NAIT 2006 Convention Proceedings

Review Process & Statistics for Selected Papers

This CD-ROM of the *NAIT 2006 Convention Proceedings* is the result of the work of many authors in technology and technology management programs throughout the United States who gathered to share their work at the 2006 NAIT Convention, "Linking the World Through Technology," in Cleveland, Ohio, November 15-18, 2006. The *NAIT 2006 Convention Proceedings* includes the *2006 Convention Selected Papers*, the convention presentations that were accepted for publication after being submitted in expanded form as complete papers for peer-review. This PDF document contains only these papers and does not include the one-page presentation abstracts.

The *NAIT 2006 Convention Presentation Abstracts* were subject to a double-blind peer review process. In 2006, the peer-review process led to acceptance of 67% of presentation proposals (194 accepted of 290 proposals submitted).

The *NAIT 2006 Convention Selected Papers* went through a similar process. Authors of accepted convention presentations were invited to submit expanded versions of their presentations and the *Selected Papers* were chosen after a double-blind peer review process, with panels of at least three reviewers involved in reviewing each submission. In 2006, of 194 accepted convention presentations, 53 were expanded into longer papers and were submitted for the peer-review process. The double-blind peer review process led to acceptance of 38% of the papers submitted, for a total of 20 "Selected Papers 2006." These 20 *NAIT 2006 Selected Papers* represent just 10.3% of the proposals accepted for presentation at the 2006 NAIT Convention, and only 6.9% of proposals submitted.

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Linking the World Through Technology

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2007 SELECTED PAPERS

NATIONAL ASSOCIATION INDUSTRIAL TECHNOLOGY
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ADMINISTRATION

Accreditation Case Study: From Charge to Delivery

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Introduction

Each year additional institutions are choosing to undergo program accreditation. Accreditation by a recognized agency adds value to degree programs and serves as a vehicle for continuous program improvement and recognition. Increasingly, programs are considering accreditation by the Board of Accreditation of the National Association of Industrial Technology (http://www.nait.org/). Faculty and administrators of associate or baccalaureate degree programs new to the accreditation process can benefit from this case study of a recent initial NAIT accreditation. This presentation discusses activities undertaken by the Department of Computer Graphics Technology (http://www.tech.purdue.edu/cgt/), housed in the College of Technology (COT) at Purdue University, to achieve a successful accreditation recommendation. The experiences of the department in pursuing initial accreditation of the baccalaureate degree program in Computer Graphics Technology (CGT) can be generalized to any program choosing to undergo NAIT accreditation.

Context

Purdue University (http://www.purdue.edu/) is a state-supported, land-grant institution enrolling approximately 38,650 students at the West Lafayette campus and an additional 30,000 students at its regional campus and statewide technology locations. The University is organized into 12 undergraduate colleges/schools including Agriculture, Consumer and Family Sciences, Education, Engineering, Health Sciences, Liberal Arts, Management, Nursing, Pharmacy and Pharmaceutical Sciences, Science, Technology, and Veterinary Medicine. The COT (http://www.tech.purdue.edu/) enrolls approximately 5,000 undergraduate students within eight departments including: Aviation Technology; Building Construction Management; Computer Graphics Technology; Computer and Information Technology; Electrical and Computer Engineering Technology; Industrial Technology; Mechanical Engineering Technology; and Organizational Leadership. According to the COT strategic plan, all eight departments are charged with achieving accreditation by 2007 or undergo a self-study equivalent to the accreditation process. As a newly appointed department head, the author discovered that CGT was one of the two COT programs not accredited. It was also the author's opinion that program review was not an option if an appropriate accreditation agency could be identified. The first step in the program's accreditation journey was determining the appropriate accreditation agency.

Determine Accreditation Agency

Although the author had previous experience with accreditation, the process was completely new to the CGT department. The CGT department (formerly the Department of Technical Graphics) had a long history of teaching engineering graphics and illustration technology as a service program and as a degree program offered at the associate level. However, the Department of Computer Graphics Technology that emerged from the former department only recently developed a baccalaureate degree program in CGT. This history and the indecision as to an appropriate accreditation agency for the program caused the delay in the department achieving the COT accreditation goal.

