RFID uses radio waves to communicate wirelessly between a transponder (commonly known as *the tag*) and an interrogator (commonly known as *the reader*). When electromagnetic waves from the interrogator strike the antenna of the transponder, it powers the integrated circuit chip contained within. The transponder emits a digital code that is received by the interrogator. The digital code is referenced against an existing computer database containing detailed information about the object to which that particular code was assigned.

Use of RFID tags allows for automated identification of parts in a manufacturing process, real-time monitoring of part movement through a process, or inventory control. The wireless nature of RFID overcomes a number of obstacles presented by the line-of-sight optical nature of Bar Coding technology (Lozano-Nieto, 2007).

The need for the inclusion of RFID technology into the ISU curriculum was compelling. Examination of the trade literature dealing with electronics, computer technology, and networking demonstrated a growing presence of the technology in the commercial and industrial sectors. In some cases, bar code systems were being replaced by RFID technology. The current driving force behind the technology has been mandates issued by the US Department of Defense and Wal-Mart to all their suppliers to use RFID for inventory control. These mandates, along with the realization by manufacturers that RFID use can assist in reducing costs and produce increased revenue has resulted in a move towards use of RFID. The US Department of Commerce has forecasted the 2008 market size of RFID technology as between \$2.0 billion and \$4.2 billion. As the market for RFID technology continues to increase, the number of industrial technology professionals who will be employed in the use of this technology will also increase (Lozano-Nieto, 2007).

However, coupled with this rise in demand, there is a shortage of available supply in human expertise in the RFID field. At the RFID Connect Asia 2007 conference, Micheal Mudd, Asia-Pacific Director of Public Policy for the Computer Technology Industry Association (CompTIA), stated that there are fewer than 1000 professionals available worldwide having expertise in the deployment and service of RFID systems(Tan, 2007). This view is supported by the results of a 2007 survey made by CompTIA of industry group members, which showed that 69.6% of those surveyed agreed that there was a shortage of trained RFID professionals and that this lack of human expertise could adversely affect the use of the technology (RFID News, 2007). This opens a window of opportunity for the industrial technology graduate who is prepared to enter this growing field.

As evidenced by David Sommer, vice president of e-business and software solutions at CompTIA, industrial technology programs are well placed to provide this expertise to the professional workforce. Mr. Sommer has stated that RFID technology professionals require a different skill set than most Information Technology (IT) programs provide. He believes that a broad base of technical expertise is needed to meet the challenges of integrating RFID with existing processes. This broad base includes skills in electronics, computer hardware, and networking, as well as computer software and data architecture. RFID professionals will need hands-on and knowledge based work skills as they will be responsible for installing, configuring, maintaining, and troubleshooting equipment (Sommer, 2007).

Overall Design Considerations of the RFID Trainer

There were several considerations in development of the trainer, including:

- compatibility with existing laboratory equipment, programming software, and networking protocols used in our labs,
- the ability to be interconnected to a wide range of sensors and other devices,
- compact “lab-in-a-box” structure that allowed the trainer to be easily moved between labs and simply assembled,
- standard 120VAC power for operation,
- safe, robust, and reliable construction, designed with the intent that it will be used in an educational setting by students, and
- the ability to be easily upgraded or expanded as future needs require.

PLC Controller and Trainer Hardware

Rockwell Automation Allen-Bradley control equipment is used almost exclusively in the automation labs at ISU. That fact drove the decision to use a MicroLogix 1500C PLC as the system controller. Pushbuttons, selector switches and indicating lamps were included in the trainer design to give students the ability to include hardware I/O operations in their lab exercises and logic programs. Additional PLC I/O points were wired to terminal blocks to allow easy connection of field located sensors and material handling systems such as conveyors and robot interface I/O that exists in the labs. All hardware I/O on the trainer is powered by a 24VDC power supply located inside the trainer panel.

RFID Reader & Hardware

An Escort Memory Systems (EMS) Cobalt RFID system was selected for this application. EMS brand equipment is widely used in industry and is a Rockwell Automation Encompass Product Partner company. The High Frequency (HF) Cobalt reader and the antenna are separate units assembled and mounted on a standard camera tripod, as shown in Figure 1.



Figure 1. Cobalt Reader assembly mounted on tripod.

The full range of swivel and tilt motion of the antenna/reader assembly on the tripod allows for positioning at conveyors or robot material handling systems, as determined by the requirements of the lab exercises or student projects. The mount was custom crafted using clear Lexan polymer sheeting, by the COT mechanical support technician, Mr. Mark Clauss. Two cables connect the reader to the trainer. One cable connects to the serial port of a PC (laptop or desk machine) from which the reader can be configured and tested using EMS brand software. The other cable supports DeviceNet communication, the means by which the reader communicates with the MicroLogix 1500 via a DeviceNet scanner module on the PLC. The Cobalt series RFID system can be purchased with either DeviceNet or EtherNet communication capabilities. DeviceNet was selected so that students working with the RFID equipment would additionally gain experience configuring and using a robust I/O network. The tags are separate autonomous units and required no action except to affix them to the object being identified and have data written to them.

Software

The MicroLogix 1500 PLC is programmed using RSLogix 500 logic software. The PLC communicates via a serial port connection to the PC via RSLinx. RSNetWorx software is required for the configuration and commissioning of the DeviceNet network via a PCID card in the PC. EMS furnishes free reader configuration software called Cobalt HF Serial Dashboard. Reader equipment can be set-up and tested as well as tag data written and read on a single event basis via this software.

Networking

Two networking protocols are featured in the trainer, namely DeviceNet and DH-485. DH-485 is a network protocol specifically designed for factory-floor applications. DH-485 allows for the connection of up to 32 devices, including PC's, PLC's, and printers. The protocol is compatible with Human-Machine Interface (HMI) development software such as RSVIEW and uses RSLinx software for communication with other nodes on the network. By use of the DH-485 interface the trainer can be networked externally to a central control computer running HMI software and exchange control data with other PLC's on the network, as well as other microcontroller equipped equipment such as robots (Rockwell Automation, 2008a).

The second network protocol featured in the trainer construction is DeviceNet. The DeviceNet protocol was developed by Rockwell Automation, Inc., with the intent of creating an open networking solution that uses the Common Industrial Protocol (CIP). Basically, this means that you can interchangeably connect and exchange data with any component from any vendor using the same protocol with a minimum of difficulty (Rockwell Automation, 2008b). While the PLC communicates with the RFID reader via DeviceNet, an additional seven DeviceNet capable smart field devices such as proximity sensors, I/O modules and motor drives can also be connected to the I/O network.

Construction of the Trainer

Once the general system specifications had been agreed upon and the major system components had been obtained by the authors, responsibility for the final assembly of the trainer was given to Edson Ryan, a student in the Master of Science in Electronics & Computer Technology program at ISU. Mr. Ryan was assisted in the construction of the trainer console by Mr. Mark Clauss. Figures 2, 3 and 4 show the trainer details.

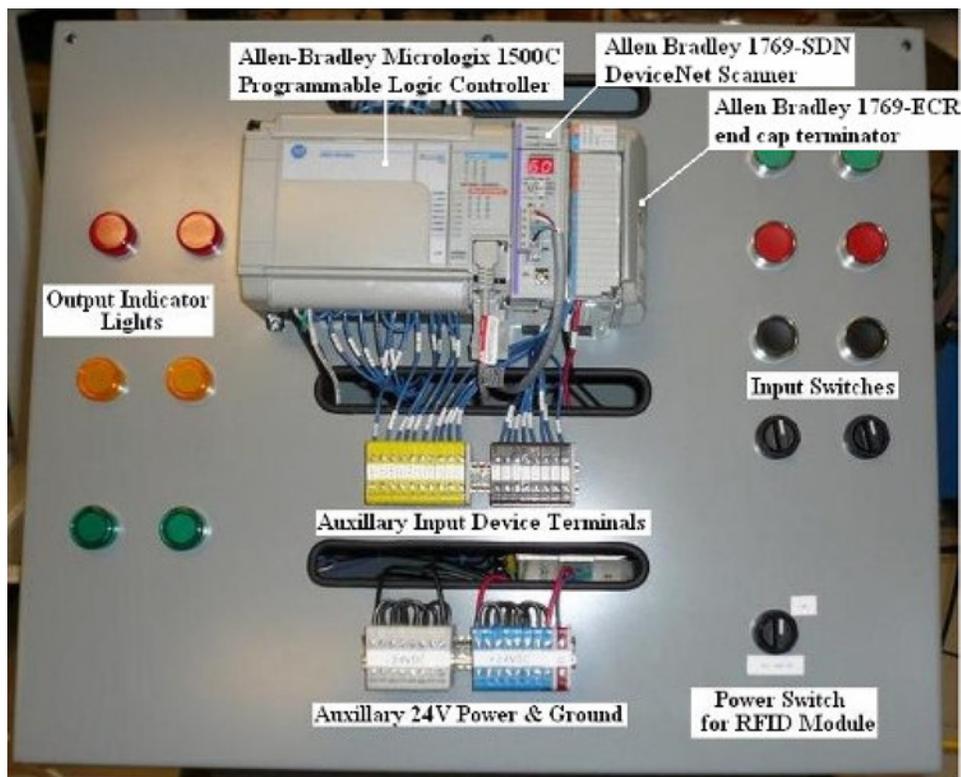


Figure 2. View of the Front Plate of the Trainer

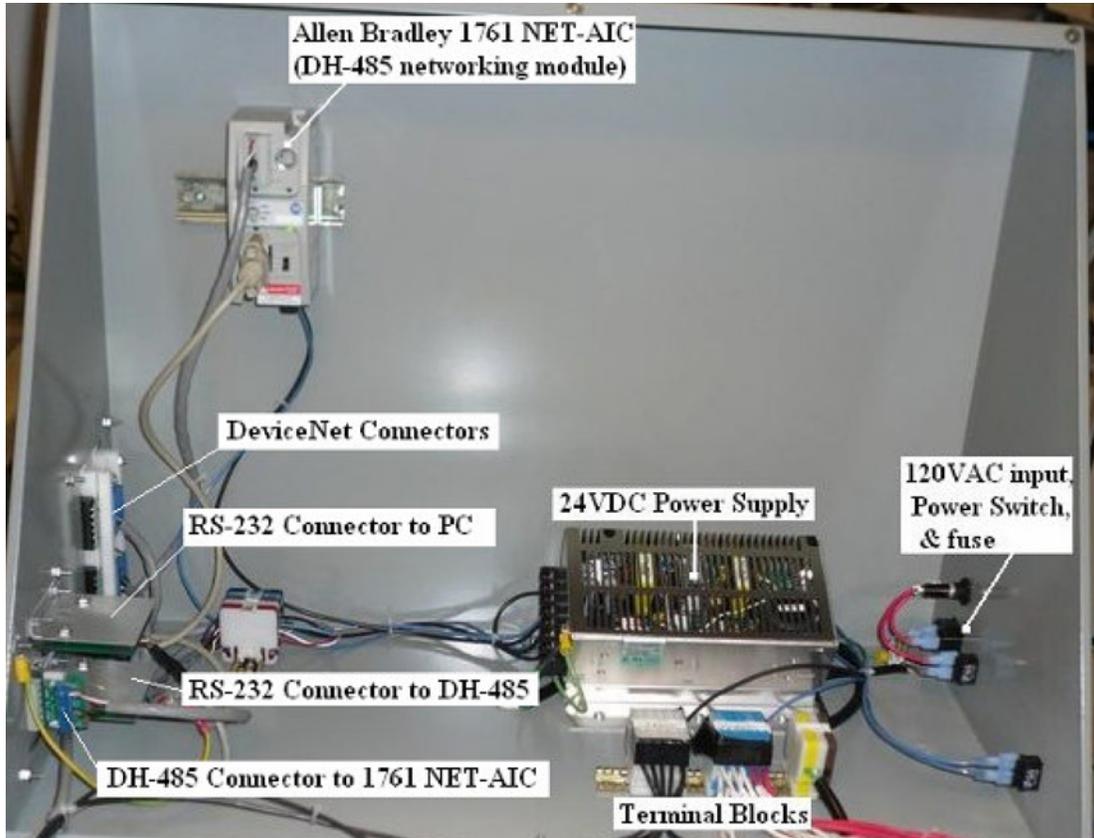
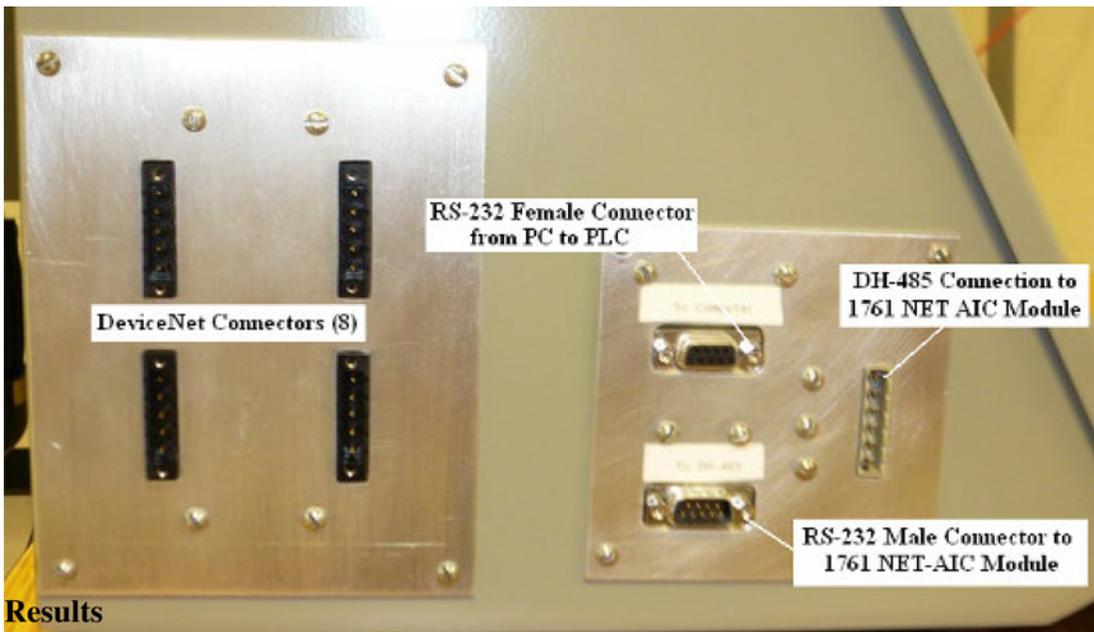


Figure 3. Inside View of the Cabinet of the Trainer



Results

Figure 4. Left Side View of the Cabinet of the Trainer

Results

Upon completion of the project, Mr. Ryan configured the software and developed a test program to read a sample tag and control a PLC output to indicate that a specific tag entry had registered with the database. One unexpected problem that was encountered was an incompatibility using RSNetWorx with the January, 2008 version of Windows XP running on our laboratory computers. It was necessary to load an older version of Windows XP to correct the problem. Upon demonstration of the trainer for the faculty the test program worked correctly.

A listing of the components needed for the construction of the trainer and their approximate cost are given in Table 1.

EMS Cobalt RFID reader, antenna, 50 tags	\$3100.
MicroLogix1500 PLC with DeviceNet scanner	\$1800.
PCID Card for PC	\$400.
Console enclosure	\$200.
Connectors, lamps, push button, switches	\$400.
Wiring, terminal blocks, cables	\$200.
RS Logix500, RSNetworx, RSLink software	\$1800.
Total	\$7900.

Table 1. Parts List and Approximate Cost

Conclusion

It is the responsibility of the industrial technology educator to effectively prepare students to successfully enter the modern global marketplace by providing them with the skills needed by industry. To respond to the demand for knowledge and skills in RFID, the College of Technology at ISU has begun taking steps to provide RFID knowledge concepts in its curriculum, as well as experiential learning in RFID technology. It is accomplishing this by means of a dynamic training module that allows RFID to be integrated with existing automated controls and processing equipment in our laboratories.

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Incorporating Field Data Received From the Cypdiso-8 Computer Interface Card into Commercial Inventory Software Programs

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Introduction

The purpose of this project was to incorporate a number of common manufacturing technologies into a problem solving exercise that would challenge students to apply higher-order cognitive skills. The tools selected to perform this project incorporated electronics, computer programming, and commercial business management software. Most technical education is performed at the “Principle” level of instruction. Merrill (2002) defines principle instruction as “always true under appropriate conditions regardless of program or practice method” (pg. 43). Students are presented information in a context and tested later to insure they have retained the standard (correct) information. Gokhale (1995) assessed that the skills required to perform this type of learning are the lower-order knowledge, comprehension, and application skills outlined by Bloom’s Taxonomy (see Figure 1).

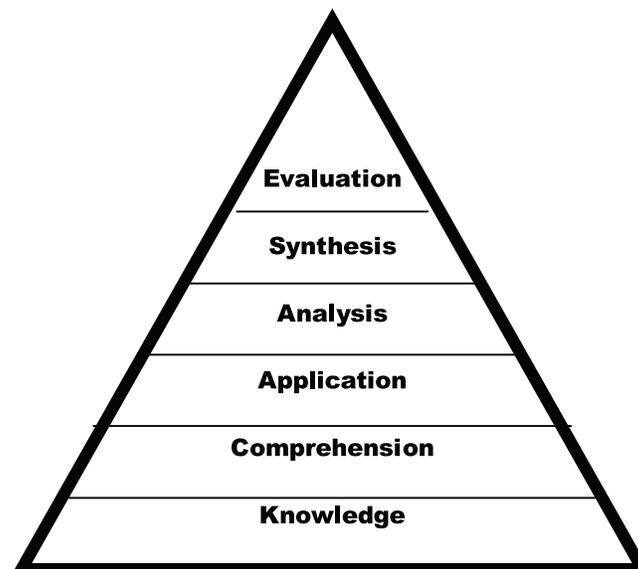


Figure 1: Bloom’s Taxonomy

The higher-order skills of synthesis and evaluation can be developed by problem solving exercises such as knowledge transfer, the ability to apply information learned in one context to new contexts. According to Devine (2006) “...three

principles are at the heart of knowledge transfer: (1) instruction should encourage students to learn conceptually; (2) instruction should be contextualized; and (3) instruction should help students understand the relationship between relevant conceptual and procedural knowledge”. Contextual teaching applies cognitive theories to practice by connecting the information to be taught with the context in which the content will likely be used (pg. 2).

Putnam (2001) reviewed studies on cognitive development from the Harvard and the Southern Illinois University School of Medicines. His analysis was that successful problem-based learning encompasses three primary characteristics:

1. The exercise should be authentic and be considered significant from both the students’ perspective and from that of the real world. The problem should be engaging and approximate how it would actually be encountered in the real world.
2. The problem should be interdisciplinary. It should address the defined knowledge and skill areas for which it was designed and be multidisciplinary when possible.
3. The problem should be ill-structured and complex. Real world problems never present themselves as simple, well-defined efforts which [sic] lend themselves to easy solutions. (pg. 9)

Based on the recommendations of the aforementioned authors, this project sought to integrate three dissimilar technical components into a sole project that reflected a challenging industrial-type problem. The student exercise developed to meet the challenge was to:

1. Identify products moving along a conveyor using some form of transducer other than an automatic identification (bar code, rfid tags, etc.) technology. The educational goal was to reflect on prior learning and to assist in the planning, design, research, selection, installation and operation of an appropriate part sensing system for a workcell given an unusual set of constraints.
2. Using a high-level programming language, write a program to determine the inventory item number for any part scanned on a moving conveyor and then update the inventory count in a commercially available MRP-II inventory software module. The educational goal was to write software to synthesize externally developed electrical signals with commercial software data; a typical function carried out on many industrial production lines.

Components

The components used for this experiment were a lab-constructed belt conveyor, two photoelectric sensors, a CYPDISCO-8 I/O computer interface card and a pc with MS-Basic and Alliance Manufacturing MRPII software. The interface card used for this project was ISO compliant and, as such, we used an older pc with its available software, hence the MS-Basic. The card manufacturer, CyberResearch Inc currently offers a PCI version of the same card (PCISO-08) and it is recommended if you wish to replicate this project.

Conveyors

We used lab-built conveyors capable of moving parts up to 48” on a six-inch wide belt. The conveyors were constructed using uni-strut channel which allowed for ease of attaching accessories at various points along the conveyor. The transducers chosen for this project were Automation Direct’s SSP-ON-4A retro-reflective photoelectric sensors. Two sensors were placed in the “high” and “low” positions at the same point on the conveyor. This allowed for tall and short items to be identified. Additional sensors could be triangulated to allow for more variety of items to be discerned.

Input/Output Card

The CYPDISO 8 I/O card is an ISO compliant 8-channel digital input/relay output computer interface card that allows 5-24 volt dc/ac (50 - 1K-hz) input signals to be analyzed and output signals up to 28 volts dc at 6 amps or 120 volts ac at 5 amps (CyberResearch, pg 1).

Programming Language

When selecting a programming language to use for this exercise, we agreed with Kostek (1995) that the C programming language “had too large a learning curve for our students”. Since “manufacturing engineers and system integrators perform mainly system type programming as opposed to program development”, BASIC was chosen as an appropriate programming platform for this project (pg 131).

Commercial Software

The software component chosen for this project was Materials Resource Planning (MRPII). MRP-II is a method used for the effective planning of all product-related, machine and human resources within a manufacturing company. MRPII is a force-pull system that manipulates tremendous quantities of manufacturing data to forecast and prioritize materials ordering, process scheduling, and shipping dates (Siripanich, pg. 2). MRPII software typically consists of integrated modules such as Bill of Material, Inventory, Sales, Purchasing, etc.

There are many MRP, MRP-II and inventory-related software packages available and many companies are installing Enterprise Resource Planning (ERP) for corporate-wide decision making. Our department currently uses Alliance/MFG and DBA (free run time version is available on internet) MRP-II programs. Both systems are used in small to medium-sized companies. Alliance/MFG was used for this project. Alliance allows users to create a database, explore data and make recommendations in production planning and scheduling. The system also performs automatic MRP calculations taking into account all sales, on-hand inventory, work-in-process, and machine or workcell availability.