Programs at Purdue in fine arts are accredited by the National Association of Schools of Art and Design (http://nasad.arts-accredit.org/). Knowing NASAD accredits liberal arts-based studio programs, that agency was judged inappropriate for CGT. Purdue programs in engineering and technology are accredited by the Accreditation Board for Engineering and Technology (http://www.abet.org/) under the ABET accreditation commissions. The Computing Accreditation Commission (CAC) was judged inappropriate for CGT, but was selected by the COT Computer and Information Technology degree program. The Technology Accreditation Commission (TAC) was also judged to be inappropriate for CGT, but accredits the COT degree programs in Computer and Electrical Engineering Technology and Mechanical Engineering Technology.

The COT degree program in Industrial Technology (http://www.tech.purdue.edu/it/) has been accredited by NAIT for years. The CGT program at Purdue is a technical managerial degree program similar to Industrial Technology, but with the specific mission of preparing visually oriented students for careers in creating and managing the production of computer

graphics within a wide range of industries. The CGT baccalaureate program combines elements of the disciplines of art, science, and technology in focusing on applications of visual information. Students develop knowledge and skills in areas such as interactive multimedia development; animation and spatial graphics; virtual product design graphics; or architectural and construction graphics technology. Alumni enjoy careers and are successful in a wide range of settings in business, industry, and education. Based on analysis of the mission of the CGT degree program, NAIT accreditation was judged fitting.

Conduct Initial Self-Study and Consultant's Visit

The NAIT Board of Accreditation provides several resources to help programs prepare for accreditation including an Accreditation Handbook, a PowerPoint presentation of the accreditation process, a cadre of approved accreditation consultants, and accreditation training. We found the Handbook (http://www.nait.org/accred/accreditationhandbook2003.html) clearly delineated the accreditation process; the accreditation standards to be addressed; the format of the self-study; and the on-site visitation procedures. It included other very helpful information as well. The department sent faculty and professional staff members to accreditation training sessions held at yearly NAIT conventions. A preliminary self-assessment of the program's perceived compliance with the accreditation standards was conducted. CGT determined that much of the evidence needed to show compliance with standards had already been in place for several years. For example, the department had a recently developed strategic plan identifying the mission of the program, its long-range goals, and target metrics for achieving the program's objectives. The department had been collecting student follow-up information, had a well-structured and active industrial advisory committee, had ample documented resources including faculty and budget, and many other items specified in the accreditation standards. Most important, preliminary analysis of the curriculum revealed the program would meet the "Minimum-Maximum Foundation Requirements" for accreditation consideration (NAIT Accreditation Handbook, p. 26).

The department then arranged for a NAIT-approved accreditation consultant to study the existing documentation, visit campus, and make a recommendation report concerning CGT's perceived fit for NAIT accreditation including a suggested list of pre-accreditation activities and time frame for making accreditation application. Although this step was an additional expense, it was well worth the cost because the consultant's visit helped the program focus on the task at hand. The consultant asked for information similar to what is required in the accreditation self-study prior to a campus visit. A two-day campus visit was conducted that helped prepare the faculty, staff, students, and advisory committee for what the actual accreditation team campus visit would be like. The consultant wrote a concise report submitted to both the department and the NAIT Executive Director making key observations, preliminary analysis of compliance with standards, identification of issues needing to be addressed, and a positive recommendation for the program to proceed with candidacy for NAIT accreditation. It is our observation that the time and expense of including a consultant was extremely worthwhile. It prepared the department for the accreditation process and helped in identify items needing attention. As a result, CGT was able to move ahead with the accreditation self-study and accreditation team campus visit on a relatively short time line.

Address Perceived Areas of Concern

As a result of the preliminary work preparing for the consultant, the campus visit, and report, several areas of concern were identified regarding the CGT program's accreditation candidacy. Solutions were informally discussed during the visit and others were included in the consultant's report. Sample items of concern included: the number of doctorate-holding faculty in the program; the need for additional data on placement of graduates and student evaluation of the program; the recommendation to expand the advisory committee's roll in competency identification and validation; and the need to document an assessment program including program development, revision, and evaluation documentation. A plan of work was developed to address these concerns.

A staffing plan was developed to increase the number of CGT faculty members holding doctoral degrees. New job descriptions were developed and advertised, resulting in the hiring of additional doctorate-holding faculty members. A new follow-up study instrument was created and administered to recently graduated alumni to collect additional job-placement and program-satisfaction data. Additional currently enrolled student program evaluation instruments were developed and administered including a survey administered in a senior capstone course and exit interviews of graduating seniors. Membership on the CGT industrial advisory committee was restructured to include student members and additional alumni and potential employers of graduates. A program competency inventory was compiled by the department's faculty and curriculum committee. Two additional industrial advisory committee meetings were scheduled where a program competencies validation process was conducted and additional program development, revision, and evaluation feedback were documented. With these accomplishments, CGT decided to proceed with NAIT accreditation and start preparing the self-study.

Developing the Self-Study Report

The next step in the accreditation preparation process was the writing of the self-study. A self-study coordinator developed a plan of work needed to document the program's compliance with the 62 standards identified in the 2003 Accreditation Handbook. Sections of the report were assigned to key faculty and staff members and information was solicited from appropriate support personnel in the college and university. As sections of the report were completed, the coordinator

edited the writing, providing the consistency needed for work completed by multiple writers. Writers were provided a template including the standard statements from the accreditation handbook typed in bold similar to the following:

> **6.3.1 Program Name: Each major program and/or program option shall have appropriate titles (titles such as business, engineering, or education that imply the focus of the program is in a related field of study are not appropriate).**

Directly following each standard statement, the contributor wrote succinct 1- or 2-paragraph statements providing evidence of the program's compliance. When more extensive evidence was needed, additional documentation was included in the report's appendix section. In actuality, the self-study appendix section, including appropriately labeled tabs to help the reader find documentation, accounted for almost 75 percent of the self-study report. Drafts of the report were reviewed at several department faculty meetings and a meeting of the program's industrial advisory committee and were published to the CGT Web page as seen at the following location: (http://www.tech.purdue.edu/Cgt/documents/NAIT_Self_Study.pdf).

Association guidelines require programs to submit a request for accreditation three months prior to a desired campus visit giving NAIT time to assign the visitation team chair and members. The visiting team assigned to CGT was identified two months prior to the visit, allowing ample time for the program contact person and the team chair to agree upon the campus visit schedule. The last step in preparing the self-study report was the development of a detailed agenda including individuals and groups to be interviewed during the campus visit. CGT express mailed a package to each team member that included a hard copy and a CD of the self-study including appendices 30 days prior to the campus visit. Upon confirmation of team members receiving the self-study materials, the department started preparing for the campus visit.

Preparing for the Campus Visit

Preparation for the campus visit began early in the school year before the self-study was started. CGT faculty teaching courses required in the major under review were charged with developing course notebooks including the detailed syllabi, example instructional materials, samples of student graded work, and other evidence documenting the program's compliance with accreditation standards. Faculty provided examples of the course textbooks and references placed on display in a faculty office dedicated to accreditation documentation. Arrangements were made for meeting rooms, meal events, telephone and Internet communications, and other items needed to support the visiting team. It was important to schedule meetings weeks in advance to ensure people such as the Provost, Dean, and other busy administrators would be available for the visit. Individuals scheduled to meet with the visiting team were either supplied sections of the self-study or were briefed in person to explain that the purpose of interviews during the campus visit is for the team to confirm evidence reported in the program's self-study regarding compliance with the standards. Arrangements were made for the team to meet with faculty, students, alumni, employers, industrial advisory board members and other key personnel. Actually, the date of the campus visit was arranged to coincide with the CGT Industrial Advisory Board's spring meeting to provide the visiting team ample opportunity to observe a meeting and interact with the CGT Board members.