Sequence of events

The main objective of the student project was to identify parts moving along a conveyor to update the inventory module in Alliance/MFG. The constraint placed on the project was that transducers were to be used rather than an auto-id device to identify the parts.

The first step in setting up the system was to integrate the hardware. This required attaching the photoelectric sensors at the exit point of the conveyor. The sensors were then wired to input points 6 and 7 on the CYPDISO-8 card (input point 6 connections are made at terminals 2 and 21 on the terminal board, input point 7 connections go to terminals 1 and 20). An optional wiring board with a D37 plug that attached to the I/O card sped the wiring process. Referring to the CYPDISO instruction manual, input point 6 corresponds to the hexadecimal address of 40 and input point 7 corresponds to 80H (refer to lines 30 and 31 of the BASIC program). For this experiment no outputs were used. The wiring connections and CYPDISO-8 were tested for proper operation using software supplied by the manufacturer.

A company database was setup in Alliance/MFG to include the parts masters for the items to be identified. A data file was then developed using the WINDOWS NOTEPAD program. The data file is a receptacle that the BASIC program updates each time there is a change in part quantities. When a run of parts was completed, the data file was then imported to the Alliance/MFG to update the inventory amounts. The data file extension must be .CDF (comma delineated format) and the placement of the data as shown in Figure 2.

Filename: VIS.CDF

Location Code, Part Number, Stockroom, Quantity

100, 10011, SR101, 9

Indicates: location 100, part 10011, stock room 101, quantity of 9

Figure 2. Example of the Notepad data file.

The BASIC program used for this project is shown in Appendix D. The italicized text instructs the reader as to the procedure being conducted on a particular line of code. In general, lines 1-4 provide instructions to the data file what format information will be presented in. Lines 5-31 sets the Base Address of the CYPDISO card at 300 hex and assign variable names. Delays were necessary at lines 36 and 47 to prevent the software from allowing multiple counts for one item as the item was located within the range of the photoelectric scanners.

IF/THEN/ELSE statements were used to analyze the input signals (points 6 & 7), determine the part identification number that corresponded to the input signals (input 6 and no input 7 equals part A, input 6 and input 7 equals part B, input 7 and no input 6 equals misread).

The final statements of the BASIC program dealt with transferring the totals added for each part number to the data file. Once a scheduled run was completed, the data file was imported into the Alliance/MFG program.

Conclusion

One example of a problem solving activity has been presented in this paper. After investigating the components of cognitive learning an exercise was developed that was significant, interdisciplinary, unstructured, and complex. Following these tenets any number of similar problem solving exercises can be developed for inclusion in current courses or as the basis for a capstone project.

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Appendices

- A. System Components
- B. Basic program
- C. Alliance/MFG Inventory Maintenance Master
- D. Alliance/MFG Import Configuration Screen

Appendix A: System Components



Data Acquisition Board



Assembled Project

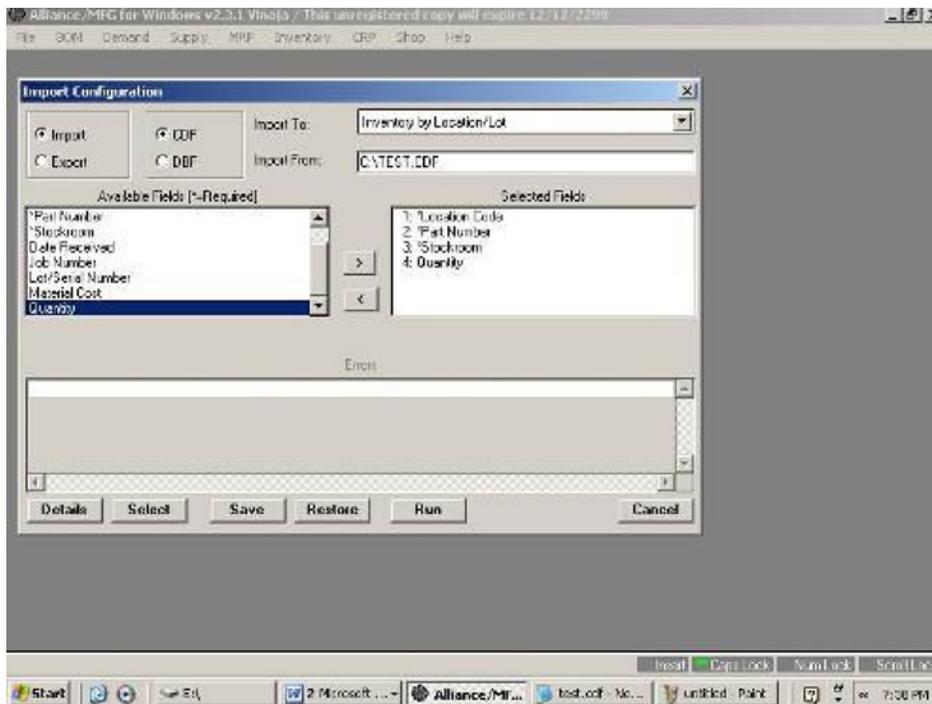
Appendix B: Basic Program

```
1 OPEN "vis.cdf" FOR INPUT AS #1
2 INPUT #1, N$, QT6
3 INPUT #1, N$, QT7
4 CLOSE #1
5 BASE% = &H300
6 LET VB=0
10 BASE = &H300
20 IN% = INP (BASE+1)
30 INP7% = IN% AND &H80
31 INP6% = IN% AND &H40
35 IF INP7% =>1 THEN I7$ = "1" ELSE I7$ = "0"
40 FOR M% = 1 TO 29999
41 NEXT M%
45 IF INP6% =>1 AND INP7%=0 THEN I6$ = "1" ELSE I6$ = "0"
50 FOR O%= 1 TO 29999
51 NEXT O%
55 IF INP6%=0 THEN GOTO 20
100 PRINT "INPUT 7 IS", I7$
110 PRINT "INPUT 6 IS", I6$
125 PRINT "qt6 = ," , QT6; " qt7=, " , QT7
130 IF INP7% => 1 THEN LET QT7= QT7+1
140 IF INP6% =>1 AND INP7% = 0 THEN LET QT6 = QT6+1
141 IF INP6% => 1 THEN LET VB=VB+1
150 IF VB=10 THEN GOSUB 199 ELSE GOTO 20
199 LET VB=0
200 INPUT "ENTER DATA FILE NAME = =>"; FILE$
210 OPEN FILE$ FOR OUTPUT AS #1
220 WRITE #1, "100, 10011, SR101, ", QT6
221 WRITE #1, "100, 10011, SR101, ", QT7
230 CLOSE #1
```

Appendix C: ALLIANCE/MFG Inventory Maintenance Master



Appendix D: ALLIANCE/MFG Import Configuration Screen



Theory, Practice, and Systems - A New Approach to Teaching Wireless Communications with MATLAB and IT Guru

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Abstract

Two important aspects of training future engineers are a thorough understanding of the theories behind engineering problems, and practical experience in implementing solutions to these problems. Theoretical knowledge can be best comprehended and acquired from a system perspective. Experimental knowledge of engineering implementation and problem-solving can be best understood and obtained through practical data. Because of its strong computational and modeling capabilities, MATLAB is an excellent tool to help engineering students further their theoretical and practical knowledge in the context of engineering systems. IT Guru is another powerful tool that provides network modeling, simulation, and analysis. In this presentation, we propose a new method of teaching the **wireless communication** course from a system perspective using MATLAB and IT Guru. In the presentation, the approach to teaching wireless communications will be discussed and the development of each laboratory based on MATLAB or IT Guru **will be provided**. The topics for experiments include source coding, modulator and demodulator design (AM, FM, ASK, FSK, BPSK), sampling and quantizing, channel characteristics, error detection and correction, CDMA and WLANs.

Introduction

Rapid advancements in wireless technologies have demanded that graduating electronics and telecommunication engineers not only be familiar with the concepts and theories behind the technologies but also be trained in them. One approach that could be used to train as well as enhance student comprehension of wireless concepts and theories is the use of available software in the classroom. Use of software in the classroom provides a platform to improve students' understanding of wireless theories and exposes them to software that is being used by industry for research and development. Upon graduation, students will exhibit the necessary training to be a skillful engineer. This paper addresses our approach to teaching the wireless communications at **Indiana State University**.

ECT 344 is the Wireless Communication class taught at the **Indiana State University**. The class introduces students to system design fundamentals - basic knowledge of communication system, noise, frequency reuse, analog modulation and demodulation, sampling, digital modulation and demodulation, channel coding, medium access control protocol, handoff strategies, and channel propagation models. It also provides the architectures of wireless local area networks (WLANs), cellular networks (GSM and CDMA networks), and satellite networks. The last part of the class addresses network security.

The software being integrated with the wireless communication class is MATLAB from Mathworks, Inc and IT Guru from OPNET Technologies, Inc. MATLAB is an excellent tool which has strong computational and modeling capabilities. IT Guru is another powerful tool that provides network modeling, simulation, and analysis.

The software is integrated into the class to supplement wireless textbook teaching and enhance comprehension of wireless concepts and theories. A two-hour lecture is devoted to the concepts and theories from textbook and the other two-hour weekly lab is devoted to the corresponding topics.

Many advantages could be realized by using the powerful software to supplement a wireless communication class. These can be summarized as follows.

- Through assigned labs, students design a complete system, analyze overall performance, and visualize the output.
- Minimal time investment of the instructor to prepare examples to present wireless concepts. The software comes with extensive tutorial examples.
- Not too many programming requirements.
- Students graduate with appropriate background and training in wireless technologies.

MATLAB and OPNET IT Guru

MATLAB is a numerical computing environment and programming language. Created by The MathWorks, MATLAB allows easy matrix manipulation, plotting of functions and data, implementation of algorithms, creation of user interfaces, and interfacing with programs in other languages. Although it specializes in numerical computing, an optional toolbox interfaces with the Maple symbolic engine, allowing it to be part of a full computer algebra system. As of 2004, MATLAB was used by more than one million people in industry and academia (MATLAB, 2008).

Simulink, developed by The MathWorks, is an environment for multidomain simulation and Model-Based Design for dynamic and embedded systems (Simulink, 2008). It provides an interactive graphical environment and a customizable set of block libraries that let you design, simulate, implement, and test a variety of time-varying systems, including communications, controls, signal processing, video processing, and image processing. With Simulink, you build models by dragging and dropping blocks from the library browser onto the graphical editor and connecting them with lines that establish mathematical relationships between blocks. You can set up simulation parameters by double clicking the blocks.

IT Guru is a very powerful network simulator. It provides network modeling, simulation, and analysis (OPNET, 2008). It has been widely used for research and professional network design. With IT Guru, an engineer and system administrator can very effectively analyze the system performance, diagnose problem, and validate changes before they are implemented. However, it is also very, very expensive. Fortunately a limited (at no cost) academic version *IT Guru Academic Edition* exists that is good enough for our labs.

Pedagogical Design

Our lecture class follows the integrated approach which combines the physical layer and the upper layer (architectures) in teaching wireless communications. We begin with an introduction of communication systems, followed by the introduction to analog modulation, sampling, digital modulation, multiple access technologies, channel propagation models, channel coding, cellular networks, wireless local area network (WLAN), satellite communication, and network security. This integrated approach was adopted instead of only focusing on the physical layer or upper layer. The idea behind this integrated approach is to have students explore both of them. We have 12 lab exercises that have been tailored according to topics from *Electronic Communication Systems* (Roy Blake, 2002), and have been trialed in the fall semester 2007 in our wireless communication course. Each lab is conducted as a two-hour session, held weekly for 12 weeks in our communication laboratory. The following lab exercises describe the lab contents.

Lab Exercises

Lab 1: Introduction to MATLAB

In this lab, students will learn the basic knowledge of MATLAB, such as how to create vector, matrix, arithmetic operation of vector and matrix, plotting graphs, and creating scripts (m files).

Lab 2: Introduction to Simulink

After this lab, students will know how to allocate memory in MATLAB, and how to access the matrix with subscription. Students will be required to create the simulation model in Figure 1. Students will be asked to modify the block parameters to implement a 1Hz full-wave rectified square wave signal using 1, 3, 5, 7, and 9 Fourier series terms.

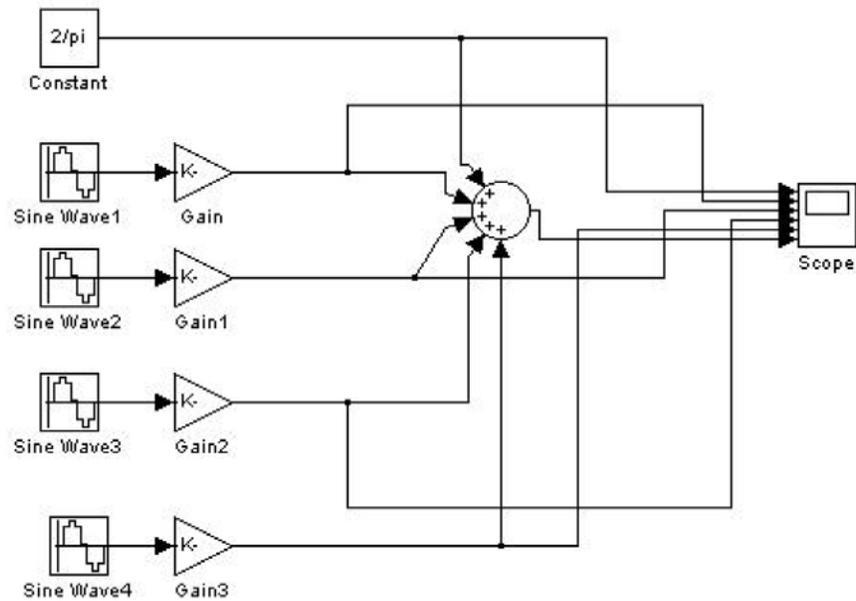


Figure 1: Simulation Model of Fourier Series

Lab 3: Simulink and Amplitude Modulation

Amplitude modulation (AM), still widely used in commercial radio today, is one of the simplest ways that a message signal can modulate a sinusoidal carrier wave. The purpose of this lab is for students to gain familiarity with the concepts of amplitude modulation.

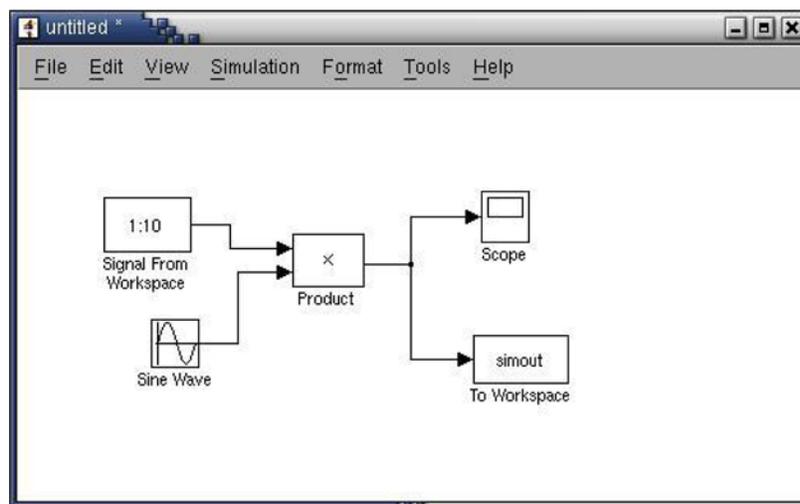


Figure 2: Simulink Model for Amplitude Modulation

Lab 4: Synchronous and Asynchronous Amplitude Modulation and Demodulation

The objective of this lab is to deepen students understanding of synchronous and asynchronous demodulation principles for amplitude modulation. Students are required to build the Simulink model for synchronous amplitude demodulation of a sinusoidally modulated signal. The modulation part can be obtained from lab 3. A block diagram of the modulator and demodulator is shown in Figure 3.

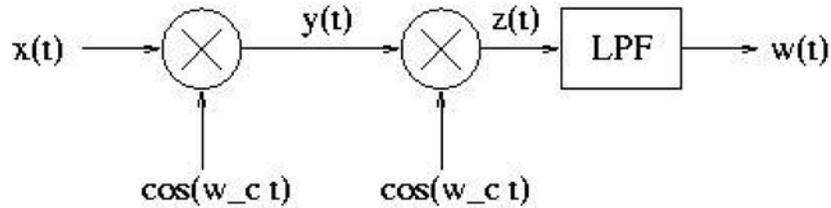


Figure 3: Block diagram of Amplitude Modulation and Demodulation

The demodulated signal $z(t)$ will pass through a low pass filter (LPF). Students need to plot the spectra of $x(t)$, $y(t)$, $z(t)$, and $w(t)$ in the same figure window but in different axes as shown in Figure 4.

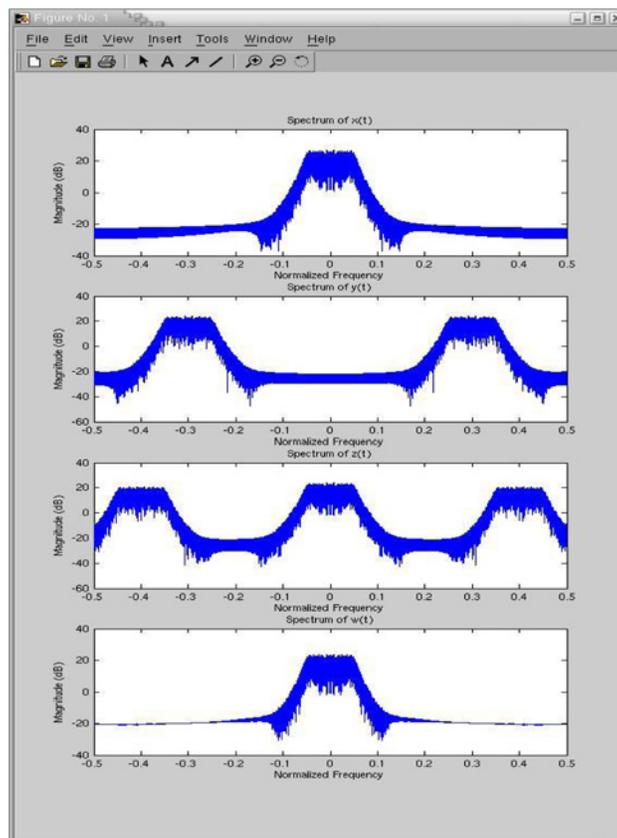


Figure 4: Spectra of $x(t)$, $y(t)$, $z(t)$, and $w(t)$

Students are required to modify the above experiment by introducing a carrier frequency offset during demodulation, and plotting $x(t)$ and $w(t)$.

Lab 5: Sampling and Reconstruction

The effects of sampling, aliasing, and reconstruction will be explored in this lab exercise. The simulation will consist of a sampling operation, followed by reconstruction.

Lab 6: FSK and BPSK Systems

Students are required to model complete FSK and BPSK systems and simulate with different attributes. The FSK system

block diagram model is shown in Figure 5. Students are required to configure the binary data source, FSK modulator, band-limited noisy channel, and FSK demodulator, and to use the scopes to watch the waveform in each step. Students can follow the same procedure used in building FSK model to build the BPSK system.

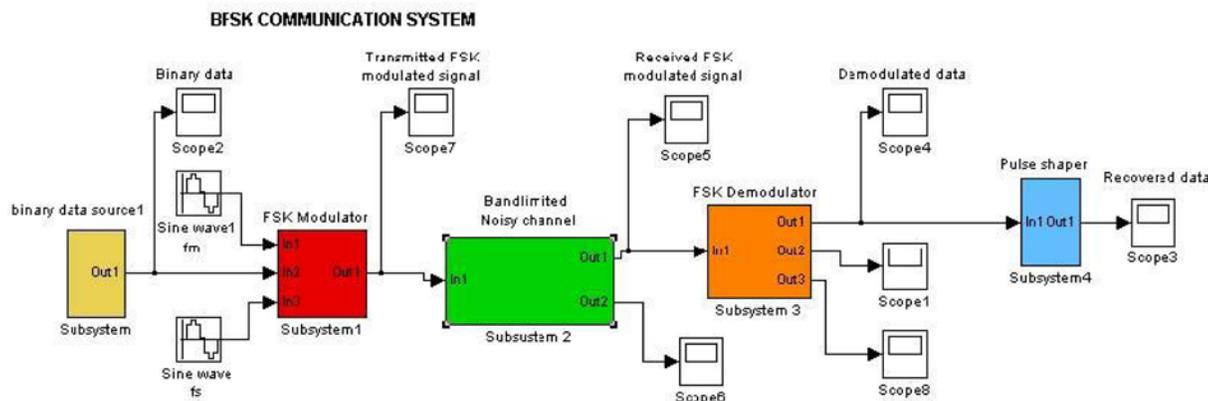


Figure 5: FSK System Block Diagram Model

Lab 7: Error Detection and Correction

The objectives of this lab are to implement the parity check and CRC error detection codes, and to implement a Hamming code. Students are required to use any programming language to generate a random 8-bit long data message, generate the check bits and send the message to the receiver. During the transmission process, students introduce 1, 2, and 3 random error bits to test the parity check and CRC codes. For the Hamming code, students randomly generate one bit error and test if the receiver can correct the error by itself or not.

Lab 8: Basics of IT Guru

IT Guru Academic Edition enables students to better understand the core concepts of networking and equips them to effectively troubleshoot and manage real-world network infrastructures. This lab teaches students the basics of using IT Guru Academic Edition, including creating projects, building models, choosing statistics, managing scenarios, and viewing results. Students will be required to follow the tutorial provided by the software.

Lab 9: Network Design

The objective of this lab is to have a design that maximizes the network performance, taking into consideration the cost constraints and the required services to be offered to different types of users. In this lab, students will design a network for a company that has four departments: Research, Engineering, E-Commerce, and Sales. Students will utilize a LAN model that allows them to simulate multiple clients and servers in one simulation object. Student will be able to define a profile that specifies the pattern of applications employed by the users of each department in the company. By the end of this lab, student will be able to study how different design decisions can affect the performance of the network.