Hosting the Campus Visit

The three-member accreditation team arrived at Indianapolis Airport about an hour away from campus on Wednesday afternoon of the visit and arrived on campus to check in at their accommodations at the University hotel located close to the COT facility. The first evening of the visit consisted of introductions and orientation discussions conducted at a dinner meeting on campus. Thursday (the first full day of the visit) included an intensive schedule of activities where the team met as a group and individually with a wide variety of individuals and groups on campus including most key administrators, department faculty, and students. On Friday, the team met with the CGT advisory board, completed other needed interviews, continued reviewing materials in the documentation room, and prepared for the exit report. It is important to recognize the extensive preparation of the visiting team and their extreme professionalism in conducting the visit on behalf of the Board of Accreditation.

The exit report is the culminating activity after all the hard work on the part of the program and the visiting team attended by key university administrators and program faculty. After briefly discussing the NAIT accreditation process, the visiting team chair presented a list of standards found in compliance, partial compliance, or in non-compliance. The chair also reported the team's accreditation status recommendation being made to the Board of Accreditation that could have included the recommendation for accreditation, accreditation with a progress report, accreditation with a progress report and a follow-up visit, or non-accreditation. CGT was found to be in compliance with 90 percent of the standard, in partial compliance of six standards, and had no standards found in non-compliance. The team recommendation was for accreditation.

Post Visit Activities

Within two weeks of the visit, the visiting team chair had the responsibility of compiling and editing the team's draft report that was sent to CGT to review for factual errors. The team chair had 45 days from the visit to file the final report with the NAIT Executive Director and the University President.

At last, it is the day of reckoning, the day of the Board of Accreditation hearings. Each program being considered for initial accreditation, re-accreditation, or needing to present a progress report is placed on the agenda for the NAIT Board of Accreditation meeting traditionally held on the Wednesday of the yearly association conference. The meeting is conducted by the Chair of the Board of Accreditation and includes the voting members made up as follows:

- University Division: 6 members (1 from each NAIT Region)
- Community College and Technical Institute Division: 6 members (1 from each NAIT Region)
- Industry Division: 6 members (1 from each NAIT Region)
- Student Division: 1 member
- Lay Public: 3 members
- Program Sponsors: Up to 3 members

The meeting room is set-up in an inverted "u" shape with the voting members along the sides. The Board Chair and a recording secretary are at the head of the setting. A table with chairs is set up at the opposite end of the meeting room where the visiting team chair and personnel from the program under consideration sit. As each program is called to the candidate's table, board members having a conflict of interest remove themselves from deliberations. After the visiting team chair and the program's accreditation coordinator make brief opening remarks, appropriate motions are made by Board members, discussions take place, and votes are taken, resulting in official actions regarding accreditation. In the case of the positive actions of accreditation, accreditation with a progress report, and accreditation with a progress report and follow-up visit, program personnel are congratulated at the meeting and sent a formal letter within 30 days. After the positive accreditation outcome, the NAIT list of accredited programs is updated and the program can publicize its NAIT accreditation.

Summary and Conclusion

Accreditation is an important value-added measure for a degree program. Most individuals experienced with the accreditation process feel that the journey is almost as important as the positive outcome. It is important to send members of the program for accreditation training to understand the process. It is helpful to have an approved consultant to help focus the task at hand. It is important to have wide participation to assure a timely and successful outcome. The many activities needed in data collected and used for the constant program improvement resulting from the accreditation journey require much work. The reward is in the accomplishment. Initial accreditation runs from the date of the Board of Accreditation meeting for four years. Re-accreditation is for a period of six years.

Recommendations

Based on the experience of the CGT program going through initial accreditation, the following recommendations are made for other programs considering pursuing accreditation:

1. Carefully evaluate the fit between the program and the accreditation agency.
2. Examine and use the resources made available by the accreditation agency.
3. Conduct an initial self-assessment of the program's compliance with accreditation standards.
4. Employ an accreditation consultant and conduct a mock accreditation review and visit.
5. Develop a well-thought-out plan to divide the tasks needed for accreditation documentation and to manage the progress.
6. Write succinct responses to the standards using the required format.
7. Place details in appendices.
8. Develop a complete set of course documentation notebooks.
9. Schedule needed resources for accreditation visit including people and facilities well in advance.
10. Brief all who will be involved in the accreditation visit to campus.
11. Develop a good working relationship with the visiting team chair and committee members.
12. Keep internal schedule on track while maintaining a positive attitude regarding the accreditation process.