Lab 10: Wireless Local Area Network - MAC Protocol

This lab addresses the medium access control (MAC) sublayer of the IEEE 802.11 standard for WLAN. Different options of this standard are studied in this lab. The performance of these options is analyzed under different scenarios.

Lab 11: Mobile Wireless Network - A WLAN with Mobile Stations

This lab simulates mobility in WLANs. The effect of mobility on TCP performance is studied. In addition, this lab studies how the request to send (RTS) and clear to send (CTS) frames are utilized in avoiding the hidden node problem usually induced by mobility in WLANs.

Lab 12: Firewalls and VPN - Network Security and Virtual Private Networks

Security in networking is more and more important today. In this lab, the roles of firewalls and Virtual Private Networks (VPN) in providing security to shared public networks are studied. Students will set up a network where servers are accessed over the Internet by customers who have different privileges.

Benefits of Lab Exercise and Student Feedback

After one trial run of the wireless communication course during the fall 2007, we have assessed the educational value of the lab exercises through feedback from students. Our results show that most of students did not have the prior knowledge concerning wireless communication. They found that these labs are very interesting and easy to follow. In the feedback form, all students answered the question “Did the lab help you understand?” with “Yes”. They stated that the lab exercises are necessary for them to understand the concepts in wireless communications. The following is a typical feedback from a student regarding Lab 6 - “This lab exercise helped me to clarify how the digital modulation works and how the noise interfere the signal message, by seeing the waveforms of each step.”

Conclusions

A series of labs has been developed which can let students “see” how the wireless techniques work. The lab exercises reinforce the topics from lecture. Feedback shows that these labs can motivate student’s interest in wireless communication and help them gain hands-on experience.

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Undergraduate Research Experience in Mobile Robot Design: From CAD to Electronic Control

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Abstract

In this paper, senior project experience in designing and implementing an experimental mobile robot is discussed. This mobile robot can be used as a platform to learn sensor interfacing, microcontroller programming, motor control, and electronic circuit design and troubleshooting. A specially designed protoboard was used so that students could experiment with various types of sensors and supporting electronic circuitry. The modules implemented in this project are: servo motor control, infrared (IR)-based obstacle detection and avoidance, temperature sensing, and IR wireless communication. An 8-bit Peripheral Interface Controller (PIC) microcontroller, operating at 20MHz, was used as a programmable controller to monitor the external environment through sensors and make appropriate decisions. PIC was programmed using PICBasic PRO, a BASIC-like high-level language. The implementation was broken down into a set of experiments, through which the students progressively added functionality to the robot design. This progressive experimentation helped students develop their knowledge of interfacing, microcontroller programming, electronic control, circuit design, and troubleshooting in an incremental manner. The robot design experiments, sensor interfacing, electronic control, supporting circuitry, and problems faced during implementation are discussed in the paper.

Introduction

An undergraduate senior design project course is an important part of an undergraduate Engineering Technology degree program (ABET, 2002). The senior design course gives students the opportunity to demonstrate what they have learned throughout their studies. Students apply basic theories to experimental projects related to real-world problems. These projects aid the student in developing critical thinking, reasoning, and analytical skills that are crucial in finding solutions to design problems (ABET, 2002). One such project done by a group of 3 undergraduate seniors was the design and implementation of an autonomous experimental mobile robot.

An autonomous mobile robot can be used for a number of applications ranging from automated guided vehicles (AGV) in a warehouse to defusing bombs in urban combat (Bostelman, Hong, & Madhavan, 2005; Groer, 2007). Mobile robots are used by the military and SWAT teams to venture into hazardous locations to detect and defuse explosive devices, lay cabling, or open doors during an operation. Another application for autonomous mobile robots is fire fighting (Groer, 2007).

The mobile robot implemented in this project was intended for use in remote temperature sensing from a hazardous environment. The temperature data can be sent via IR wireless communication to a host PC at a remote location. The project group first conceived a 3-D model of the mobile robot in Pro E software as shown in [Figure 1](#). To complete this design, each individual part was created as its own .prt file in Pro E. Some components such as the base and the wings were designed specifically for this project. After all of these components were modeled successfully, Pro E's constraint based assembly system was used to bring all of the individual components together into one completed design. This was

followed by machining of the mobile robot base and wheel assembly. Once the base and wheels were manufactured and assembled the electronic control and sensor interface modules were added to the design.

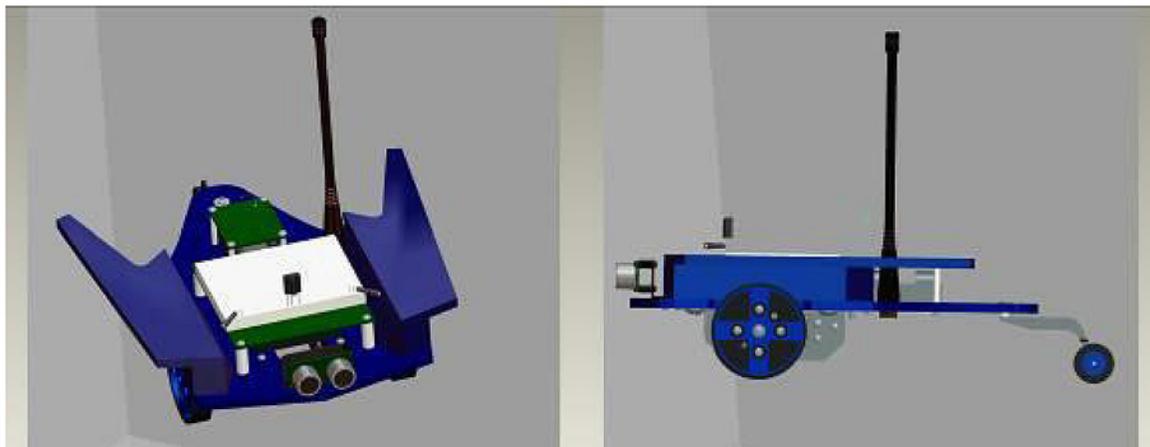


Figure 1. 3-D Model of Mobile Robot

The mobile robot designed and implemented in this senior project course has several features, such as obstacle avoidance and navigation, temperature sensing, and data communication using short range infrared (IR) technology. This experimental mobile robot is an excellent learning platform to gain knowledge of sensor interfacing, microcontroller programming, motor control, and electrical circuitry design and testing. The remaining paper is organized as follows.

The next section discusses the programmable hardware and software used in implementation of the project. Section 3 discusses the robot design experiments. In this section, the individual experiments/modules will be discussed. Section 4 highlights the technical problems faced during implementation and troubleshooting. Finally, the relevant conclusion is presented.

Programmable Hardware and Software

An intelligent mobile robot requires programmable hardware to act as its brain. Microcontrollers are the most commonly used programmable controllers for this purpose. It monitors sensory feedback or input from sensors and uses the information for making decisions regarding navigation, object detection and avoidance, and even communication. The microcontroller used in this design is the PIC16F628A, an 18-pin, flash-based, 8-bit CMOS microcontroller manufactured by Microchip (Microchip, 2008). The PIC16F628A is characterized by low power consumption (about 0.6mA @ 4MHz) and the integrated 2Kwords of flash program memory. This allows modification to the robot control program within minutes depending on the particular application or new extension hardware. The PIC16F628A has two I/O ports, namely PORTA (5 bits) and PORTB (8 bits). Together the two ports provide 13 I/O lines. It also features 128 bytes of EEPROM data memory, a Capture/Compare/PWM (CCP) module, a Universal Synchronous-Asynchronous Receiver Transmitter (USART), 2 Comparators and a programmable Voltage Reference that make it ideal for analog/integrated level applications in automotive, industrial appliances, and other consumer applications.

The programming software used is the microEngineering Labs (meLabs) PICBasic PRO. The PICBasic PRO compiler is specifically designed for programming PIC microcontrollers using BASIC-like high level language. A single PICBasic PRO command is enough to replace several lines of assembly language instructions. This makes code easier to debug and significantly reduces programming time. The program code was burned onto the PIC microcontroller using meLabs USB programmer.

Mobile Robot Design Experiments

The mobile robot was designed, implemented, and tested in steps. Each module was implemented and tested independently and then integrated to form a fully functional mobile robot. The modules used in mobile robot are: servo motor control, IR obstacle detection and avoidance, ultrasonic distance measurement, temperature sensing, and IR wireless communication. These modules/experiments are discussed next.

Controlling Servo Motors Using PIC16F628A

To provide the maneuvering ability (mobility) around obstacles in its path, the mobile robot uses two servo motors. Servo motors used are the Grand Wing (GW) standard servo motors with a torque of 47-56oz-in and an operating voltage between 4.8-6V. Each servo motor is pre-modified for continuous rotation and comes with Fatuba spline control horn. The wheels used were machined out of lightweight but sturdy expanded PVC material. The wheels weigh 26gms, measure 2½” in diameter, with tread (made from polypropylene rubber) width of ½” and are attached to the servo horns.

The servos are controlled by Pulse Width Modulation (PWM) signals sent through the command/control wire. The angular position is determined by the duration of a pulse that is applied to the control wire. The standard servo timing pulses are shown in [Figure 2](#).

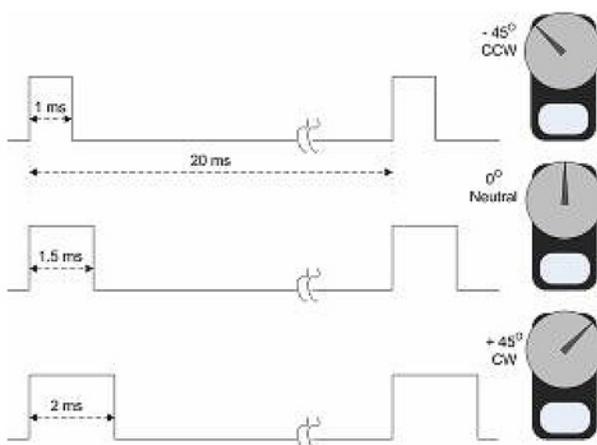


Figure 2. Servo Motor Pulses

The servo expects to see a pulse every 20ms or approximately 50 times a second (50 Hz). The servo control pulses were generated using PICBasic PRO PULSOUT command. The PULSOUT command has a resolution or period of $2\mu\text{s}$ when operating at 20MHz. Even though the mobile robot uses servo motors that have been pre-modified for continuous rotation, they still require the same position pulses for rotation. Referring to [Figure 2](#), a pulse of 1ms ($1000\mu\text{s}$) or servo direction constant of 500 ($500 \times 2\mu\text{s} = 1000\mu\text{s}$) will cause counter clockwise (CCW) rotation of the motor, while a pulse of 2ms or direction constant of 1000 ($1000 \times 2\mu\text{s} = 2000\mu\text{s}$) would cause clockwise (CW) motion. A pulse of 1.5ms or direction constant of 750 ($750 \times 2\mu\text{s} = 1500\mu\text{s}$) is required to stop the servo motor. To have mobile robot travel in a straight line, at full load, slight adjustments are necessary to stop mobile robot from veering from its intended course. Students experimented with servo motors to determine the exact motor direction constants. The experimental direction constants for the two (left and right) servos are summarized in [Table 1](#).

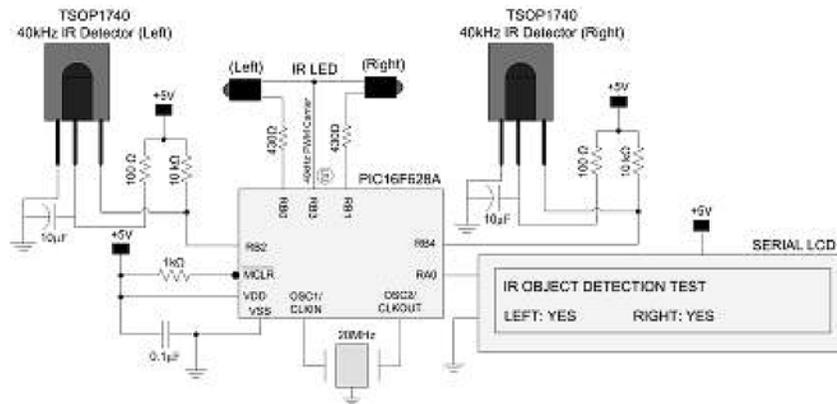


Figure 4. IR Obstacle Detection Interface

As seen in [Figure 4](#), the IR obstacle detection circuit has PORTB I/O-pins (PORTB.0 and PORTB.1) each connected to IR LED cathode side to control each IR LED. When the 40kHz PWM signal is on, logic 0 (ground) on PORTB.0 will turn on the LED. Logic 1 (HIGH) on PORTB.0 will turn off the LED. The outputs of IR detector are sampled at PORTB.2 and PORTB.4 pins, once the IR LED cathode is made low. A logic 0 indicates the IR energy is striking the detector, and an object is in the robot's path. A logic 1 on the detector's output indicates there is no object present to reflect IR energy back onto the face of the detector. Once the circuit was set up, the PIC16F628A was programmed to control the IR LEDs and read IR detector outputs. The circuitry was tested by placing objects at different angle in front of IR LEDs. For the experimental purpose a serial LCD was connected to display the presence or absence of an object.

Distance Measurement Using Ultrasonic RangeFinder

An ultrasonic sensor, like radar, uses the principle of echo location. An echo signal is created when a short pulse is sent in a specific direction and hits an object that does not absorb the pulse (Zhao, Guo & Abe, 1997). This echo can be picked up by a detector circuit. By measuring the time between sending the pulse and detecting the echo, the distance to the object can be determined.

The ultrasonic rangefinder used in this project is a Devantech SRF04 module. The Devantech SRF04 ultrasonic rangefinder provides precise, non-contact distance measurements from about 3 cm (1.2 inches) and 3 meters (3.3 yards). The sonar module interface diagram is shown in [Figure 5](#). It only requires two I/O pins to connect to the PIC microcontroller. Output from the SRF04 is in the form of a variable-width pulse that is proportional to the distance to the target.

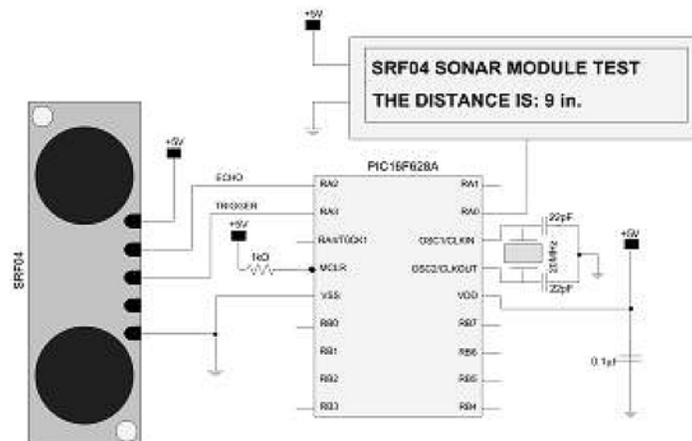


Figure 5. SRF04 Ultrasonic Module Interface

The timing pulses required for the operation of SRF04 module are shown in [Figure 6](#).

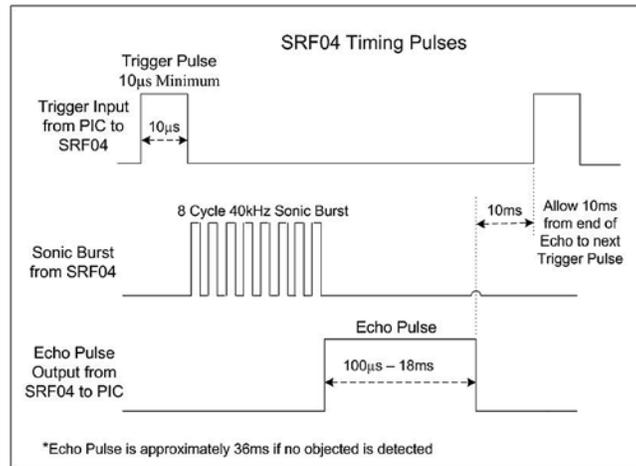


Figure 6. SRF04 Timing Pulse

A short $10\mu\text{s}$ pulse is sent to the TRIGGER input of the SRF04 by the PIC16F628A to start the ranging. The TRIGGER input is connected to PORTA.3 of the PIC microcontroller. The SRF04 sends out an 8 cycle burst of ultrasound at 40kHz that travels through the air at about 1.125 feet per millisecond (speed of sound in air) and raises its ECHO line high. The ECHO line is connected to PORTA.2 of the PIC microcontroller. It then listens for an echo and as soon as it detects one it lowers the ECHO line again. The ECHO line is therefore a pulse whose width is proportional to the distance to the object.

By timing the pulse it is possible to calculate the range in inches. If no object is detected then the SRF04 will lower its ECHO line after about 36ms. The trigger pulse must be at least $10\mu\text{s}$ long. Again, PICBasic PRO's PULSOUT command is used to generate this pulse. The other requirement is that there is at least 10 ms of wait time between measurements. The PICBasic PRO's PULSIN command is used to measure the width of the pulse output on the SRF04 ECHO pin. The resolution for PULSIN is the same as with the PULSOUT command ($2\mu\text{s}$ at 20MHz). The SRF04 outputs a pulse on the Echo pin after each ultrasonic measurement. The resulting pulse width returned by the PULSIN command is divided by a factor of 74 to determine the distance in inches. After the PIC microcontroller was programmed, the circuitry was tested by placing objects at varying distances in front of the sensor and noting the displayed distances on a serial LCD.

Temperature Sensing

In this experiment, the Dallas DS1820 1-Wire™ Digital Thermometer was used to aid the robot in sensing the temperature of its surrounding. The DS1820 uses a unique 1-Wire™ interface that requires only one port pin for communication with the microcontroller. The center pin (DQ) of DS1820 1-Wire™ Digital Thermometer is connected to PORTA.1. For details on the DS1820 temperature sensor, refer to the DS1820 datasheet (DS18S20, 2008).

The PicBasic PRO OWIN and OWOUT commands are used for communicating with DS1820. After the 1-Wire™ temperature sensing device is identified and the unique 64-bit ROM number contained within the device is recorded, communication with the temperature sensor begins. The unique 64-bit ROM code identifies, i) 8-Bit Family Code, ii) Unique 48-Bit Serial Number, and iii) 8-Bit CRC Code. The temperature data is stored in first two data-bytes of the internal scratch pad memory. For details on using 1-Wire™ devices and 1-Wire™ technology refer to (AppNotes1796, 2003). The schematic of DS1820 temperature sensor interfaced to PIC microcontroller is shown in [Figure 7](#).

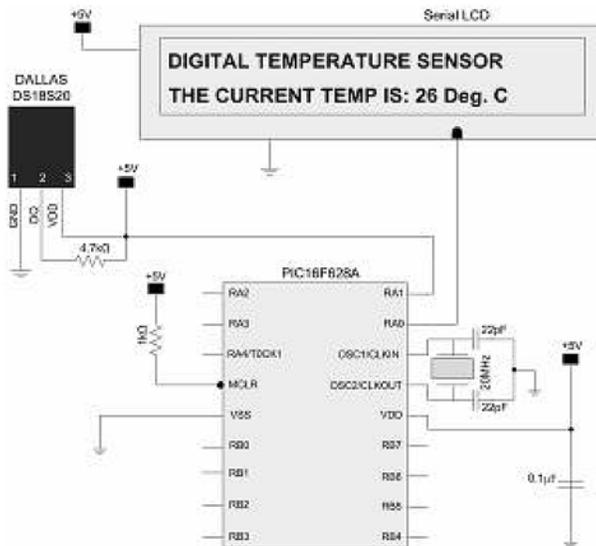


Figure 7. Temperature Sensing Interface

Once, the temperature data is available it is transmitted to a remote PC using IR wireless. The IR wireless communication system is established using IR LEDs and an IR detector. These components are similar to the one used for IR obstacle detection and avoidance circuit discussed earlier. The IR wireless communication system is discussed next.

IR Wireless Communication

A simple IR transmitter requires an IR LED and a means of modulating (turning on and off) the IR LED at carrier frequency. The internal hardware PWM feature of the PIC16F628A microcontroller available through pin PORTB.3 is used to generate the 40kHz carrier for modulating serial data. The IR transmitter circuit is shown in [Figure 8](#).

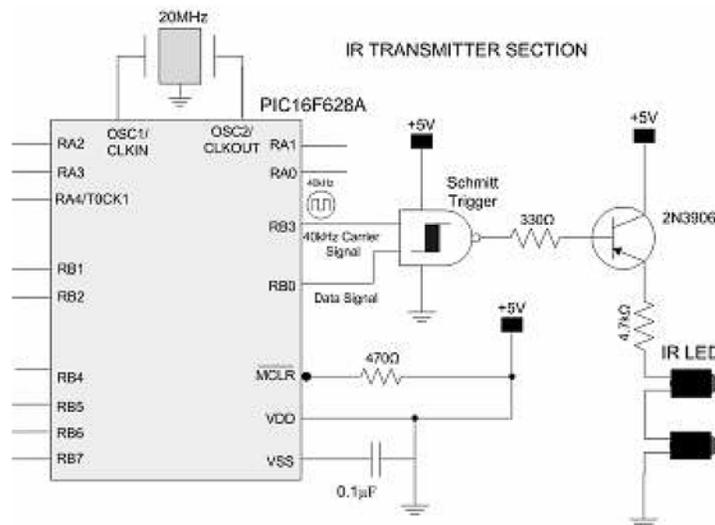


Figure 8. IR Transmitter Interface

In order to configure the PIC16F628A microcontroller for hardware PWM, internal 8-bit registers CCP1L and CCP1CON are used. The configuration register CCP1CON controls the operation of CCP1 (PORTB.3) pin. Writing a value of 12 to CCP1CON set the Mode Select bits to use and turn PWM output signal on. The hardware PWM can be turned off by writing

a value of 0 to CCP1CON. The PWM duty-cycle is set by writing to the CCPR1L register. The hardware PWM is configured in the beginning of the code. The PWM feature is only used to generate the carrier frequency while driving the infrared LEDs during the data transmission. Hardware PWM consumes a lot of power, and when not in use, it is simply turned off.

The transmitter circuit consists of the CCP1 (PORTB.3) pin of the PIC microcontroller connected to one of the two inputs of a 74HCT132 Schmitt Trigger NAND gate. The PORTB.1 pin is used to send serial data stream to the other input of the NAND gate. The Schmitt Trigger NAND gate combines the two incoming signals into an output data signal modulated at 40kHz. The Schmitt Trigger output will only go to logic 0 when both inputs 1 and 2 are at logic 1. This effectively holds the PNP drive transistor off until both inputs are at logic 1. Since the carrier frequency is 40kHz, considerably faster than serial data, the serial data will cause the PNP transistor to turn on during each logic 1 data-bit. Basically, the serial data turns the carrier on/off for the same bit-time as each data bit in the serial data-stream.

The heart of the receiver circuit shown in [Figure 9](#) is the Vishay Telefunken 40kHz IR detector module. This enhanced data-rate IR detector module can be used for applications operating at 40kHz and baud rates up to 4000bps. It includes a visible light cutoff region to help eliminate interference from visible light source (AppNotes82606, 2008).

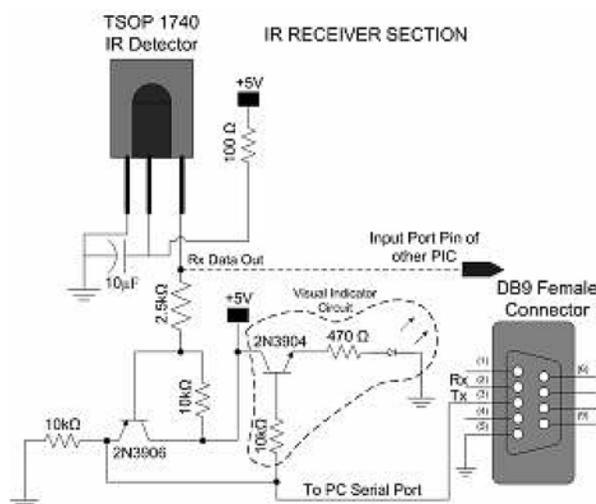


Figure 9. IR Receiver Circuit and Serial Interface

The idle (not receiving data) output state of the infrared detector module is logic 1 or +5V when no infrared energy modulated at 40kHz is detected, and logic 0 or ground when IR energy modulated at 40kHz is striking the face of the detector. The data exiting the PNP transistor in the receiver circuit is inverted. This is important since the default mode for most serial LCD displays, and all PC serial ports is inverted. The output of the IR detector module can be connected to any available I/O pin of the PIC microcontroller on another robot or to a PC serial port as done in this project. An extra circuit using an NPN transistor and a regular LED is added to indicate data reception. The system was tested at a baud rate of 2400bps over a transmission distance of six meters. This system is capable of achieving baud rates up to 4000bps and transmission distances more than ten meters. For power consumption and transmission distance calculations refer to Rawat, et al. (2007).

Implementation Issues and Troubleshooting

Like most projects, this one also had few problems during implementation. Some of these issues were related to servo motors, IR detection, and programming.

Servo Motor Issues

During testing, the servo motors did not function with the standard pulse widths of 1ms, 1.5ms, and 2 ms. The exact servo direction constants (reported in section 2) were obtained through manual control of servos at different direction constants. Once the exact directions constants were identified for both the servo motors the problem was resolved. Also it

was necessary to provide at least 200mA current for servos to function. The current drive is guaranteed by the use of 4AA batteries in the final implementation, but during experiment dual power supply in the laboratory was used to test servos. In addition, while testing for different movements of robots (forward, reverse, left, and right) incorrect servo direction constants were being sent, due to which the robot was not moving in the intended direction. For example, due to the placement of the left and right servos, for forward movement one servo must rotate CW while the other rotates CCW.

IR Detection Issues

During the testing of IR obstacle detection, the circuit was not working consistently. It was later realized that the IR LEDs and IR detectors were not placed within the beam deflection angle. This problem was fixed by placing IR LED and corresponding IR detector at a cone angle of 40 degrees. The placement of heat shrinks on the IR LEDs was also corrected so the IR energy is focused to the front rather than dissipating from sides. After proper placement of IR components, the final robot required only one IR detector for both left and right obstacle detection.

Programming Issues

While testing the first program, it was found that 20MHz crystal oscillator was not generating any clock signal when logic probe was placed on its pins. The crystal was replaced with another 20MHz crystal, but the problem persisted. Then it was replaced by a 4MHz crystal from another working circuit. The logic probe detected clock pulses on the pins of 4MHz crystal. It was later realized that during the programming of hex code into the PIC microcontroller, the default setting of meLabs programmer was not changed to accommodate 20MHz crystal. By default the programmer software assumes XT setting, which is for crystal frequency up to 4MHz. For a higher speed crystal it must be changed to HS_OSC to indicate the use of 20MHz crystal.

Conclusion

An autonomous mobile robot can be used for a variety of applications, such as search and rescue, fire-fighting, and defusing explosives. When conditions are too hazardous for human beings to operate in, the mobile robots are the ideal solution for completing the task. One such mobile robot was designed and implemented as a part of senior design course. A modular approach was used in implementing this robot. The experimental modules discussed in this paper were, servo motor control, IR obstacle detection and avoidance, temperature sensing, and IR wireless communication. Through these experiments, students progressively added functionality to the design. In this process they gained knowledge of circuit design, interfacing sensors, programming microcontrollers, and motor control. This project proved to help develop critical thinking, team skills, and problem-solving/troubleshooting skills. The final mobile robot implementation was tested in an application requiring remote temperature sensing.

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Management



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Imagine the Possibilities!

Using Quality Management Systems to Meet Food Traceability Requirements of the Bioterrorism Act of 2002 (*Best NAIT 2008 Conference Proceedings Paper*)

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Introduction

The events of 9/11 intensified concerns about the safety of food. Legislation requirements for food traceability present challenges for US grain handlers in meeting new regulations of the Food and Drug Administration (FDA) (Iowa Grain Quality Initiative, 2006). With the goal of protecting the US food supply, the Public Health Security and Bioterrorism Preparedness and Response Act of 2002 (known as 'the Act').

The Act requires that any facility engaged in manufacturing, processing, packing, or holding food for consumption in the United States register with the FDA. The Act also increased the need for traceability in US commodity production with the regulatory requirements of as noted on FDA's website: <http://www.fda.gov/oc/bioterrorism/bioact.html>. Section 306 of the Act requires that registered locations maintain records which identify the immediate previous sources and the immediate subsequent recipients of food, including packaging. Connecting the records of suppliers and customers may allow the FDA to trace backward or track forward suspect food product(s) in the supply chain. The FDA requires that a location produce records within 24 hours (FDA, 2002a; 2002b).

FDA will allow an organization to utilize existing records if the immediate supplier(s) and subsequent recipients(s) are identified. While this should reduce the overall cost of organizations in meeting the records requirements, the ability of a commodity grain handler to meet the Act will test that organization's management system.

A number of recall events concerning cereal grains highlight the difficulty of commodity grain traceability. The USDA spent over \$60 million to contain and eradicate Karnal Bunt in American wheat over a small origin area in Arizona. The reduction in exports was valued at over \$250 million (Casagrande, 2000). In 2001, 500,000 bushels of soybeans were destroyed at a Nebraska elevator after commingling with 500 bushels of soybeans containing engineering corn (BioTrek, 2002). In the most famous case, Starlink corn, unapproved for human consumption, was planted on one percent of total US corn acreage in 2000. Discovery of Starlink corn in the human food chain resulted in the recall of over 300 food products and caused major disruptions in the food chain (Lin et al., 2002). The commingled total of Starlink with other corn eventually reached 124 million bushels in 2000 (Lin et al., 2002). These events demonstrate the consequences of poor traceability. Considering these events, how will a commodity grain elevator be able to meet new traceability expectations of the Act?

Quality Management Systems and Traceability

The nature of grain handling makes food traceability difficult. The grain supply chain is based on infrastructure built to move large flows of product based on a limited variety of attributes (Golan et al., 2004). Cereal crops are commingled immediately upon receipt by a grain elevator based on quality attributes such as moisture, damage, or foreign material. Grain from different sources is blended together to achieve a homogeneous quality level. Bailey et al. (2002) note that meeting traceability requirements will be most difficult for commodity handlers due the blending from multiple sources before processing.



After peer-review, this paper was designated the Best Conference Proceedings Paper of the NAIT 2008 Conference, ranking the highest of all 38 papers submitted for review.

Hurburgh and Sullivan (2004) note that a large grain elevator cooperative should be able to track raw material through elevator operations based on the implementation of a quality management system certified to the ISO 9001 standard. Defining guidelines for the grain industry, the basic traceability metric for a grain elevator is based upon a traceability index (Hurburgh, 2004, 2006). The definition of a traceability index (TI) for quantitative measure is as follows:

$$\text{Traceability Index} = \text{suspect volume} / \text{volume being tracked}$$

By the process of elimination separating where problem grain could not have been located, the amount of possibly contaminated grain becomes progressively less than the entire amount of grain within an elevator facility (Hurburgh, 2006; 2007). TI provides a method of continuous improvement supported by an objective target for grain elevators.

Farmers Cooperative Elevator Co, Farnhamville, IA, (FC) implemented a quality management system to create additional opportunities for marketing grain. The objective was to have a universally recognized quality system in place, so that as end-users (food processors) sought specialty grain origination, the company could present a program that would have an immediately recognizable creditability. However, Hurburgh (2003) notes the benefits of the quality management system were through improvements to operations management such as systematic inventory management and grain accounting. In the context of food safety, adoption of a quality management system changed the mindset of the employees from handling a commodity product to grain as a foodstuff (Sullivan and Hurburgh, 2002). The resources needed for food traceability were put in place with requirements such as standard operating procedures, discipline in process control and documentation of responsibility throughout the production history (Hurburgh, 2004). To understand how a formal QMS met the Act requirements, a series of mock recalls were done at the elevator.

Methodology

To demonstrate the effectiveness of the QMS in food traceability, FC conducted a total of 41 mock recall events at 27 FC elevator locations in 2006 and 2007. Of the 41 total mock recalls in 2006 and 2007, 17 were forward and 24 were backward. A forward recall is defined following grain identity from a known supplier to an unknown customer and/or elevator location. A forward recall is typically used as a good business practice and would not be the method of recall initiated by FDA in the likelihood of a trigger event. In the event of an actual event, FDA would utilize a backward recall where suspect material in the hands of a known customer would be traced backward through the food supply chain to unknown sources and initial locations (FDA, 2002a; 2002b).

Of the 41, 14 elevator locations did repeated recalls: 1 forward event in 2006 and 1 backward event in 2007 for a total of 28 repeated recall events. The time duration was recorded in both 2006 and 2007 recalls. The traceability index was recorded in the 2007 recall events. The data for the study consisted of reports filed by the location managers. This meant that the some data (or quality of data) was not available for every recall. Table 1 displays the data sets for these mock recalls.

Mock Recalls by Year	Recall Events (n)
First Round (2006)	
Forward	21
Backward	0
Second Round (2007)	
Forward	3
Backward	17
New	3
Repeats	14

Table 1: Farmers Cooperative Co. mock recall data set

The forward recall process was initiated electronically by the Quality Management department with information concerning the suspected commodity (corn or soybeans), quantity, scale ticket number, and producer name. Scale tickets were chosen

randomly by the Quality Manager. The elevator management was to track the suspected lot of grain forward through the facility, identify the customer(s) of the grain, locate all possible storage bins that would still have contaminated material, and identify all bins that did not have possible contamination. A record of the recall time was kept.

The backward recall event included the lot size, amount of suspect material, and scale ticket number loaded out on a specific date. The elevator management was to trace backward the grain and identify all supplier(s), contaminated storage bins, and bins not contaminated. Again, the Quality Manager chose outbound lots randomly. All statistical analysis was done in Minitab® Release 14 statistical software.

With the QM system procedures in place, the principal research questions were:

1. Does the QMS-based traceability system meet the FDA guideline for 24 hours maximum recall duration under the Act? This is only mandatory requirement of the Bioterrorism Act at this time. Quality and acceptability of data are at the judgment of investigators should an event arise.
2. Does the forward or backward information flow impact the time duration of a recall?
3. Is time duration of the mock recall event impacted by the level of precision of traceability (TI)?
4. Is grain traceability precision (TI) impacted by the forward or backward information flow?
5. Does the quantity of suspect material (lot size) impact the time duration of the recall event?
6. Does the lot size of suspect material impact the traceability index of the recall event?

Results

As shown in Table 2, the results show that most FC facilities met the Act requirement. The average time was 13.42 hours with a standard deviation of 11.18 hours, well below the 24 maximum time limit. 25 percent of the elevators reported results within three hours. The summary results in Table 2 also demonstrate the variability of grain traceability precision through the TI. The mean TI was 180 with a wide standard deviation of 300. Fewer facilities reported sufficient data since elevator managers reported results. Since the traceability index is not a requirement of FDA, it is a guideline for future improvement in traceability for the grain handling industry. The range of TI results was of 8 - 942. While the range was large, a minimum of 8:1 demonstrates possibility of grain traceability using a QMS. At the maximum, a large traceability index of 942 demonstrated a lack of grain traceability. This elevator location did not follow all the requirements of the QMS and the operator reported that he had no idea where the grain came from, which made the entire inventory of the elevator suspect.

Mock recall description	Time Duration (hours)			TI (2007 only)		
	N	Mean	SD	n	Mean	SD
All elevator locations	41	13.42	11.18	16	180	300

Table 2: Overall results of mock recall exercises at FC grain elevator locations

Since the 24 hour limit is the single requirement of the Act, distributions of the results in 2006 and 2007 are displayed in figure 1. In the 2006 events, all of the mock recall events were forward and the distribution displayed a right skew.

One elevator location required 39 hours required to report results. This elevator location had the responsibility to follow grain through another FC elevator due to intra-company transfer of the tracked grain. The longer the grain flow in the cooperative, the longer it takes to track grain. FC often transfers grain from one elevator location to another by truck. The Act requires an organization maintain records while the product is in the organization’s custody. Still having custody of the grain, significant time was added to the recall event.

In the 2007 mock recalls, the results displayed a more normal distribution of duration. In the 2007 set, four elevators did not meet the 24 hour rule. Two of these locations were new to FC, merged into the company from another elevator company within six months prior to the mock recalls. Three of the elevators that reported results past the 24 hour limit conducted backward recalls.

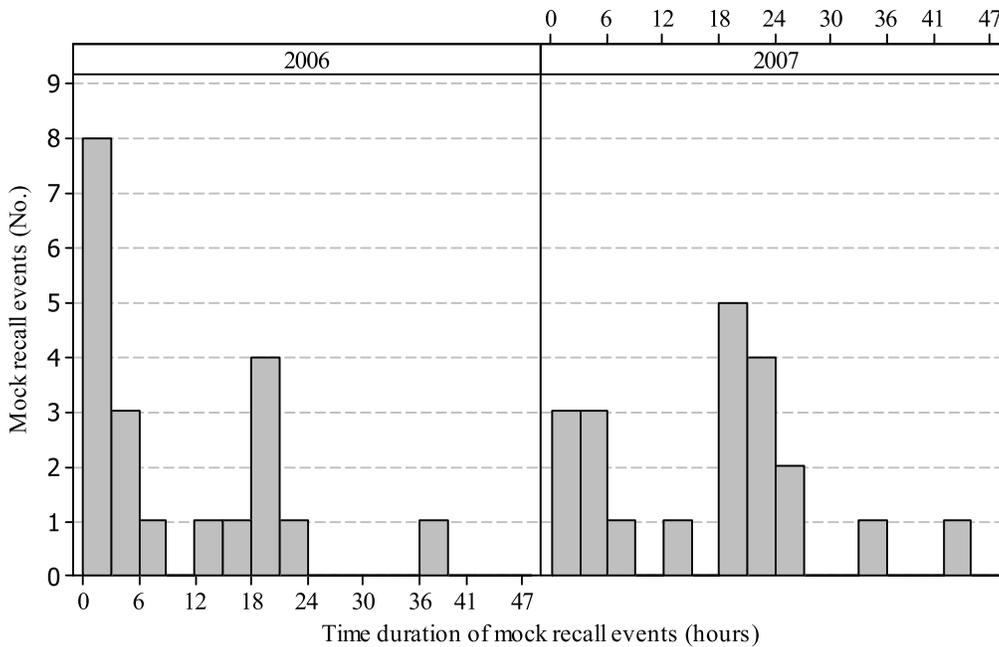


Figure 1: 2006 and 2007 distribution of time results

As shown in figure 2, there was no significant relationship between the time required for the recall event and the precision of grain traceability (TI). The length of time of the traceability processes was not impacted by their tracking precision. The majority of locations reported results no matter how well defined their inventory control. Since time is the only FDA requirement of grain elevators, then reporting results, no matter how accurate, would be expected. If grain handlers expect to manage an actual FDA event, specifying a level of traceability would be good practice. For example, simply presenting a list of suppliers and customers of an elevator cooperative to FDA upon request will not meet the requirement of the Act (FDA, 2002a; 2002b). FDA is letting the industry progressively set standards as it improves compliance.

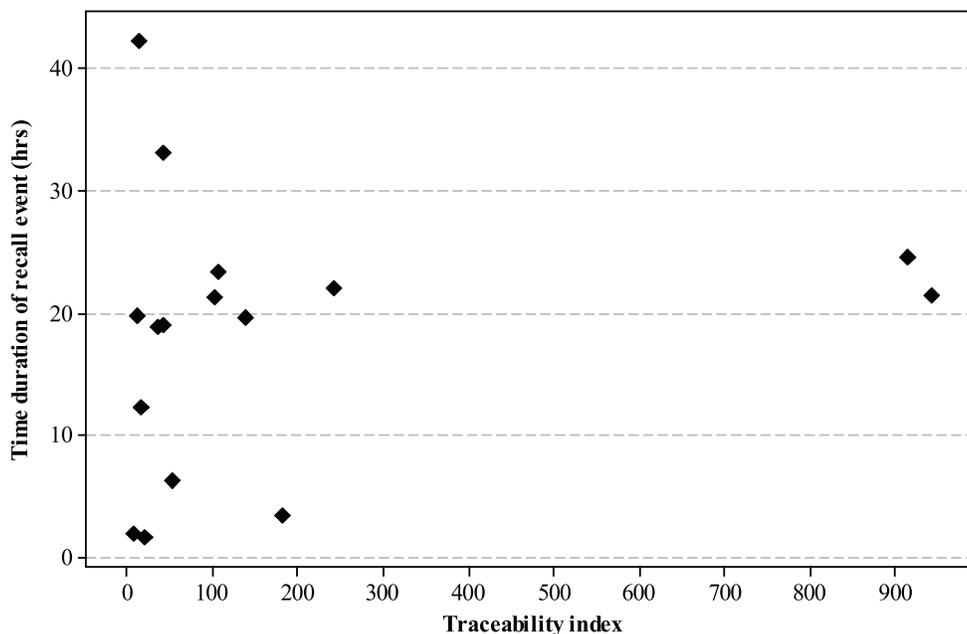


Figure 2: Traceability index and time duration of mock recall events

The results in Table 3 demonstrate that there was a significant difference in the amount of time required to report elevator recall results between the flows (backward and forward). Of the total 41 recalls accomplished, there were 14 elevator locations which did two recalls: one forward and one backward.

The time required to report results took significantly longer in a backward event. This is because tracing suspect material back to the origin also required tracking forward to identify where that material subsequently went. Both backward tracing and forward tracking were required in backward recall events.

Mock Recall Description	Time duration (hours)		
	n	Mean	SD
Forward (First recall)	14	7.9 ^a	8.4
Backward (Second recall)	14	18.4 ^b	10.2

^{a,b}Means with different letters significantly different at p = 0.05

Table 3: Time duration of repeated mock recall exercises at FC grain elevator locations

In 2007, the set of mock recalls included both forward (N=3) and backward (N=17) events. The backward events reported less precise TI's than locations doing forward events as shown in table 4. But the sample size of events is small and the precision of traceability (TI) was not significantly impacted by the flow of the event (backward or forward). The mean difference in TI's was lessened by the large standard deviation. Grain elevators should conduct both types of recalls to test a traceability system since forwards and backwards recalls are different in nature.

Mock recall description	Traceability Index				
	n	Mean	SD	Min	Max
Backward	17	215	324	8	942
Forward	3	25	15	13	42

Table 4: Traceability index of 2007 mock recall exercises at FC grain elevator locations

There was no relationship between the suspect bushels being tracked (lot size) and the amount of time required to provide data (figure 3). Minimizing the amount of suspect material should be the goal of a commodity grain handler because in the event of an actual FDA recall, suspected product could be destroyed per FDA regulations (FDA, 2002a). The tracking process is more important in response to an FDA event; not how large the triggering event was.