Table 1: CGT Accreditation Time-Line	
Accreditation Activity	Completion
Hired New Department Head	July 2004
Investigated Potential Accreditation Agencies	Summer 2004
Made NAIT Accreditation Decision	September 2004
Attended Accreditation Training	October 2004
Conducted Consultant's Review	November 2004
Reviewed Consultant's Recommendations	December 2004
Restructured Advisory Committee	January 2005
Conducted Outcome Validation Study	February 2005
Revisited Student Follow-Up Data Collection	March 2005
Conducted Advisory Committee Curriculum Review	April 2005
Developed Self-Study Report	Summer 2005
Conducted Student and Advisory Board Review of Self-Study	October 2005
Edited Self-Study	December 2005
Prepared for Campus Visit	February 2006
Conducted Campus Visit	March 2006
Reviewed Team's Draft Report	April 2006
Received Team's Final Report	June 2006
Attended Board Hearings	November 2006

Assessment of Experiential Learning for Technology Students

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Introduction

Assessment of academic programs has been getting significant attention for over the past ten years with the focus primarily on outcomes and measures or indicators. "'Left to our own devices, we pay too much attention to things of too little importance to the customer' – illustrates the predicament that higher education finds itself in." (Seymour, 1995) Assessment of university programs significantly varies even though in the end, they meet the required needs of various accrediting bodies. Institutional effectiveness and assessment cannot be successful unless the academic programs take responsibility for all aspects of assessing their programs (Nichols & Nichols, 2000). Experiential learning opportunities, whether required or not, play a significant role in many academic programs related to fields in technology. The variability regarding the types of experiential learning, the frequency of assessment or the input used for experiential assessment may be attributed to the history of a program, an overall casual approach to experiential learning by faculty, or the lack of structure in implementation of a program. Whatever the reason, it is important to realize that it is as essential to assess these types of learning opportunities just as it is in a "formal course." Assessment must not only be documentation in a report, however it must be acted on and utilized as an integral part of continuous improvement and program accountability (Soundarajan, 2004). This paper will provide direction to identify measures for experiential learning for application in successful overall program assessment.

Assessment of learning starts with values (Mercer, 2006). Technology-related programs have traditionally identified themselves as application-based or constructivist theory-based. Experiential learning can be defined in loose terms as 'learning by doing' or as specific as "the process of actively engaging students in an authentic experience that will have benefits and consequences. Students make discoveries and experiment with knowledge themselves instead of hearing or reading about the experiences of others. Students also reflect on their experiences, thus developing new skills, new attitudes, and new theories or ways of thinking" (Wikipedia, 2006). It can take the form of many different types of experiences including Internship, Practicum, Co-op, Service Learning, or Study Abroad. The National Society of Experiential Education has identified eight standards of good practice for all types of experiential learning activities. These include Intention, Preparedness and Planning, Authenticity, Reflection, Orientation and Training, Monitoring and Continuous Improvement, Assessment and Evaluation, and Acknowledgement of Learning and Impact (NSEE, 1998). Each of these practices plays a role in assessment of experiential learning.

There is not one assessment plan or instrument that is mandated for experiential learning. Continued success of any program, in this day of budgetary confinements and accountability, must rely on regular measures that must contribute to the overall academic program assessment. Traditional courses, whether delivered online or face-to-face, have measures that include tests, peer-reviews, assignments, and other cognitive measures. Many of these measures may not be appropriate for some experiential learning activities. To measure what a student has done or could do based on accomplishing the learning outcomes should be best assessed by behavioral change and performance and attitudinal assessment methods (Nichols & Nichols, 2000). Perhaps one of the most powerful forms of behavioral assessment is to gather information from alumni. Reflection, documentation of employment, attitudes, values, and perceptions are very powerful. Alumni can also document performance measures based on their positions, experience and success. Utilizing behavioral change and performance measures takes effort to locate individuals and persistence for regular implementation. Attitudinal surveys can also be

very beneficial to programs concerning students' and employers' attitudes regarding the discipline, the academic program, preparation, and the institution (Nichols & Nichols, 2000). Experiential learning outcomes can be assessed best through these methods. To illustrate how these assessment measures can be used, a case study utilizing them will be discussed. As referred to earlier, there are many different types of experiential learning that would be beneficial to Technology-related programs. All of them contribute to the basic values espoused by the development of these programs from the early 1900's. One of the most common types of experiential learning is cooperative education. With roots in apprenticeships, cooperative education seems to be more valuable today than ever based on some assessment data documented in the literature. "Survey after survey tells us that the recruitment of co-op students is part of the strategic hiring practices more and more common among employers." (Zimpher, 2005, p.32) Cooperative education is "a structured educational strategy integrating classroom studies with learning through productive work experiences in a field related to a student's academic or career goals" (National Commission of Cooperative Education). Since Herman Schneider created the cooperative education program in 1906 at the University of Cincinnati, many higher education institutions have developed their own cooperative education programs to allow students to apply the knowledge they learned in the classroom to a "real-life" work environment. Researchers have conducted studies over the past century to analyze the outcomes that cooperative education has on the student. As part of the research conducted, Fletcher (1991) created a model that summarizes the outcomes of cooperative e*ducation into three areas: personal development, career development, and academic achievement.* To illustrate the use of assessment in an experiential learning program, a case study involving measures of behavioral change and attitudinal assessment is documented.

Case Study of Assessing Cooperative Education Learning Outcomes

Since 1968, approximately 12,000 Bowling Green State University students have been placed in cooperative education experiences in areas related to technology. In 2005, a study was conducted to identify the impact that cooperative education had on the College of Technology, Bachelor of Science in Technology graduates who participated in the required cooperative education experiences (Bloomfield, 2005). A behavioral change and attitudinal assessment survey was developed based on the learning outcomes of the College of Technology Cooperative Education program and a review of literature. The survey was e-mailed or mailed to 773 College of Technology graduates from 2000 through 2004. Approximately 22% of the graduates responded to the survey providing information on the impact of cooperative education. The information gathered from the survey provided demographic, employment-related, and behavioral change and attitudinal assessment information. As a result of this study, a revised list of comprehensive learning outcomes was created. Demographic and employment-related information showed that the graduates are career focused and have made informed career decisions. Overall, the behavioral change and attitudinal assessment showed favorable results regarding the impact of cooperative education on the College of Technology graduates from Bowling Green State University.

Assessment Survey

For this study, a cross-sectional survey was utilized to gather information from the College of Technology graduates. This survey (Appendix A) consisted of a series of selected-response and open-ended question in three sections to measure the impact of cooperative education on the College of Technology graduates. The first section included 18 demographic and employment related questions. The second section consisted of 29 statements about behavioral change and attitudinal change. The respondents indicated on a four-point Likert scale to what degree they agreed each statement applied to them. The third section included two open-ended questions for respondents to provide information on the most valuable lesson learned during their cooperative education experience and what recommendations could they provide to those currently in the program. There are two survey instruments that were created to collect data for this research, an electronic and mail survey. The layout of the mail survey was a duplicate of the electronic survey so that results were consistent. The graduates had approximately two weeks to complete and return the survey.

Discussion of Findings

The survey was sent to 773 College of Technology graduates from the classes between May 2000 through December 2004 either by postal mail or through e-mail. Based on the data collected in the survey, there are a number of observations that were made throughout the study. First, when comparing the number of respondents from the mail survey compared to the electronic survey, the overall response rate to the electronic survey was higher, 27.89% compared to 14.20%. Even with this difference in response rate, the respondents were similar enough that the groups could be combined. A total of 157 respondents completed the survey for a response rate of 21.75%.