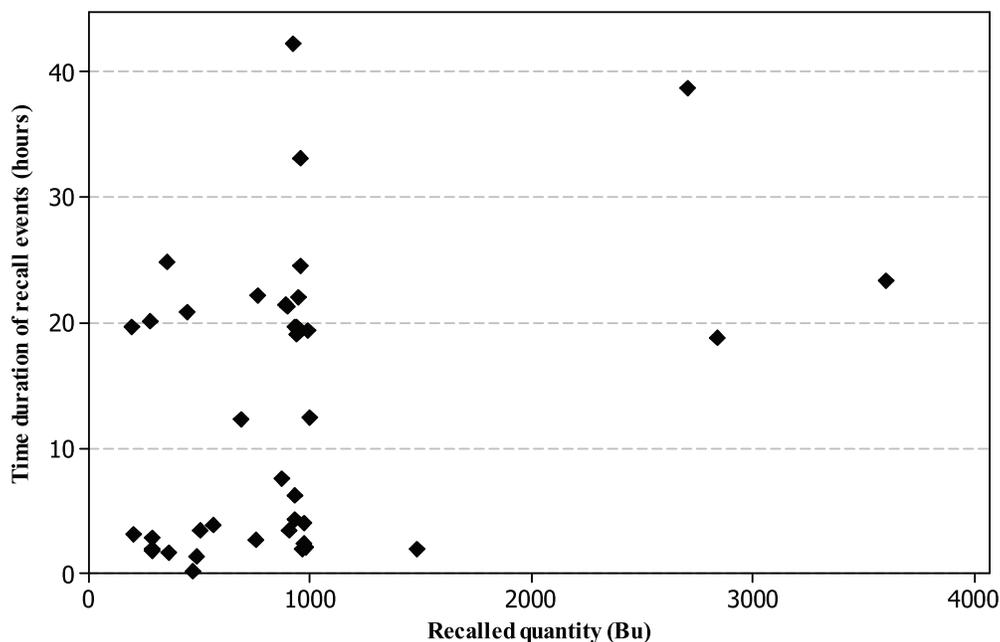


Figure 3. Time duration and lot size of 2006 and 2007 mock recall events

In figure 4, the amount of grain traced (lot size) did not have a significant impact upon the precision of the traceability index. Most of the data were clustered together with a few locations reporting large TI's. Both of the locations reporting the largest TI's conducted backward events. This could be evidence that backward events are harder to manage. There were also two elevators with larger than the average lot size (approximately 1,000 bu) and low TI's at 36 and 107. These elevators demonstrated average grain traceability precision, even though the lot sizes were larger. The process of traceability was more important than how much suspect material was at stake. This was also the second time that these elevators had done mock recalls. The impact of improvement from the first round of events is unknown.

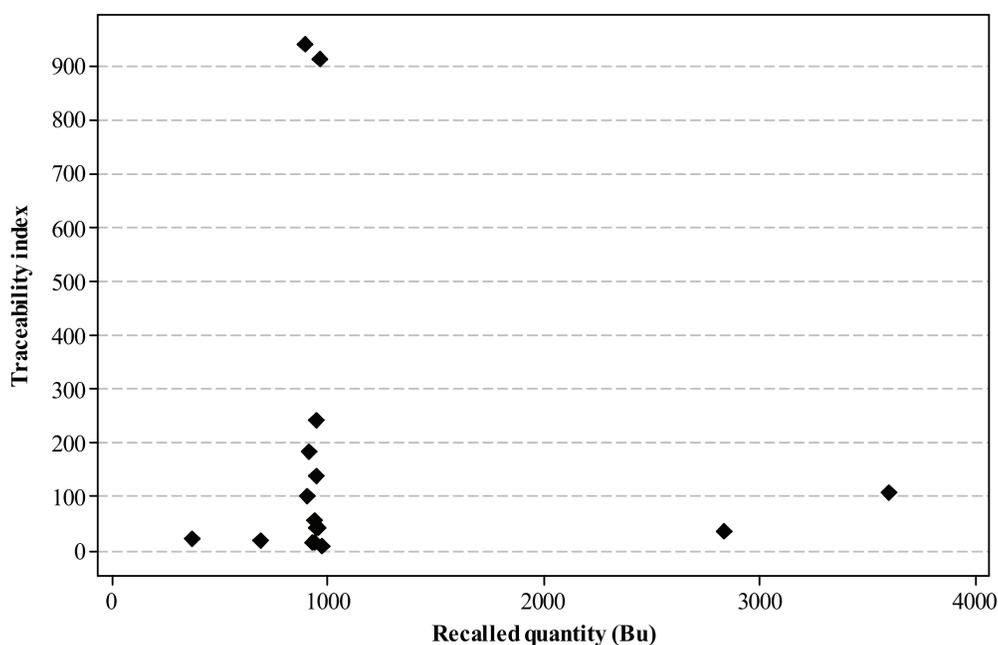


Figure 4. Traceability index and lot size of 2007 mock recall events

Discussion and Conclusions

Farmers Cooperative Co. implemented quality management system grain traceability processes at 27 elevator locations. The results of the mock recall study demonstrate that the QMS provided a benchmark for improvement. A traceability index (TI) was created for use as a guideline for the grain industry. FC initially designed and implemented a QMS to meet external goals. Its subsequent focus on internal improvements enabled the organization to meet new, unforeseen government regulations.

FC was able to produce results within the 24 hour timeframe required by FDA. Timeliness of recall could prevent the closing an entire elevator operation in the event of an actual recall. The flow of the recall event was significant. A backward event took significantly longer than a forward event. But the process flow of an actual recall event is not within the control of the grain industry. By definition, an FDA recall would be backward due to the nature of tracing backward from a triggering event.

The ability to meet the 24 hour deadline was not related to the lot size of grain traced in the facility, demonstrating that the QMS processes of traceability were robust. Grain elevator operations handle large volumes of grain and the commingling of different sources of grain can result in large lot sizes. The time required by FC to produce results was not affected by the lot size.

The precision level, or TI, of recall event was not related to the time required to produce results. In the event of a recall, identification of suppliers and customers requires precision. More precise levels of grain traceability apparently will not require more time.

The traceability index did not change significantly with regard to a backward or forward elevator recall event. While a backward event takes longer, the level of precision did not change significantly.

The interaction between lot size and the traceability index was not significant. During an actual event, the amount of suspect grain could be large. The FDA would likely quarantine suspect material at quantities greater than the original lot size. This was demonstrated in the spinach recall of 2006 by the FDA (Cuite et al., 2007). Following the QMS traceability processes could minimize the need to destroy large amounts of suspect grain.

An organization that meets the ISO 9001:2000 quality standard also incorporates traceability processes. QMS adoption by FC enabled the company to meet the unanticipated regulation of the Bioterror Act at nominal additional effort. A QMS system requires continuous improvement of quality related activities. It is possible that a more precise level of grain traceability will occur through the ongoing use of a quality management system. This study provides benchmark data on which to evaluate improvement.

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Academia's Response to a Changing Environment: Are We Keeping Pace?

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Introduction

In today's globally competitive and technology-driven manufacturing industry, the manufacturing technologist and engineer must select and effectively use the appropriate technologies to sustain continuous improvement. Recent surveys of both academia and manufacturing professionals reveal agreement concerning the most vital skills needed by the manufacturing professional. Among these tools are Lean Processes, Six Sigma, and CAD/CAM. In a globally competitive environment, it is critical that schools of manufacturing technology and engineering provide relevant curricula that address these tools. This paper continues an analysis of an industry survey originally relating to career opportunities and needed skills for manufacturing professionals (Callahan, Smith, Jones 2007). This study will present a comparison between surveys of academia and manufacturing professionals concerning these critical needs. The results of an evaluation of curricula with respect to integration of these tools are also presented. Recommendations are given regarding how academia can keep pace with the rapidly changing needs of manufacturing.

Background

Educational programs in the areas of Industrial and Manufacturing Technology are increasingly under pressure due to a rapidly changing manufacturing environment and globalization. As globalization continues to accelerate companies increasingly feel the pressure to become more productive and efficient. Manufacturing companies remaining in the United States face strong global competition as they strive to survive and grow.

Although fewer people are working in manufacturing in the United States, this sector still accounts for about 22-25% of the gross domestic product as it has for the past 50 years. (Shinn, 2004). The remaining manufacturing professionals such as manufacturing technologists and manufacturing engineers play an increasingly important role in improving the efficiency and competitiveness of the company. Manufacturing professionals in the United States are increasingly asked to perform new and different tasks. It is no longer acceptable to only understand the technical components of the operation. A broader understanding of the overall business environment, competitive forces, and trends is necessary in order to properly apply technical knowledge (Sinn, 2004).

Various continuous improvement tools are widely used in industry today as a means for meeting the additional expectations placed on manufacturing professionals. Lean and Six Sigma methodologies are prominent examples of these tools which strive to eliminate waste, improve quality and reduce production time. Implementing these types of programs can improve value for the customer while increasing profits for the company (Summers, 2007). According to one recent survey conducted by Industry Week and the Manufacturing Performance Institute 40% of manufacturers have implemented some form of lean manufacturing program. Another 12% have implemented a combination of Lean and Six Sigma (Katz 2007). Some companies considering outsourcing have found that they can stay competitive and meet financial goals by implementing lean concepts while remaining in the United States. Small-to-mid sized companies in particular may be better off implementing lean concepts rather than migrating offshore (Langer, 2007).

Rapidly changing technology is also a factor in educating the manufacturing professional. New high tech industries are developing and expanding as a result of advances in material science, health care, and electronics. Microtechnologies

and nanotechnologies typify the trend toward converging technologies where several disciplines such as material science, biology, chemistry, engineering, and physics are all critical in the development and manufacture of a product (Kalpakjian and Schmid, 2006). These new and developing industries require the same process improvement and efficiency skills as traditional manufacturing organizations. Examples of products currently being developed around the convergence of disciplines include microsensors for healthcare testing, automation applications using intelligent software, and high performance materials using carbon nanotubes (McCann, 2006). These new industries and technologies bring expectations and challenges to skilled professionals that must be addressed by both continuing education and traditional college degrees. Plaza (2004) proposed developing some core college technology courses around a topic involving several disciplines and instructors. This integrative approach could be particularly helpful at the introductory or capstone level in demonstrating the importance and application of the convergence of technology. Continuing education may also play an important role in updating the working professional on new technologies and applications.

Advances in software and internet applications can play an important role in the success of a manufacturing organization. Software to support lean concepts that required a major investment in the past is now available incrementally in much more affordable packages. Internet-enabled software is also now available in specialized segments allowing cash strapped companies to purchase only what they presently need as they begin to implement a lean or continuous improvement program (Peake 2003). Knowledge of these tools along with the training and skills needed to use them can provide companies with a significant competitive edge.

Methodology

To better understand the current and future educational requirements for manufacturing technology programs, a survey was administered to a wide range of manufacturing professionals working in a variety of manufacturing and process-related industries in the United States. The survey was e-mailed to approximately 6000 individuals, with 261 responding. The addresses were supplied by the Society of Manufacturing Engineers (SME) and were selected from a database that consisted of both members and participants in SME events. This database generally represents manufacturing professionals who often have a technical component associated with their jobs.

To compliment this study, an additional survey similar in content to the SME survey was administered to academic professionals in schools of technology associated with the NAIT (National Association for Industrial Technology) manufacturing list serve. The survey was e-mailed to the approximately 200 manufacturing list serve subscribers with 41 responding.

Comparison of Educators and Practitioner Surveys

When analyzing the surveys, participants in the SME survey are referred to as “practitioner participants” since 96.5% identified themselves as part of specific industries while only 0.4% were identified as academics (3.1% listed as “other”). Participants in the NAIT survey are referred to as “educator participants” since 95% listed their position anywhere from graduate student through the professor rank (5% listed as “other”) in schools of technology having a manufacturing focus.

Referring to Figure 1, the percentage of educator participants with 4-year or advanced degrees is similar to that of practitioner participants. In contrast, over twice the percentage of practitioner participants were identified as having a 2-year degree as compared to the educator participants. The percentages of participants with advanced degrees were nearly identical at about 30% for both educator and practitioner participants. The high percentage of practitioner participants with advanced degrees might be related to the fact that almost half of that group were from companies with more than 500 employees. Large companies can have extensive research and development programs that may be better positioned than smaller companies to attract engineers and technologists with advanced degrees.

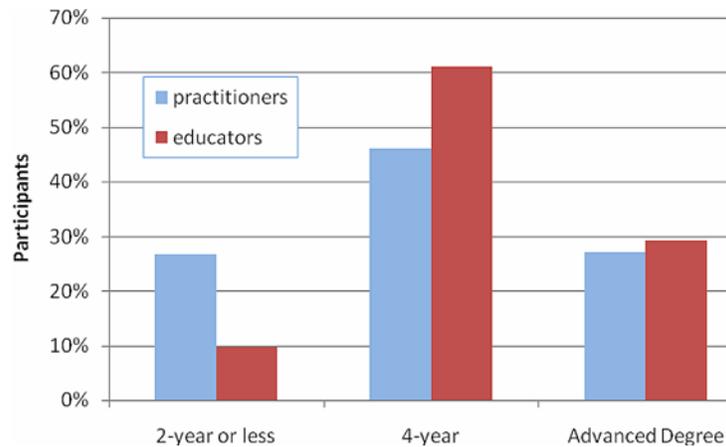


Figure 1: Education levels of the participants

Regardless of the reasons for the high percentage of advanced degrees among practitioner participants, it indicates that the practitioner participants were essentially educated as much as the educator participants. Therefore, both groups were capable of providing informed opinions on the educational needs of manufacturing engineers and technologists. One basic measure of the educational needs is the level of education attained. To address this, both the practitioner and educator groups were asked the following question: “In your opinion, what is the minimal required level of formal training needed by a manufacturing engineer or technologist?” Figure 2 below shows the response to this question from both groups.

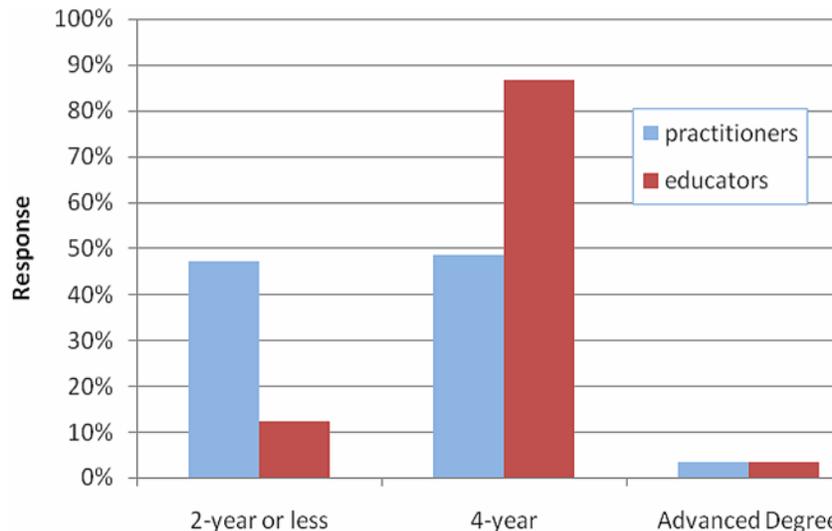


Figure 2. Participant opinion response on minimal education level needed

Comparison of Figures 1 and 2 indicates the education level of the specific group reflects their opinion of what minimal education level is needed by the manufacturing engineer or technologist. For example, the practitioner group consisted of a higher percentage of “2-year or less degrees” and had a higher response for that level as the minimal education than did the educator group. Similarly, the educator group consisted of a higher percentage of “4-year degrees” and had a higher response for that level as the minimal education than did the practitioner group. This could be expected since one’s level of education might influence what one believes is an adequate education for others. In other words, a person might express “What is good enough for me is good enough for everyone.” Note that the differences between the practitioner and educator responses within each education level are greater for Figure 2 than for Figure 1. Regardless of

the reason, Figure 2 indicates a clear difference of opinion between practitioners and educators regarding the minimum education needed by a manufacturing engineer or technologist. Could it be that academia is perceiving a more educated manufacturing engineer or technologist than what is needed in practice for industry? Also notice that the response of “Advanced Degrees” in Figure 2 is less than one-tenth that shown in Figure 1. This could also be expected since the question asked for minimal educational levels would not be normally associated with “Advanced Degrees”. Therefore, the difference of opinion concerning minimum education needed was focused on the choice of “2-year or less” versus “4-year” degrees for the manufacturing engineer or technologist.

Agreement relative to the minimum level of education is weak between the two groups with a correlation of only .57 and a p_s value of .0720 which indicates that there is no significant correlation between the groups. The data on this question further distinguished between the ME and MT. It is perhaps important on this question to recognize that the correlation between the two groups is .81 for the ME indicating stronger agreement while on the MT is only .48.

Participants were asked “What areas of continuing education or training are important to the manufacturing professional in today’s environment? Mark all that apply”. The choices of areas were as listed in the following table:

A. Lean Manufacturing
B. Quality Management
C. Six-Sigma
D. CAD or Modeling
E. Statistical Analysis
F. Facilitator/Train the Trainer
G. Leadership or Supervisory
H. New Processes and Technologies
I. New Materials
J. None of the above.

Table 1: Choices for areas of continuing education or training for manufacturing professionals

The responses to the above “continuing education” question are depicted in Figure 3. Note the practitioner participants’ responses are arranged from highest to lowest percentage response. The corresponding responses from the educator participants are listed alongside the practitioners’. Participants were also asked the same question regarding continuing education but with respect to the future: “What areas of continuing education or training are important to the manufacturing professional over the next 10 years? Mark all that apply.” The choices of areas were the same as listed in Table 1 and the responses are depicted in Figure 4:

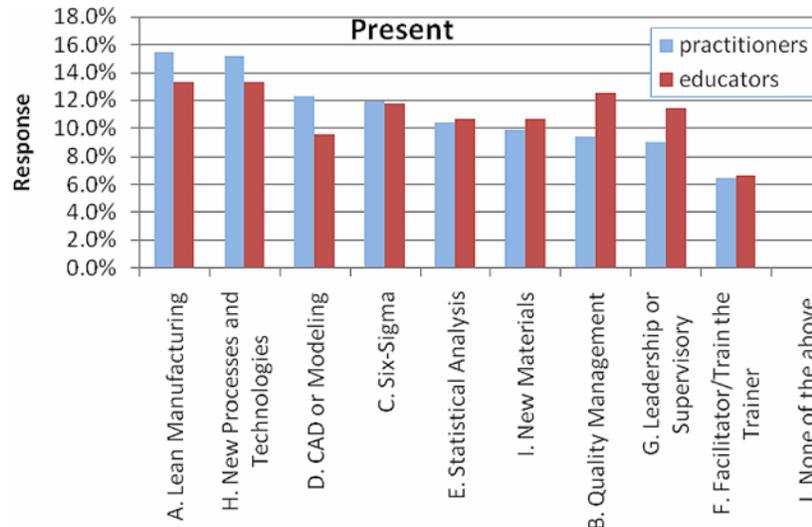


Figure 3. Response on present important areas of continuing education

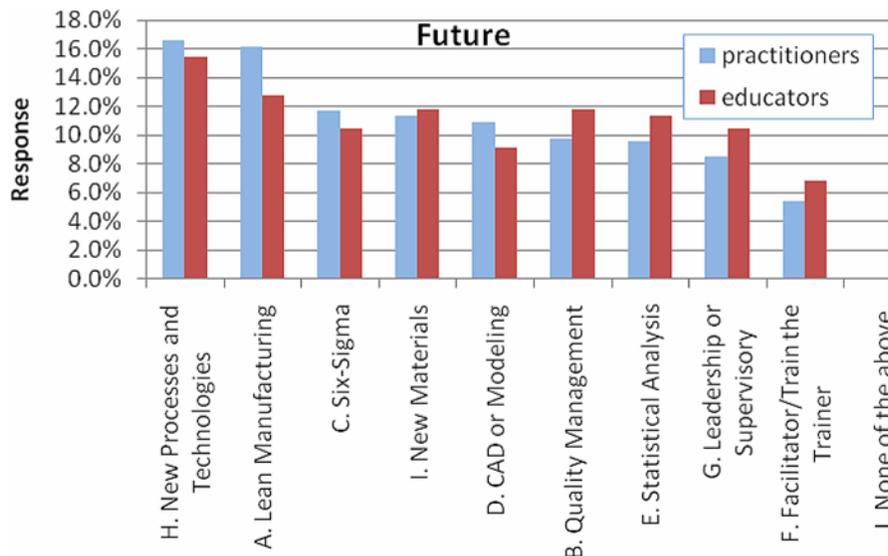


Figure 4. Response on future important areas of continuing education

The calculated correlation between practitioner and educator responses in Figure 3 is 0.91 for the present important areas of continuing education. Similarly, the calculated correlation between practitioner and educator responses in Figure 4 is 0.92 for the future important areas of continuing education. These relatively high correlations indicate agreement between both participant groups regarding what are the important areas of present and future continuing education for the manufacturing engineer or technologist.

Another basic measure of educational needs is what areas of responsibilities would a manufacturing engineer or technologist be involved in the workplace. An assumption is that rapidly changing areas of responsibilities may necessitate the development of new educational curricula to provide initial or continuing education relevant to manufacturing practice. To address this, both the practitioner and educator groups were asked the following question: “In your opinion, choose the most important areas where a manufacturing engineer or technologist would be regularly involved and responsible. Mark all that apply.” The following table gives the choices from which the participants could select:

A. Designing new products and product features
B. Developing manufacturing methods, processes and systems
C. Troubleshooting production problems
D. Selecting or designing equipment and tooling for manufacturing
E. Supervise professional staff
F. Facilitating process improvement methodologies on the factory floor (Lean, etc.)
G. Factory floor layout and design
H. Financial analysis
I. N/C; CNC machine programming
J. Interfacing directly with customers
K. Supervising production operations
L. Preparing capital spending plans and business-case justifications.
M. Researching new methods/processes for improving future manufacturing
N. Interfacing with vendors/purchasing
O. Education and training
P. Quality assurance/quality control
Q. Production scheduling/inventory control
R. Maintaining equipment and facilities
S. Other

Table 2: Choices of most important areas for manufacturing professionals to be involved

Figure 5 below shows the responses of the practitioner participants compared to the responses of the educator participants for same choices. The highest three response percentages were the same for both the educator and practitioner participants. The highest five response percentages were the same for both groups except the educator participants had “D. Selecting or designing ...” as 4th with respect to response percentages. Note that practitioner participants had “M. Researching ...” as 4th with respect to response percentages, but it was not even in the top 10 of the educator group. One might expect that research would be emphasized more by academia. Perhaps the practitioners have experienced inadequate R&D funding resulting in a loss of long term competitiveness.

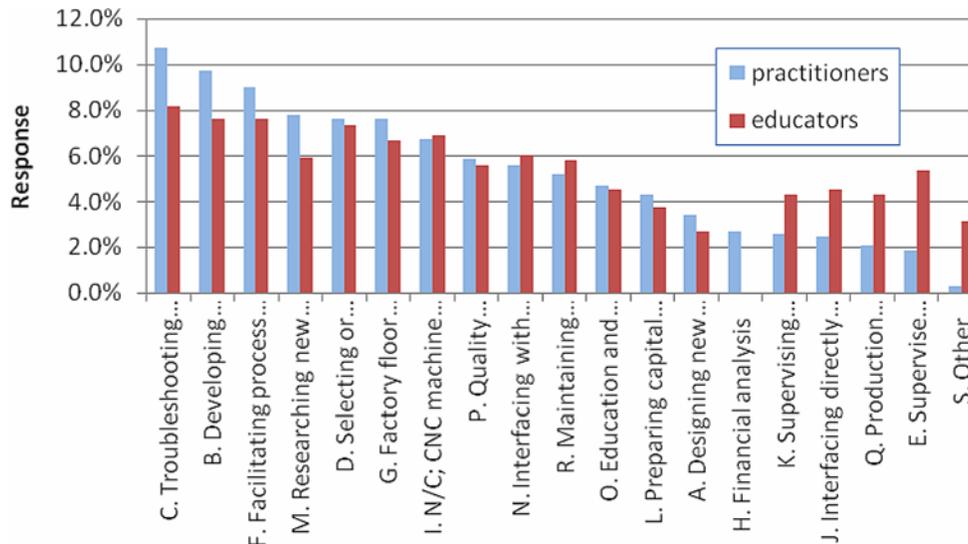


Figure 5. Participant opinion response on areas of responsibility

The calculated correlation between practitioner and educator responses in Figure 5 is 0.80 for the areas manufacturing engineers or technologists have responsibility. This would indicate less agreement between the two participant groups regarding areas of responsibility than found between them regarding areas of continuing education. For more detailed comparison of the two participant groups regarding areas of responsibility, correlations were calculated for responses considering manufacturing engineers separately from the responses for that of manufacturing technologists. The practitioners' responses had a correlation of 0.81 between what were the areas of responsibility of the manufacturing engineer compared to those areas for the manufacturing technologist. The educators' responses had a correlation of only 0.65 between what were the areas of responsibility of the manufacturing engineer compared to those areas for the manufacturing technologist. These last two correlations indicate that practitioners more so view the technologist as equivalent to the engineer regarding responsibility than do educators.

Participants were also asked to consider the following list of technologies with respect to their present importance through the following question and choices: "In your opinion, what technologies are manufacturing engineers or technologists required to use in today's environment? Mark all that apply."

A. Expert systems, artificial intelligence and networking
B. Automated material handling
C. Sensor technology, such as machine vision, adaptive control, and voice recognition
D. Laser applications, including welding/soldering, heat-treating and inspection
E. Integrated manufacturing systems
F. Advanced inspection technologies: on-machine inspection, clean room, technology ...
G. Flexible manufacturing systems
H. Simulation
I. Composite materials
J. CAD, CAE, CAPP, or CAM
K. Manufacturing in space
L. Bio-technology
M. Lean Process Improvement Tools
N. Six Sigma
O. Design of Experiments
P. None of the above.

Table 3: Choices of technologies required

Participants were also asked to consider the same above list of technologies (Table 3) with respect to their future importance through the following question: “In your opinion, of the technologies listed above, which do you see increasing in importance over the next ten years for manufacturing engineers or technologists? Mark all that apply.” Figures 6 and 7 below depict the participants responses to the above last two questions:

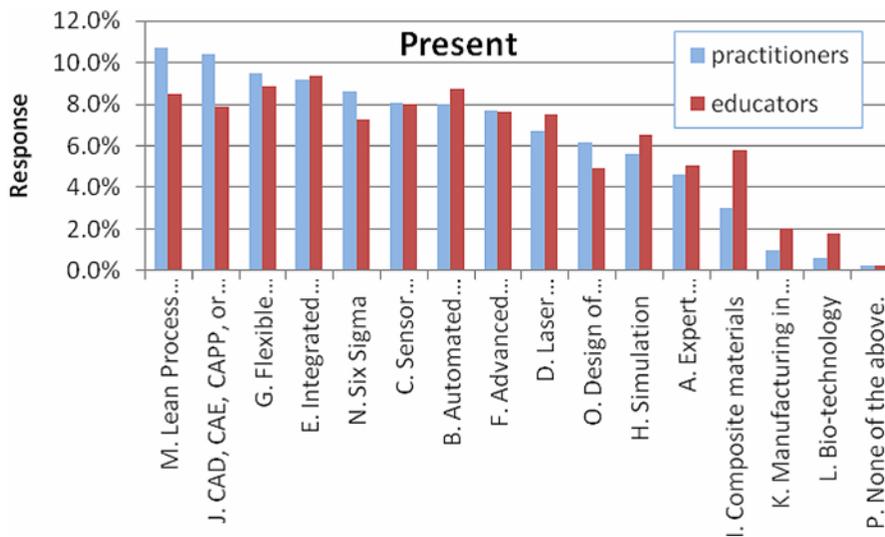


Figure 6. Participant opinion response on present technologies required

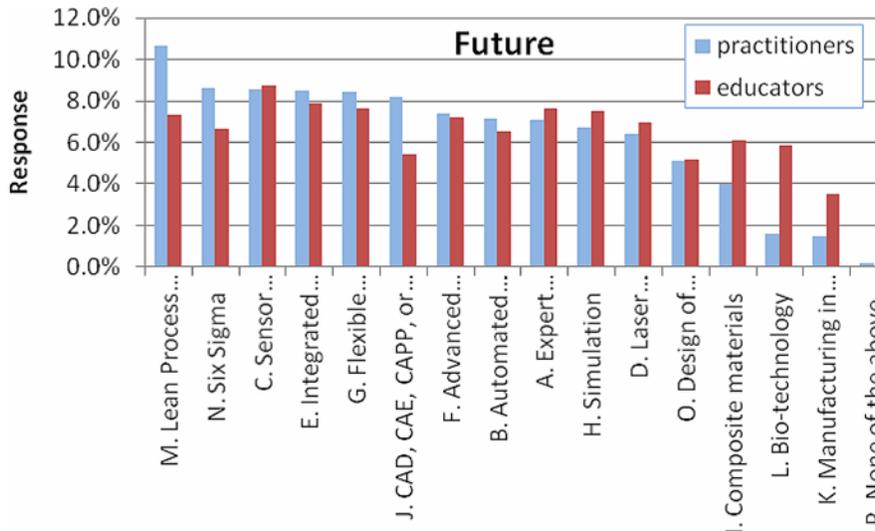


Figure 7. Participant opinion response on future technologies required

The calculated correlation between the two groups' responses for present technologies required was 0.93. Similarly, the calculated correlation between the two groups' responses for future technologies required was only 0.79. Therefore, the two groups agreed fairly well on present technologies required but did not agree as well regarding future technologies. Obviously, it is not possible to determine which groups will prove to be right.

Evaluation of Survey Data

The Spearman Rank Correlation was used to determine the agreement or lack thereof between the two groups, educators and practitioners. Table 4 below is a summary of the results of that analysis. In order to determine the significance of these correlations the following hypothesis was tested for each:

$$H_0: p_s = 0 \text{ (reject } H_0 \text{ if } p_s \leq .05)$$

$$H_a: p_s \neq 0$$

Under the null hypothesis (H_0) of no rank correlation ($p_s = 0$), the rankings are independent. The standard normal random variable Z was used to test the null hypothesis for each of the data sets represented in the figures listed below. The Spearman Rank Correlation is given for each along with the associated p_s value. With the exception of Figure 3 the null hypothesis is rejected for each indicating that there is significant correlation between the responses of the two groups.

Figure and Topic	Spearman	p_s value
Figure 2. Participant opinion response on minimal educational level for an ME or MT.	0.5733	0.0720 *
Figure 3. Participant opinion response on present continuing education for an ME or MT.	0.9061	0.0060 *
Figure 4. Participant opinion response on future continuing education for an ME or MT.	0.9321	0.0060 *
Figure 5. Participant opinion response on areas of responsibility for an ME or MT.	0.7945	0.0006 *
Figure 6. Participant opinion response on present technologies required for an ME or MT.	0.8765	0.0006 *
Figure 7. Participant opinion response on future technologies required for an ME or MT.	0.6794	0.0100 *
* Significant if $p_s \leq .05$		

Table 4: Spearman rank correlations

Evaluation of Curricular Integration

Researchers were also interested in the integration of these topics into curricula within schools of technology with a manufacturing focus. To that end the team utilized the NAIT directory of technology schools that reported to have a manufacturing emphasis program. Using that resource a website search was conducted to seek out course titles and descriptions. This effort revealed 60 schools with adequate information on their web site for the analysis. Table 5 is the result of that search. If the topic was in the course title or predominant in the description, the number of credit hours was recorded. Of the topics of interest flexible manufacturing and integrated manufacturing systems did not have a dedicated course nor was sufficient evidence found within course descriptions to warrant recording them as covering the topic. CAD/ CAM was clearly covered in 88.3% of the 60 schools with an average 4 hours of course work integrated into the curriculum. Lean manufacturing at 15% was highest followed by six sigma at 6.6%, sensory technology at 6.6% and automated material handling at only 3.3%.

	Lean Mfg.	CAD/ CAM	Flexible Mfg.	Integrated Mfg.	Six Sigma	Sensors Tech.	Automated Material Handling
Total hours for all schools	36	327	0	0	24	12	6
Number of schools with a dedicated course	9	53	0	0	4	4	2
Average hours of course when dedicated	4.0	6.17	0	0	6.00	3.00	3.00
Percent of schools with a dedicated course	15.0%	88.3%	0.0%	0.00%	6.67%	6.67%	3.33%

Table 5: Curricular integration data from technology schools

Conclusions and Recommendations

There was agreement between educators and practitioners relative to present and future continuing education, areas of responsibilities, and technologies. This would suggest that educators are current in their understanding of industry trends, roles, responsibilities, and technologies required in practice. However, there is limited evidence concerning the integration of identified practical topics into the curricula of schools of technology. Educators should integrate these identified practical topics into manufacturing curricula and clearly identify them in course titles and descriptions. Future opportunities for research include further investigation of curricular integration through detailed feedback from department leaders and manufacturing faculty.

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International Manufacturing: A Compilation of Technical Management Case Examples, Best Practices, Practical Issues, and Solutions for Manufacturing Educators and Practitioners

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Abstract

Manufacturing is and will continue to be critical to the economies around the world. U.S. manufacturers utilize numerous off-shore suppliers and also own and operate foreign production facilities; in turn, a substantial percentage of the U.S. industrial base is foreign-owned. Technology and technology management graduates in a variety of fields must, to be effective, become familiar with global concepts, issues, cultures and industry practices. In particular, to become a manufacturing professional with a skill set complementary to business and engineering graduates, students need to have an awareness of and insights to the diverse practical elements that may challenge the planning, conduct, and success of international operations. Upon request, the author will provide related course resources for which there is not room to convey within this paper.

Introduction and issues

Global industrial competition is intense. It is essential that related university engineering and technology programs provide industry with professionals who are knowledgeable and capable of serving effectively as team members/ counterparts to graduates of business programs. The Dean of a major U.S. engineering school asked Sony's founder, Akio Morita, "If we teach our students JIT, computer aided design, flexible and lean manufacturing methods, is that what you want?" Morita answered, "No, we already know that; produce students who understand the spirit and process of a Global manufacturing business." (Weinig, 2007) (emphasis by source).

Students of industry need an accurate perspective. In recent years there has been much debate about whether manufacturing is being supplanted by a "service economy". Entire books have been written on this topic; a summary statement would be that while services now represent a majority component of developed nations' economies and GDPs, manufacturing remains critical as the foundation for services. "Without demand for transportation, for example, the need for trucks, buses, ships, and airplanes would collapse" (The Service Economy, 2000). It is manufacturing which creates wealth (by which to purchase services) by adding value through conversion of raw materials. If manufacturing were not important, cities, states, and nations would not be competing for it.

In the current "global economy", international business concerns extend beyond the fields of banking, finance, and marketing. The significance of manufacturing operations is often discounted or misunderstood, not only by the public but also by top management of global or "would-be" global firms.

Kaj Grichnik and Conrad Winkler, vice presidents and manufacturing transformation specialists at the global consulting firm Booz Allen Hamilton, have co-authored a new book, "Make or Break: How Manufacturers Can Leap from Decline to Revitalization". In an on-line interview (Earing, 2000, ¶ 2), Winkler states "We've written a lot of articles on the decline of manufacturing and over the last couple of decades we've seen businesses lack awareness of their manufacturing operations -- resulting in a decline that we feel is really threatening. On the other hand we've seen a handful of companies that actually treat manufacturing as an incredibly important part of their competitive advantage and they have reaped amazing rewards from it." Winkler further explains that "... when we talk about global manufacturing, having sophisticated process technology is part of having a competitive advantage."

“Companies that repeatedly place manufacturing low on its list and consider it a cost center will be at the greatest risk. You can see this ‘break’ moment has already happened in many of the Tier 1 automotive companies. They robbed themselves of a competitive manufacturing footprint -- they didn’t have innovative process technology and when the industry went down they suddenly all went bankrupt. And if you look around the world and think it is an automotive problem in general, ask yourself -- have Korean manufacturers gone bankrupt, have the Japanese? Europeans? No. It was only U.S. manufacturers. Unless companies invest in their manufacturing, many other industries could face a similar ‘break’ moment” (Earing, 2000, ¶ 9).

Such concerns go beyond the financial health of U.S. companies. The Small Business Committee of the U.S. House of Representatives, chaired by Rep. Don Manzullo (R-Ill.), has initiated a wide-ranging investigation into the deteriorating health of the industrial base and its impact on national security. The project leader, analyzing the military’s problems due to outsourcing and globalization, “... believes that policymakers are not making the connection between national and economic security, and that the health of General Motors is as important to the nation’s security as the health of a large defense contractor like Lockheed Martin. ‘We may be able to supply our military with [manufactured parts] from our allies, but while they may be military allies they definitely are not economic allies...’ “

Fed by media coverage which typically does not provide a complete view, a common misconception by the U.S. public, including many current and future university students, is likely to be that manufacturing in the U.S. is going overseas due to domestic high wages. However, if that were the primary issue, companies such as Honda, Hyundai, Mercedes, BMW, and Toyota would not continue to build factories in the U.S. Foreign industrial investment within the U.S. has grown at a rate of over 18% per year since the mid-1970s. Increasingly, as reflected by those firms and many more, a key reason is to better address the needs of a target market (Waldrop, 2003). This certainly is nothing new, as U.S., Asian, and European auto manufacturers and their many suppliers have been setting up plants around the globe since the era of the Model-T Ford, and continue to do so. Daimler AG said announced in June 2008 that its Mercedes-Benz car unit will invest US\$1.24 billion to build a plant near Budapest, Hungary, creating up to 2,500 new jobs. Said Dieter Zetsche, the company’s chief executive officer, “... our expanded product range will allow us to tap into new customer groups and open up new market regions,” (Daimler Building Factory In Hungary, 2008).

Among the many such news releases about global industry, a substantial number concern foreign investment in the U.S., including suppliers co-locating with the new Hyundai/Kia auto plant in Columbus, Georgia. South Korean auto supply company DongNam Tech announced that it will locate its first U.S. plant in Columbus, creating 350 jobs. “Gov. Sonny Perdue said Thursday that DongNam Tech will create an offshoot called DNT Georgia for the new facility, planned to be 100,000 square feet on 26 acres in the Muscogee Technology Park. The company will manufacture carpet and floor mats for a number of automakers and suppliers, including Hyundai Mobis, Kia Mobis, General Motors and Nissan. DongNam also has a distribution center in Detroit. (Auto Supply Company Brings 350 Jobs To Georgia, 2008).

Another, less frequent, reason to establish offshore facilities is to tap into a special resource at that location, such as unique raw materials or a world-renown research center.

Past and future graduates of engineering and technology programs will be working in or with those global suppliers and partners, foreign plants in the U.S. and U.S. plants around the globe. Who else will define the technical requirements, coordinate projects on-site, document and exchange information, interface with and train production personnel, and manage JIT supply issues? Insight to the unique challenges and opportunities may come from content dispersed through several courses, or a focused course. At SUNY/Stony Brook University, a course entitled The Global Enterprise is taught by Professor Sheldon Weinig, a former Vice Chairman of Engineering and Manufacturing for SONY America. Among the primary and sub-topics covered are: Why should a Corporation go Global?; Culture - the major obstacle of successful globalization; Problems of Global Corporations; Benchmarking; Manufacturing Methods; and Design Methods & Supply Chains for Global Corporations (Weinig, 2007).

Similarly, as an introduction to global manufacturing issues relevant to technical management, the course TMAE 5230/5230G International Manufacturing at the author’s university includes topics such as ISO standards and procedure-writing skills, methods of auditing offshore suppliers, JIT logistics challenges, technology transfer, and business culture issues, among others. Topic content elements from that course are presented here.

Technology Transfer Problems

In many cases involving a company establishing production in another nation it is not a simple matter of picking up an existing cell or its specifications and dropping it in place. In interviews with industrial engineers at a U.S. firm's partnership in Querétaro, Mexico, it was clear that when they received a work cell from the parent U.S. plant, they did not do a "cut/paste" installation, but reviewed the project for "lean" improvements. Tooling standards are another possible area of difference to consider.

When transferring equipment internationally, special consideration must be given in regard to reliability. For example, a U.S./Japanese joint venture facility in Missouri produces interior components as a certified supplier to Toyota. One assembly cell contains a piece of equipment transferred from Japan, and occasionally there is a failure of a non-standard controller circuit board. Replacements are only available from Japan, and lead times can be problematic.

In some instances, voltage may be comparable, there are other electrical issues. Certain electro-mechanical timers (for example) made to operate on U.S. 60-cycle current will not function when supplied with 50-cycle current in Europe. In Mexico, as in other locations, electrical power may not be stable, so any new operation may be best served by investing in power conditioning and backup systems. A common alternative is to build the plant in a new, self-sufficient industrial park, such as the four developed in Mexico by the Houston-based firm, Hines. At the request of a client firm, they can perform a complete design, build, utilities, and equipment installation project.

There are concerns beyond hardware or productivity. Workers and engineers may be sent to the U.S. to be trained in the cell's operation and care before it is transferred, or U.S. workers and engineers may be temporarily sent to the offshore location to facilitate the cell start-up and training. There are cases in which technical managers, within weeks of being hired, have been sent overseas for the purpose of documenting processes that were then transferred to the U.S. facility. A key element in developing countries is the availability of properly educated workers and professional staff. What may be relatively commonplace modern technologies in industrialized countries may not be a good choice. In addition to not having the local talent to set up, maintain, and operate automated equipment, it may simply not be necessary because the labor rates are so low. The field of "appropriate technology" is very applicable in this context.

In addition, technical and technical management personnel must have awareness of host nation issues, status, requirements and methods involved in industrial process safety, personnel safety and health, and environmental safety and regulatory compliance.

Foreign Supplier Selection and Quality Audit Methods

A formal checklist is an excellent tool for initial qualification as well as periodic audits, and is a tool that can be provided to students and practitioners. This serves to get them beyond simply being aware that supplier selection and audit activities must be done, so they understand more specifically what must be done. One premium-goods manufacturer has all manufacturing done in Asia, and shared their checklist. Key elements include:

- Supplier's training programs, including procedures and records for all areas of the plant. Does the workforce - on and above the "shop floor" - know how to perform their jobs and deal with problems?
- Preventive maintenance procedures, checklists and logs
- Housekeeping procedures and housekeeping audits. In addition to supplier documents, use a checklist during a direct "walk-through" inspection of production facilities. Are there potential problems such as contamination from floor sweepings being "recycled" into injection molding machines?
- Quality goals, inspection data, and reporting media, e.g. recent charts and graphs, clear evidence of use of SPC, and evidence of how management actually utilizes quality data in pursuit of continuous improvement.
- Documentation of annual color acuity tests.

The last item is unique to this company's product specifications. As a producer of top-of-the-line leather goods, the ability of workers to precisely color-match died leather components is critical.

Supplier/vendor qualification and certification case situations are numerous, generally available through interviews with engineers and managers responsible for quality or purchasing, and provide excellent "lessons learned". The magnitude of the impact cannot be underestimated, as evidenced by recent major health-related recalls of toys and pharmaceuticals

manufactured in China. It may be reasonably argued that a significant portion of responsibility lies with the U.S. personnel who were the liaison to the offshore contractors.

Assumptions cannot be made about product or process standards and specifications being uniform. The firms contracting with industries in developing nations must provide highly detailed specifications - e.g. regarding non-lead-based paint formulations - and monitor the output. According to the editor-in-chief of the Chinese-language newspaper *Sing Tao Daily* in San Francisco, "Regarding problems with exported Chinese goods, such as the recall of toys containing lead, the responsibility does not lie only with China, as Western media would like to claim. These products were investments by Western companies in China, and therefore these companies should be held responsible for the products they produce, whether the products were produced in China, the United States or India." (China-Bashing on the Rise, 2007).

The assumptions that may be made, things taken for granted, can lead to surprising revelations. This author served as manager of a supplier capability assessment and development project for a U.S. Fortune-500 aerospace firm. It was discovered that the to-be supplier partner had no established system of receiving inspection because, in that formerly socialist dictator-led nation, their prior customer had been the government-run aircraft industry, which provided their own materials pre-inspected. Even more surprising was the fact that this supplier had no idea of how to respond to a typical RFQ (request for price quotation to do a job). They had no data available on direct or indirect costs, as their former customer had simply told them what to do and how much they would be paid.

Import and Export Paperwork and Other Challenges

The International Manufacturing course at the author's university was initiated in part due to the program's industrial advisory board's concern that the graduates have in-depth knowledge of how to fill out Customs forms for goods being shipped offshore for assembly work.

Whether infrequently transferring process equipment or daily shipping and receiving and shipping of production materials, parts, and assemblies, associated technical management personnel need to be knowledgeable of the governmental requirements, restrictions, and related paper or electronic forms. This can be a severe problem today, given the security concerns and the demands of JIT production. As described by an expeditor at the U.S. operations of a major European construction equipment manufacturer, a checkmark in the wrong category box of a Customs form can cause a whole shipment of critical items to be held up for days.

A large tool and die facility was delayed for weeks in its planned installation of a new German CNC machine tool, all because it arrived at the U.S. port on a pallet made of a wood that was quarantined. The shipper had to have it returned to Europe where it could be re-packaged.

Anticipating and Managing Issues of Culture On and Above the Foreign Shop Floor

There are not only cultural differences between nations, but also within them. Any international course must address these issues. It is unreasonable to expect recall of all such details, but, rather, it is important to ensure awareness of the need to research these aspects before traveling or hosting visitors, and insight to information resources.

Workplace cultural issues range from extreme prejudice between ethnic groups to small-scale working environment details. For example, in some U.S.-operated facilities in Mexico it is not uncommon to find religious shrines within work centers. A plant manager in Mexico has explained that the "line-stop" concept of the Toyota Production System can be difficult to implement. Well-paying factory jobs are highly sought after, and there is a tendency for hourly workers to avoid use of the Andon problem signals because they fear for their jobs and do not want to be somehow associated with a problem situation.

Virtually all nations today are multi-cultural, with production workers and professionals from a variety of backgrounds such as strict religious routines in their lives that may conflict with standardized situations. In other cases it may simply be differences in religious holidays. Insight to contemporary issues and training in communications are essential for technical managers.

Key Reasons for and Means to Avoid Failure in Foreign Work Assignments

For U.S. personnel abroad, cultural differences outside the workplace may have even greater significance than within the professional environment. Most all professionals in foreign firms speak English as their second language (shop floor workers often do not), but conversational language ability can make or break the level of comfort with an offshore assignment during non-work hours in the daily public. A good instructional resource for addressing individual, personal success issues in long-term offshore assignments is the video Going Global: the Expatriate Experience. It provides an excellent, enlightening case study for discussion.

The bottom line is that most individuals' failures in offshore assignments are not due to poor work knowledge and skills, but personal - especially family - issues (Dennis and Stroh, 1992). Married professionals face significant challenges in expatriate assignments: separation, or a working spouse who must interrupt their own career and lose their income; where children will be educated and how they will adjust; how to deal with a vacated house back home; is comparable housing available and affordable; transportation; compensation; communication with the extended family; and medical care. Their employers must provide their own and/or contracted service resources to facilitate the changes, minimize the disruptions, provide on-going support so that these personal challenges do not develop into unacceptable situations.

Summary

Industrial technologists and engineers may reasonably expect to experience a foreign short-term project or longer-term work assignment, and most certainly can expect to be involved with import and export of materials, parts, assemblies and end products, technology transfer, and interface with foreign counterparts. It is essential that they are well-oriented and prepared by their professional academic programs and, subsequently, by their employers. College study of a foreign language and pursuit of a study abroad experience can make a significant difference in the desirability of graduates in the eyes of potential employers, as well as in success in the established career. Those with a demonstrated level of comfort with foreign travel may have a greater chance for selection and involvement in both short- and long-term assignments.

University faculty members are encouraged to share case studies, new literature, and other resources that can facilitate appropriate depth, breadth, and quality in such programs. Industry practitioners are encouraged to provide case studies and other useful insights to faculty members for the purpose of continuous improvement of content to be provided to future graduates. The author will share/exchange resources upon request.

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On-Line Cutting Tool Condition Monitoring System Developments in CNC Turning Center Using a Signal Decomposition Technique and a New Approach of Searching Artificial Neural Networks Architecture

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Abstract

The present paper shows the development of on-line tool condition monitoring (TCM) system utilizing signal decomposition technique and artificial neural networks (ANN) system. The raw signals obtained from sensors under different machining conditions were examined and decomposed to multiple components. The most significant components of each signal were implemented to develop on-line tool monitoring systems.

Over 900 neural networks structures were tested using a new ANN architecture methodology to find an optimized structure of artificial neural networks based tool condition monitoring (ANN-TCM) system. The presented technique provided systematic test results of the all possible ANN structure with higher accuracy compared with the traditional manual trial-and-error methodology. The developed ANN-TCM system showed 97% accuracy from 151 test samples with the reject flank wear size of 0.2 mm or larger. The result shows that a successful development of a TCM system which can be implemented as a practical tool to reduce machine downtime associated with tool changes and to minimize the number of scraps.

Introduction

The metal cutting process, which has played an important role in modern manufacturing history, relied on highly skilled labor until the mid-1950s, when automated machining was introduced to replace traditional labor, decrease production costs, increase productivity, and enhance product quality (O'Donnell, Young, Kelly, & Byrne, 2001). Not after long time, the industry also demanded another task from manufacturers. Products became more individualistic, varied, and complex to manufacture. Manufacturers needed new technologies and methods that would allow small-batch production to gain the economic advantages of mass production (Willow, 2002). The development of CIM (Computer-Integrated Manufacturing) and FMS (Flexible Manufacturing Systems) seemed to be ideal solutions by increasing machining flexibility in addition to flexibility in routing, process, product, production, and expansion (Singh, 1996).

Although the combination of CIM and FMS technologies showed great promise as a cost-effective solution to meet new demands, CIM-FMS systems could not be implemented until certain prerequisites were met. One of major prerequisite was uninterrupted machining to achieve maximum efficiency (Venkatesh, Zhou, & Caudill, 1997). Deteriorating process conditions, such as tool condition, often forces manufacturers to interrupt machining processes to respond. Thus, developing an effective means of monitoring machine conditions has become one of the most important issues in the automation of the metal cutting process (Li, Dong, & Venuvinod, 2000).

Among the many machining conditions requiring monitored, tool wear is the one of most critical issue to ensure uninterrupted machining. Any effective monitoring system must sense tool conditions, allow for effective tool change strategies when tools deteriorate, and maintain proper cutting conditions throughout the process (Lee, Kim, & Lee, 1998). If the monitoring function cannot maintain proper cutting conditions, the cutting process could result in poor surface quality, dimensional inaccuracy, and even machine failure (Li et al., 2000). Furthermore, a reliable tool wear monitoring system can reduce machine downtime caused by changing the tool, thus leading to fewer process interruptions and higher efficiency. The information obtained from the tool wear sensors can be used for several

purposes, including the establishment of tool change policy, economic optimization of the machining operation, on-line process manipulation to compensate for tool wear, and, to some extent, the avoidance of catastrophic tool failure.

TCM Studies

The traditional process for predicting the life of a machine tool involves Taylor's (1906) equation for estimating tool life: $VT^n = C$, where V is cutting speed, T is tool life, and n and C are coefficients. This equation has played an important role in machine tool development (Kattan & Currie, 1996). Since advanced machining was introduced in the mid-1900s, various methods to monitor tool wear have been proposed, expanding the scope and complexity of Taylor's equation. However, none of these extensions has been applied universally, due to the complex nature of the machining process (Xiaoli & Zhejun, 1998).

Researchers have searched reliable methods to monitor tool wear. These methods are an area of active research because tool condition strongly influences the surface finish and dimensional integrity of the workpiece, as well as vibration in the tool. More automated approaches were attempted using computer-numerical control (CNC) technology. However, the CNC approach also has several obstacles to widespread implementation, such as narrow learning capability of CNC machines, limited flexibility of the CNC controller, relatively large dynamic errors encountered in CNC operations, sensor noises, variability between machines (Chen, 2000). Many studies tried to overcome these limitations by finding and utilizing proper sensor technologies and signal process techniques. Therefore, numerous sensor techniques were introduced and tested in tool wear monitoring studies.

Tool condition monitoring methods can be classified into direct and indirect methods, depending on the source of signals collected by sensors. Direct methods sense tool conditions by direct measurement of the tool. Direct methods include optical, radioactive, and electrical resistance. Alternatively, indirect methods sense the tool condition by measuring secondary effects of the cutting process, such as acoustic emission (AE), sound vibrations, spindle and feed motor current, cutting force, and machining vibration. Direct methods are beneficial because they take close readings directly from the tool itself. By contrast, indirect methods must rely on conditions other than the tool itself to judge tool condition. However, direct methods are limited because the machining process must be interrupted to make the direct measurements (Bradley & Wong, 2001). As a result, machine downtime increases, as do costs for tool condition monitoring.

Since indirect methods do not require access to the tool itself to measure the tool conditions, signals that indicate the tool condition can be gathered in real time, while the machine is running. However, despite the benefits of on-line measurement, indirect methods also have some disadvantages. Since the information (or signals) collected by indirect sensors does not contain direct measurements of the tool conditions, additional systems are required to correlate the indirect measurements with its tool condition. Additionally, indirect measurements are weakened by noise factors associated with the machining process. Noise factors tend to weaken or totally eliminate relationships between the indirect information (or signals) and actual tool conditions. Many studies have sought to correlate indirect measurements with actual tool conditions using statistical regression techniques (Choudhury & Kishore, 2000), fuzzy logic (Ming, Xiaohong, & Shuzi, 1999), artificial neural networks (Chen & Jen, 2000; Özel & Nadgir, 2002), and fuzzy-neural networks (Balazinski et al., 2002; Chen, 2000). In many of the studies, the relationships between indirect signals and tool condition were weak because unknown factors and noise factors diluted the signals collected by the indirect sensors during machining.

Some studies attempted to eliminate or minimize noise factors from the signals collected by indirect sensors. Wavelet transform methods were used to remove noise factors from the information collected by the sensors (Al-Habaibeh & Gindy, 2001; Xiaoli & Zhejun, 1998). These studies showed that a wavelet transform process can increase the correlation between the de-noised signals and tool conditions (Wu & Du, 1996). However, these studies still did not show the relationship between the signal components, which were treated as noise factor, and tool conditions.

A limited number of sensors have been adopted in most studies involving indirect sensing systems. The most widely used indirect sensor is the dynamometer (Chen, 2000; Ertune & Loparo, 2001; Lee, Kim, & Lee, 1998), which is not practical because of its high cost and lack of overload protection. The acoustic emission (AE) sensor is another sensing technology that has been used in a number of studies (Li, 2002; Liang & Dornfeld, 1989), but it is limited in its application due to its noise integrity. Some studies adopted multi-sensor techniques to improve tool condition monitoring systems (Dimla Jr.,

Lister, & Leighton, 1998; O'Donnell et al., 2001; Scheffer & Heyns, 2001). By combining multiple sensing technologies, these studies sought to develop more robust on-line TCM systems.

Experiment Setup

From the review of the past TCM studies, two sensor technologies, tri-axial accelerometer and AE sensor, were employed in this study to detect multiple direction vibrations and the energy generated from the interaction of tool and workpiece. The accelerometer was mounted under the shank holding cutting tool and AE sensor mounted under workpiece. The signals detected by the accelerometer were amplified and transferred to an A/D converter with the signal from the AE sensor simultaneously. The signals were recorded to a computer storage by a data acquisition program, which was also utilized to analyze the data. Carbide insert tools (CNMG-432) with variable tool wear amounts were mounted in a CNC lathe machine to cut aluminum alloy workpieces (AL6061). Figure 1 shows the illustration of the experiment setup.

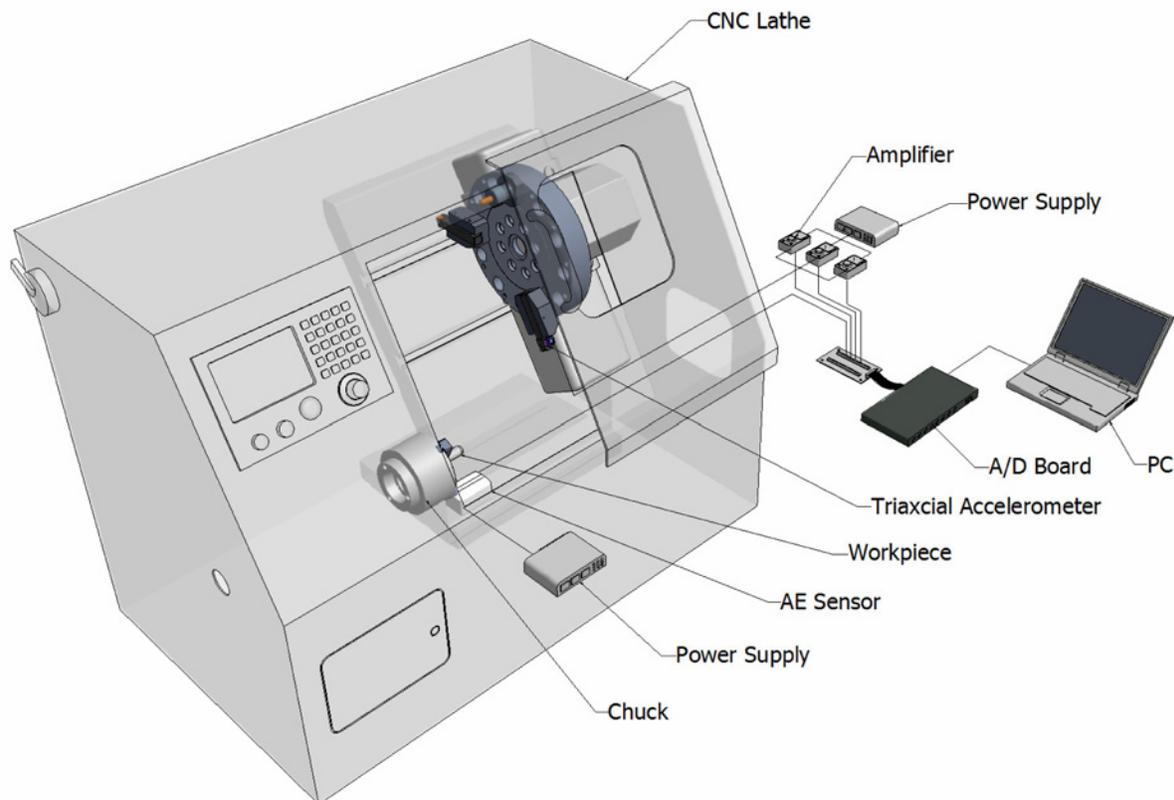


Figure 1. Experiment Setup

Experimental design

The goal of this study was to develop a tool condition monitoring system using three machining parameters (spindle speed, feed rate, and depth of cut) and the signals detected by the two sensors. To conduct the experiment, an experimental design was established. A full factorial design was utilized for this experiment. An ANN model was deployed based on the independent variables for a input neurons. The independent variables utilized in this study were: 3 spindle speeds (SP), 3 feed rates (FR), 3 depths of cut (DC), and signals captured during machining (S_i). Three insert tools with different amounts of flank wear (0.010714", 0.017857", and 0.019643") were measured under a microscope before the machining. The measured values were used as the outcome of the developed TCM system.

To test the flexibility of the developed TCM system additional sets of machining parameters and condition were

employed. These sets includes additional values for spindle speed, feed rate, depth of cut, and tool conditions (0.007143” and 0.014285”) which are not used in the analysis and system development. After the experimental design, each cutting condition—including cutting conditions from the flexible data set—were randomly reorganized before the machining was performed to eliminate any systemic integration from the cutting conditions. Table 1 shows the experimental design of this study and the flexible data set.

Training Data Set										
SP		500			1,000			1,500		
FR	DC	0.01	0.02	0.03	0.01	0.02	0.03	0.01	0.02	0.03
0.01		S ₀₁	S ₀₂	S ₀₃	S ₁₀	S ₁₁	S ₁₂	S ₁₉	S ₂₀	S ₂₁
0.02		S ₀₄	S ₀₅	S ₀₆	S ₁₃	S ₁₄	S ₁₅	S ₂₂	S ₂₃	S ₂₄
0.03		S ₀₇	S ₀₈	S ₀₉	S ₁₆	S ₁₇	S ₁₈	S ₂₅	S ₂₆	S ₂₇

Flexible Data Set					
SP		625		825	
FR	DC	0.015	0.025	0.015	0.025
0.015		S ₂₈	S ₂₉	S ₃₂	S ₃₃
0.025		S ₃₀	S ₃₁	S ₃₄	S ₃₅

Table 1. Experimental design and flexible data set (S_i: Specimen)

Tool Condition Monitoring System Developments

Signal Decomposition Process

A total of 270 data sets containing raw signals were obtained from the experiment. Since the traditional time-domain analysis does not provide a clear method to analyze raw signal data due to the randomness of each data points, the statistical characteristics of the signals of each machining condition were tested. Among the many characteristics, the adjusted means values of each membrane were employed to represent responses of sensors to the each machining conditions, including machining parameters and tool conditions. However, the raw signals data restrain other machining effects including the effects of machining parameters and machining environments. Therefore, it is necessary to decompose the raw signals into the multiple components and adopt only the significant components to develop TCM system.

Among a number of signal processing technology, wavelet transformation was employed. In the past, wavelet transformation methodology has been used to eliminate the noise factors, but in this study, which components are noise factors or significant responses to tool condition are indistinguishable. In order to find the most significant component to tool condition, a series of statistical data analysis were carried out. Figure 2 shows an example of decomposition process and Table 2 shows the statistical analysis results of the components of each signal. The analysis results shows that 6th components of x, y, and z direction vibrations and original raw signal of AE sensor show stronger relationship to tool condition. It indicates that by utilizing 6th components of vibration signals, decomposed by wavelet transformation from the raw vibration signal, and raw signal of AE sensor, can provide more accurate TCM system.

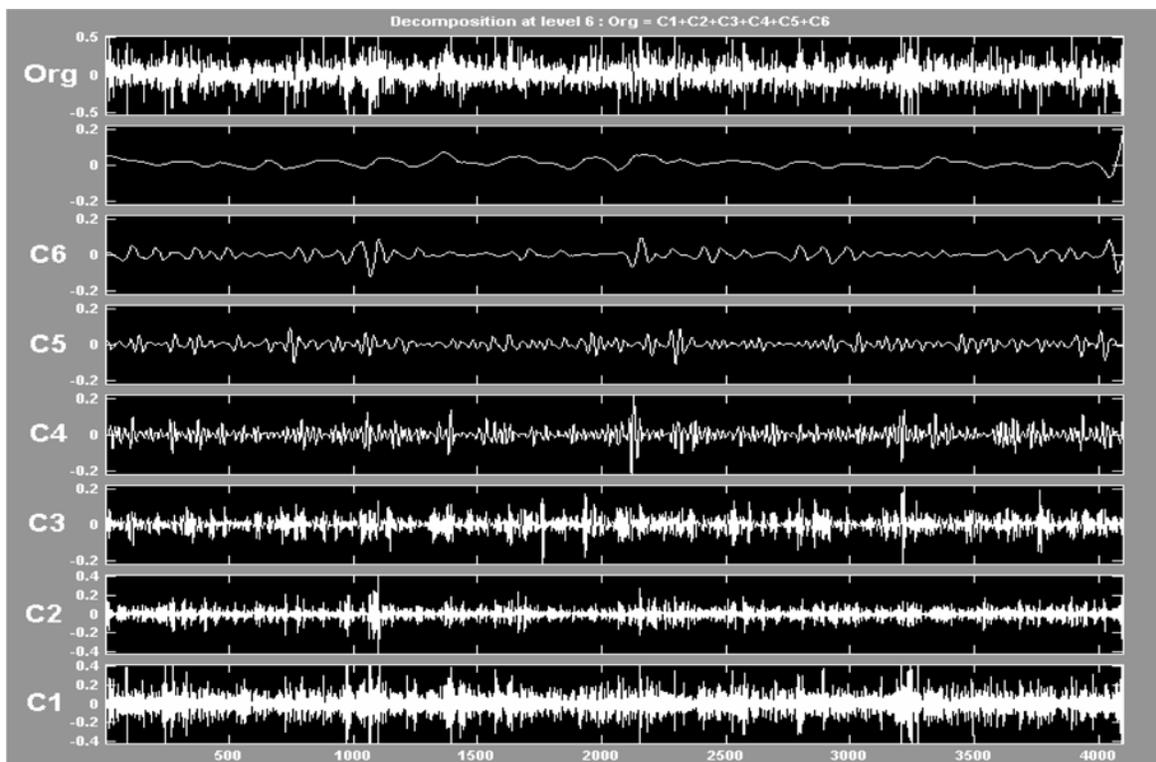


Figure 2. Example of signal components decomposed by wavelet transform

Signal	Org	Comp1	Comp2	Comp3	Comp4	Comp5	Comp6
X	.041570	.000708	.036834	.079329	.266055	.241379	.536925
Y	.095862	.013675	.026677	.028840	.072718	.075334	.361890
Z	.003057	.019938	.043196	.057798	.192967	.200215	.513471
W	.121421	.087464	.086403	.059550	.079244	.030679	.042767

X: x-direction vibration, Y: y-direction vibration, Z: z-direction vibration, W: AE signals
 Org: original signal, Comp1 - 6: signal components

Table 2. Correlation factors of tool wear and signal components of four signals

Artificial Neural Networks Structure Developments

Artificial neural networks provide an artificial means of making some of the same kinds of decisions that a highly skilled machine operator would make before, during, or after the machining process (Masory, 1991). Human operators learn to make accurate judgments of tool conditions based on relationships observed during the machining process. As human operators gain experience, their sensitivity to these relationships increases. More recent experience reinforces or adjusts the patterns developed from prior experience. ANNs work in a similar fashion, continually training their ability to accurately judge tool conditions. By adjusting the weights among neural networks nodes until the number of test errors falls to an acceptable level, the nonlinear relationships among the factors and tool condition are updated and tested. Determining the networks structure (the number of hidden layers and nodes of each layer) that performs best is one of

the biggest challenges in the process of developing ANNs. Many machining tool studies tested only a limited number of cases by trial-and-error in order to determine the appropriate structure (Dimla Jr., Lister & Leighton, 1998; Chen & Chen, 2002). Investigating a limited number of cases of the ANN structure often leads to a low probability of obtaining the best-performing system with the available data. Alternatively, in a trial-and-error methodology, the researcher has to spend a great amount of time to modify the ANNs structure, including the numbers of hidden layers and nodes, and the each structure must be trained until the test results are valid. As a result, this method requires a great deal of time to optimize the network training time and output results (Dimla Sr. 1999).

A novel methodology to find the optimized ANNs structure for tool condition monitoring is proposed in this study. In order to overcome the problems of the traditional manual method (inefficient, time consuming, and inaccurate) to determine the ANNs structure, a computer-assisted structure search methodology was employed. The method used in this study tests all possible structures with a simplified learning process and training iteration, providing fitness scores for each structure to allow focus on a limited number of structures with higher scores.

For the input layer of ANN-TCMS, three machining conditions (spindle speed, feed rate, and depth of cut), three accelerometer signals (vibration from the x-, y-, and z-direction), and AE (acoustic emission) sensor signals were adopted. The output layer has one node (the amount of flank wear of the tool used in each experiment). For the accelerometer and AE signals, the best components of each signal were utilized since they exhibited a closer relationship with tool conditions than raw signals. In order to utilize the data in ANNs training, a preprocessing of the data is required to give equal initial weights into the input layer. All input layer node data (machining conditions and sensor signals) were transformed into the range between -1 and 1 and the output node (the amount of flank wear) was transformed into the range of between 0 and 1 (normalization).

After the preprocessing, the best-performing ANNs structure was determined using a computer-assisted neural-networks structure search method. This methodology verifies the performance of all possible structures systematically based on the criteria of interest. In this study, the number of the hidden layers was limited to one and two (the both cases were tested), and the number of nodes per hidden layer was limited to thirty, due to the limitations in available computing power. Therefore the number of possible structures for the ANNs system is 930. Each of these possible structures was tested and scored based on its fitness to the tool conditions. During the test, a simplified learning algorithm (Quick-propagation) was utilized to shorten the learning time with a limited number of iterations. Table 3 shows top 30 ANN structures nominated by the process based on each fitness scores. The results show that multiple hidden layers perform a better fitness to the examined data compared to a single hidden layer system. An irregular relationship between the degree of fitness and the structure of ANNs systems (the number of nodes in each hidden layers) was also observed. From the test results, the top 22 structures (all with a fitness score of 400 or more), were evaluated to determine the best fit for the tool condition monitoring system.

ID	Architecture*	Number of weight	Fitness score	Inverse test error	Train error
236	7-14-8-1	409	448.703444	0.002229	0.003321
195	7-29-6-1	767	431.531508	0.002317	0.002982
101	7-19-3-1	444	427.816747	0.002337	0.003125
738	7-12-26-1	605	425.111223	0.002352	0.003446
598	7-12-21-1	535	425.080106	0.002352	0.003281
852	7-14-30-1	761	423.547217	0.002361	0.003237
242	7-20-8-1	577	422.291485	0.002368	0.003369
327	7-21-11-1	674	421.018051	0.002375	0.003256
851	7-13-30-1	711	418.271546	0.002391	0.003387
351	7-17-12-1	569	411.719799	0.002429	0.003428
138	7-28-4-1	681	411.177160	0.002432	0.003003
272	7-22-9-1	657	410.725640	0.002435	0.003480
739	7-13-26-1	651	405.973689	0.002463	0.003597
239	7-17-8-1	493	404.659469	0.002471	0.003181
111	7-29-3-1	674	404.409089	0.002473	0.003454
189	7-23-6-1	611	402.797041	0.002483	0.003681
269	7-19-9-1	570	401.746901	0.002489	0.003762
150	7-12-5-1	311	401.460845	0.002491	0.003479
271	7-21-9-1	628	401.443044	0.002491	0.003261
245	7-23-8-1	661	401.366359	0.002491	0.003185
580	7-22-20-1	921	401.267746	0.002492	0.003457
267	7-17-9-1	512	401.249401	0.002492	0.003419
737	7-11-26-1	559	399.767005	0.002501	0.003660
222	7-28-7-1	771	396.488573	0.002522	0.003405
436	7-18-15-1	661	396.432191	0.002522	0.003367
93	7-11-3-1	260	395.568345	0.002528	0.003196
251	7-29-8-1	829	395.425971	0.002529	0.003434
692	7-22-24-1	1017	394.911352	0.002532	0.003491
829	7-19-29-1	990	394.889463	0.002532	0.003397
214	7-20-7-1	555	394.358644	0.002536	0.003241

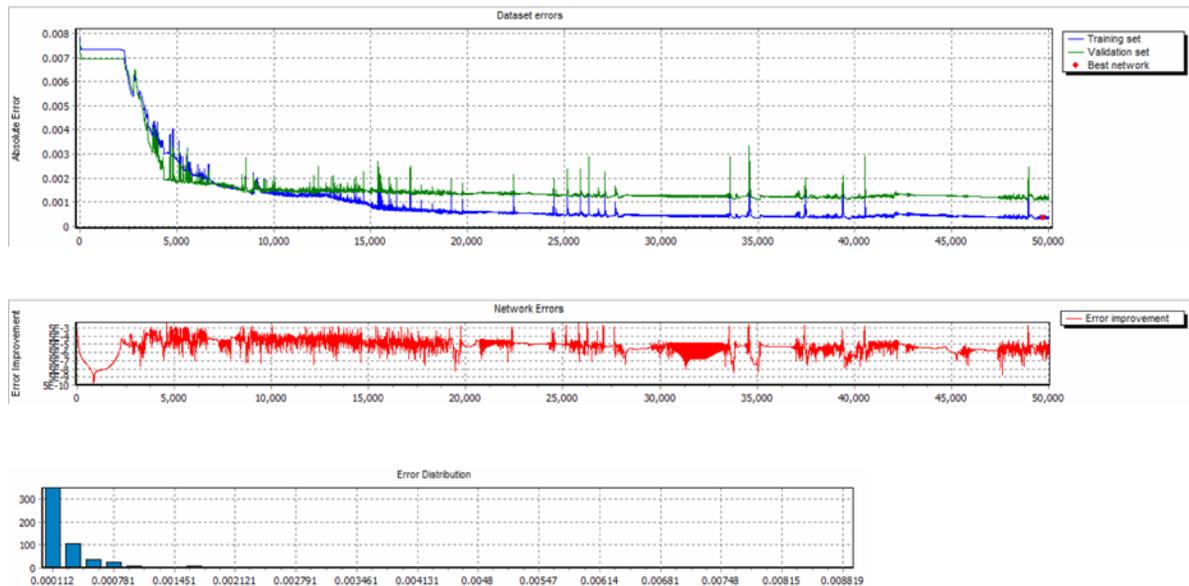
* Input Layer - Hidden Layer 1 - Hidden Layer 2 - Output Layer

Table 3. Summary of the top 34 networks systems after structure search

A new series of neural-networks training was performed with top 22 network structures. A total of 405 data sets were used as training data, including three different spindle speeds, feed rates, and depths of cut with five different tool conditions. A back-propagation learning algorithm was used for the network learning algorithm. Learning rates and momentum values for each neural-networks were arranged by the negotiation of the speed of convergence and the prevention of divergence during the training. The iteration number for training was set at 50,000 and each structure was trained four times. This setup helped to ensure that the learning results avoid a local solution, which is a false response of neural-networks during the process of node weights adjustment in the training.

During the training iterations, the convergence of the system was checked by monitoring the system training error, error improvement, and error distribution. Figures 2 show an example of training and its monitoring process. The test results show the successful convergence of the all 22 networks systems with high R-squared scores, the range between 0.831101 (networks ID: 150) and 0.996173 (networks ID: 245), which indicated that the tool conditions used in training procedures

can be explained by the input variables up to 99.61%. However, the result could be from the learning characteristic of neural networks and does not always indicate the prediction capability of the network structures. Therefore, the prediction capability of the networks structures was tested with the test data set not used in the process of training. The 22 network systems were able to explain the test data set with an accuracy range between 73.65% (network 150) and 87.78% (network 245). From its higher accuracy, network 245 (7-23-8-1) was nominated as the best structure for the ANN-TCM system in this study.



Correlation: 0.998130, R-squared: 0.996173, Training time: 0:50:50

Figure 3. Summary of training results of networks 245 (7-23-8-1)

Results and Conclusion

With the selected network structure, a test was performed based on the criterion of detecting the rejecting tool condition (0.00787” [0.2 mm] or bigger), which could practically be adopted as a “STOP-GO” tool in the real manufacturing. The developed ANN-TCM system successfully predicted 146 tests out of a total of 151. From the 62 “sharp tool” tests, five samples were predicted as a “worn tool” (five Type II errors). Within the 89 “worn tool” tests, zero samples were predicted as a “sharp tool” (zero Type I errors). Overall the developed neural networks prediction model can identify the tool condition with 97% accuracy.

For the further study, enlarging the number of machining parameters, tool conditions, types of insert tool, and types of workpiece is recommended. Increased numbers of hidden layers and nodes of ANN system are also recommended with high computational power.

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Safety



Globalization of Technology

Imagine the Possibilities!

Incorporating Health and Safety into a Senior Capstone Course: Critical Exposure for Future Industrial Leaders

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Abstract

Many National Association of Industrial Technology accredited programs rely, in part, on senior-level capstone projects for the development of students as future industrial leaders. Most senior capstone projects focus on the student's academic major such as manufacturing, electronics, and industrial management providing important practical work experiences. Few capstone courses include a rotation in the Health, Safety, & Environmental Department. This paper serves as a petition to include exposure to safety and health in each student's capstone experience. It outlines the unique benefits of spending time in the HSE Department.

Introduction

One of the crucial elements necessary for a successful organization is effective leadership and management. Leadership is often described as the process of inspiring others to work hard to accomplish tasks (Schermerhorn, 2004). Management has been defined as the process of getting things done, effectively and efficiently, through and with other people (Robbins and Decenzo, 2001). Management is commonly referred to as a process consisting of four basic components: planning, organizing, leading, and controlling. Many National Association of Industrial Technology (NAIT) accredited programs rely, in part, on senior-level capstone projects for the development of students as future organizational leaders. Traditionally, these capstone courses incorporate an industry-based internship, cooperative education experience, or some other type of industry-based project. Hands-on experience allows students to better comprehend the theory discussed in the classroom. This integration of theory and practice is especially critical for industrial technology programs emphasizing the application of technical and management skills. Students with this type of real world experience are more successful in obtaining that all-important first job after college. This capstone experience typically revolves around the student's major area of study, whether that is manufacturing, industrial management, electronics, or occupational safety. The purpose is to provide the future leader an opportunity to develop and practice their technical and management skills in an industrial setting. Another purpose of this capstone experience is to allow the student the opportunity to cultivate relationships while forming a "big picture" of the organization.

An often overlooked opportunity of this capstone experience is providing these future leaders a chance to develop an understanding of the "big picture" of the organization that includes managing aspects of workplace safety. One of the best areas of an organization to develop vital management skills is the organization's Health, Safety, and Environmental (HSE) Department. Unless the student is majoring in occupational safety, it is uncommon for the student to encounter more than a cursory exposure to the management of workplace safety and health.

This paper will serve as a petition for the deliberate inclusion of a "tour of duty" in the organization's HSE Department as a required component of each student's capstone experience. This paper will outline the unique benefits of spending time in the HSE Department. HSE managers are compelled to develop effective management skills especially in the area of leading or leadership. For example, HSE managers are responsible for motivating employees who are not under their direct supervision. Perhaps more importantly, HSE managers are responsible for coordinating and motivating other managers to accomplish their HSE objectives. As part of their capstone experience, students will learn how to motivate employees without the use of enforcement (discipline). Another benefit is the development of an understanding of worker behavior and how a leader can use this understanding to improve the organization. Students will develop an applied understanding of what can prompt a worker's behavior (antecedent) and what can encourage and maintain desired behavior (consequences). Finally, these future leaders will have a hands-on opportunity to develop a personal

understanding of the importance of employee safety and establish safety as a true organizational value early in their professional career. In addition, this paper will describe the efforts of an industrial technology program with a range of academic majors in developing a flexible senior-level capstone course that attempts to directly incorporate experiences in safety and health for each student.

Development of Future Organizational Leaders

Organizations are groups of people working together to accomplish a goal. Management's role in the organization is to accomplish these objectives with and through these groups of people. Peter Drucker defines the ultimate test of management as organizational performance (Dessler, 2001). In order to accomplish the organization's goals, managers must plan, organize, lead, and control the work and the people in the organization. These four basic elements of the management process as described by Dessler may be defined as follows:

- Planning is setting goals and objectives, establishing strategies to meet these goals, developing rules and procedures to coordinate activities necessary to meet these goals.
- Organizing involves identification of the specific tasks, deciding who should do these tasks, how these groups are organized, delegating authority and coordination of work.
- Leading is influencing and motivating other people while accomplishing these tasks. Leading includes maintaining morale and resolving conflicts.
- Controlling is monitoring the performance of the organization by holding people accountable and providing necessary feedback and implementing corrective actions.

Successful organizations implement programs for the identification and development of future leaders. It's hard to believe that less than half of all employees with management responsibilities receive formal leadership training and development (Caudron, 2000). There are many examples of new college graduates being put in charge of people without the knowledge of how to manage them, or the newly promoted supervisor who has difficulty changing roles from peer to manager. Many new managers don't instinctively know how to manage. Management development is indispensable for improving managerial performance.

One vital objective of a senior capstone course is to prepare and improve the management skills of students in order to improve the performance of the organization where they work. Senior capstone courses should be designed, in part, to provide students broad experience through exposure to many different areas of the organization. This type of capstone experience allows the student to observe the application of management skills over a cross-section of the organization. The student is able to develop an overall appreciation or a "big picture view" of the organization. Sometimes when a manager works only in one area or department they develop tunnel vision that limits their ability to solve complex organizational problems and to comprehend the overall organizational objective. In addition, the student has the opportunity to cultivate relationships with people from a cross-section of environments. Few of these senior capstone programs include a rotation in the organization's HSE Department. Effective organizations and effective managers understand their responsibility with regard to the wellbeing of people in the organization. This omission is not intentional disregard of worker health and safety but perhaps due to a lack of understanding of safety management principles and techniques.

Effective Health, Safety and Environmental Departments

Everyone wants a safe and environmentally friendly workplace. When asked, managers often state that the wellbeing of workers is a top organizational value. Research and experience show that management plays a critical role in promoting safe and healthful work practices (Friend, et al., 2005). Management commitment to safety is an essential element of an organization's successful safety and health process. Maintaining a safe workplace has been shown to enhance an organization's global competitiveness and enables the organization to meet desired objectives (Goetsch, 2008). Safety and health, like other management activities, consists of planning, organizing, leading, and controlling.

The key to an effective safety process is the understanding that everyone has a role to play. Management is as responsible for managing safety as for managing productivity and quality. Workers are responsible for following the directions and accomplishing the tasks required by management safely. Obviously, management has responsibility for organizational safety and the HSE Department is a staff function similar to customer service, human resources, or purchasing. Staff functions serve as a resource to line management. They assist managers in accomplishing their

objectives more efficiently. This requires that the HSE Department assist management in setting safety objectives and developing strategies and procedures for meeting these objectives (planning). The HSE Department helps management with organizing and delegating authority to accomplish these safety objectives. The HSE Department supports management in their responsibility for leading this safety process. Finally, the HSE Department assists management in meeting their responsibility for ensuring the safe performance of the organization (controlling).

Typically, the HSE Department has no direct authority over line management; however, effective HSE Departments do have influence over line management. How can the effective HSE Department gain this influence? This influence is equivalent to leadership. Effective HSE Departments influence others in the organization to achieve safety objectives without direct authority. These effective HSE Departments provide a unique opportunity for future organizational leaders to observe and learn leadership as well as a chance to practice the other management principles of planning, organizing, and controlling.

Health, Safety and Environmental Department: Unique Capstone Experience

The HSE Department provides a unique situation for management development and as a result should be incorporated into each student's senior capstone experience regardless of academic major. No direct authority means that to be effective or meet safety goals established by management, the HSE Department manager must become a leader. Leading and influencing requires an understanding of people's behavior and motivation. In fact, a majority of safety efforts involve influencing behavior. A student in the HSE Department would have the opportunity to learn the essentials of behavior analysis.

Behavior can be influenced in two ways; by what happens before the behavior and by what happens after the behavior. Antecedents are things or events that happen before the behavior such as task instructions, training, or safety posters. Antecedents communicate information in an attempt to prompt behavior. Consequences are things or events that follow a behavior. Recognition for a job well done or a reprimand for not wearing proper safety equipment are examples of consequences. Antecedents without consequences have short-term effects. Antecedents get a behavior started, but only consequences maintain behavior. Consequences provide the key to influencing people's performance. Research shows that managers spend, on average, approximately 85% of their time delivering antecedents such as figuring out what to do, telling people what to do, or figuring out what to do because people didn't do what they were told to do (Daniels, et al., 2006). Although these are important activities, managers often spend far too little time delivering consequences (less than 15%). Effective HSE Departments recognize this and capitalize on this knowledge - a great lesson for future leaders.

Students in the HSE Department would be provided the distinct opportunity to learn and practice leading people without the benefit of direct authority. For example, how can the HSE manager influence the use of required safety eye protection without the singular threat of discipline? Successful HSE Departments can show the student how to analyze, diagnose, and correct problem behaviors. Students would get a chance to determine the antecedents and consequences for a particular behavior and learn to develop alternative consequences that are positive, immediate, and certain. For example, the student may discover that workers are not wearing safety glasses because they are uncomfortable or perhaps the cabinet where the glasses are stored is some distance from their workstation. The student may recommend purchasing adjustable glasses to ensure greater comfort and relocating or getting a second storage cabinet for convenience. These positive, immediate, and certain consequences may influence the use of safety glasses. This may be an over-simplified example but the point is the student would need to understand how to motivate and influence the behavior of workers by using behavioral analysis across the organization without being their direct supervisor.

Another unique learning opportunity offered by the HSE Department is developing an appreciation of the responsibilities of the frontline supervisor. Effective HSE Departments understand that a key individual in the organization's safety effort is the frontline supervisor. Effective leaders master the skill of motivating and influencing these supervisors. Supervisors are the first level of management representation. Their job is to ensure workers carry out management instructions in an efficient and safe manner. HSE managers cannot usurp this supervisory responsibility by becoming the enforcer of safety rules. The role of enforcement, including safety, belongs to the supervisor. Organizations that rely on the HSE Department to enforce safety are not as effective. The HSE staff can't be in every department watching each process - that's the job of the supervisor. The supervisor is responsible for ensuring the task is accomplished safely. The effective HSE manager learns to motivate supervisors to enforce safety in their areas. The HSE manager relies again on behavior analysis. Supervisor behavior can be influenced by consequences just as employee behavior. Successful safety efforts

utilize positive consequences for supervisors. For example, job performance measures can be developed for encouraging supervisory enforcement of safety rules. The student would have the opportunity to observe the practice of influencing the behavior of peer managers, another valuable lesson for a future leader.

A tour of duty in the HSE Department also provides the student an opportunity to interact with top management on critical issues. The effective HSE manager becomes proficient at communicating with and influencing top management. Successful safety efforts require management commitment and involvement. The student will have the opportunity to observe and practice developing and recommending programs for management approval. Learning how to win management support is another valuable lesson for future leaders.

Finally and most importantly, the student will have an opportunity to develop a personal understanding of the importance of organizational safety. Unfortunately, the student may have the occasion to observe or handle an injury incident. Being exposed to the impact of an employee injury and the burden on the employee's family can be sobering. This personal understanding of the significance of safety will enable the future leader to develop an appreciation of safety as a true organizational value. The student will also be exposed to the financial impact of poor safety on the organization. This "big picture" view of the impact of safety on the organization will better enable the future leader to solve complex problems encountered later in their career.

Implementation Efforts

One NAIT accredited program has made an attempt to incorporate safety and health activities in each student's senior capstone experience. This industrial technology department serves approximately 200 students in four different academic majors: electronics, occupational safety and health, industrial management, and manufacturing systems. In their final semesters, students complete either an industrial internship or an industrial project. These internships and projects are completed at various manufacturing facilities in the local area. Each student works individually (not a team project) and completes a minimum of 100 industry-supervised hours.

The student completes this internship or project in his or her area of academic major. There is an additional requirement to incorporate safety and health into the experience. Preferably, the student works with the HSE manager for a short time. This allows the future industrial leader the opportunity to gain first-hand direct experience in safety and health. If working with the HSE Manager is not possible, the student is required, with the assistance of their faculty advisor and internship supervisor, to identify and participate in a safety and health related activity at the manufacturing facility. These activities may include a range of safety issues, such as conducting safety inspections, developing and conducting safety training/meetings, or simply identifying and controlling hazards at their facility. At the completion of the capstone experience students are required to submit a written report and make a formal presentation on their internship. This report and presentation includes a "lessons learned" in the area of safety and health.

Conclusion

Effective management is essential for the success of an organization. Senior capstone courses are important in the development of students as future leaders. The HSE Department provides a unique opportunity for students to observe, learn, and practice management skills. A tour of duty in the HSE Department provides the student opportunities to develop technical, conceptual, and human skills while interacting with employees, supervisors, and top management. During the capstone experience the student will be exposed to technical or job-specific skills based on their academic major. These job-specific skills will be critical in the early stages of the new leader's career. In addition to these technical skills, new graduates will have an understanding of technical safety issues and behavioral analysis skills. The development of conceptual skills learned in the HSE Department will have long-term advantages for the new leader. The span of control of the HSE Department covers the entire organization and as a result a rotation in the HSE Department exposes the new leader to all aspects of the organization. This expansive coverage provides exposure to a variety of problems and gives the new leader a unique opportunity for developing the ability to solve complex problems. Most important, is the opportunity to develop human skills. The student will learn how to handle people at all levels of the organization. The new leader will learn to motivate employees to act safely. They will master the art of influencing supervisors to enforce safety. They will learn to communicate effectively with top management in order to build support for organizational safety. Lastly, the student will have the opportunity to develop a personal sense of value for safety that will produce future leaders with a distinctive outlook on the role of top management and the organization's safety

effort. I strongly petition the inclusion of a tour of duty in the Health, Safety, and Environmental Department for all future organizational leaders in their senior capstone experience.

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