Regarding demographic information collected, Table 1 summarizes the information provided on the respondents.

- The largest graduating class to respond was December 2003, representing 12.10% of the respondents.
- 73.72% were males and 26.28% were females, which is comparable to the current percentage of males and females in the college according to the College of Technology Office of Program Services.
- 16.67% were Associate Degree holders.
- 7.01% had already achieved a degree beyond their Bachelor's Degree.
- 98.08% are currently employed, while 1.92% are unemployed.
- 92.67% are working full-time, while 87.73% are working in a field related to their major.
- Approximately 29% made between $30,000 and $39,999 through full-time employment.
- 72.73% of those who worked part-time made less than $25,000.

Table 1. Demographics of Alumni Sample

As mentioned previously, there was employment-related information collected from the respondents. Regarding the employment-related information given by the respondents the following Table 2 is provided.

- 46.50% have had one job since graduation.
- 61.69% secured their first job before graduation.
- 35.14% had one interview before they accepted their first position.
- 55.10% interviewed with one company before they were offered their first position.
- Average hourly rate of pay for their TECH 489 co-op was $11.06. $32.00 was the highest and $4.25 was the lowest hourly rate of pay.
- 63.23% reported that co-op did assist them in finding current or previous employment. 50% of these respondents are or were employed by their co-op employer.

Table 2. Employment Related Findings of Alumni Sample

The behavioral change and attitudinal assessment component was the section that was developed to see if the learning outcomes of cooperative education were being met according to the respondents. There were 29 statements in this section that asked the respondents to indicate on a four-point Likert scale to what degree they agreed that each statement applied to them.

At least 54% of all respondents either strongly agreed or agreed with each of the statements. More than 90% of the respondents indicated they agreed or strongly agreed with four of the statements. These statements were, "My co-op experiences increased my ambition toward my career," "My co-op experiences increased my problem-solving skills," "My co-op experiences increased my interpersonal communication skills," and "My co-op experiences helped to develop my professional work habits." The statement that received the lowest response in strongly agree or agree was, "My co-op experiences helped me to develop a sense of purpose in life," with 54.42% of the respondents either strongly agreeing or agreeing. Appendix B summarizes the responses to the behavioral change and attitudinal assessment component.

It was also found in the study that many of the respondents (73.89% and 75.16% respectively) had comments to provide for the two open-ended questions in the survey. The first question asked the respondents to list the most valuable lesson they learned through co-op. The second question asked the respondents to provide recommendations for the current College of Technology co-op students. Many of the responses were closely related to the learning outcomes identified. Overall, the responses to these questions clearly displayed the attitude of the respondents towards cooperative education. Appendix C summarizes the responses to the open-ended questions by category.

Application of Research to Assessment

Gathering assessment information and reporting it may be the end of the utilization of this information. Much attention has been placed in the development of the measures, however less attention has been place into the utilization of the information in program improvement (Soundarajan, 2004). In fact, after the data is gathered, the real work begins. In this case study, information from the survey instrument was used to reevaluate the learning outcomes, thus affecting the cooperative education course. The list of current learning outcomes for the College of Technology Co-op program was very comprehensive and covered academics, professionalism, and personal attributes of cooperative education. Upon further research, there were additional learning outcomes included in the student learning outcomes list for this study. These learning outcomes only further completed the list from the College of Technology Co-op program. A revised list of

student learning outcomes was created based on the knowledge gained from this study. Appendix D displays the revised list of cooperative education learning outcomes.

Additional information documented by the case study must be used in the program and in student assessment. "Closing the loop" has been a term that has be identified in the literature as the ultimate use of assessment data. One approach to utilizing the data in a student assessment model is depicted in Figure 1. Not only is information gathered throughout a student's progress toward a degree, but also should be continued after graduation. Gathering information such as program review, self-assessment, university outcomes review, employment data, and attitudinal assessment is crucial to the complete assessment picture. Utilizing the information for continuous improvement is as important as gathering the information to begin with.

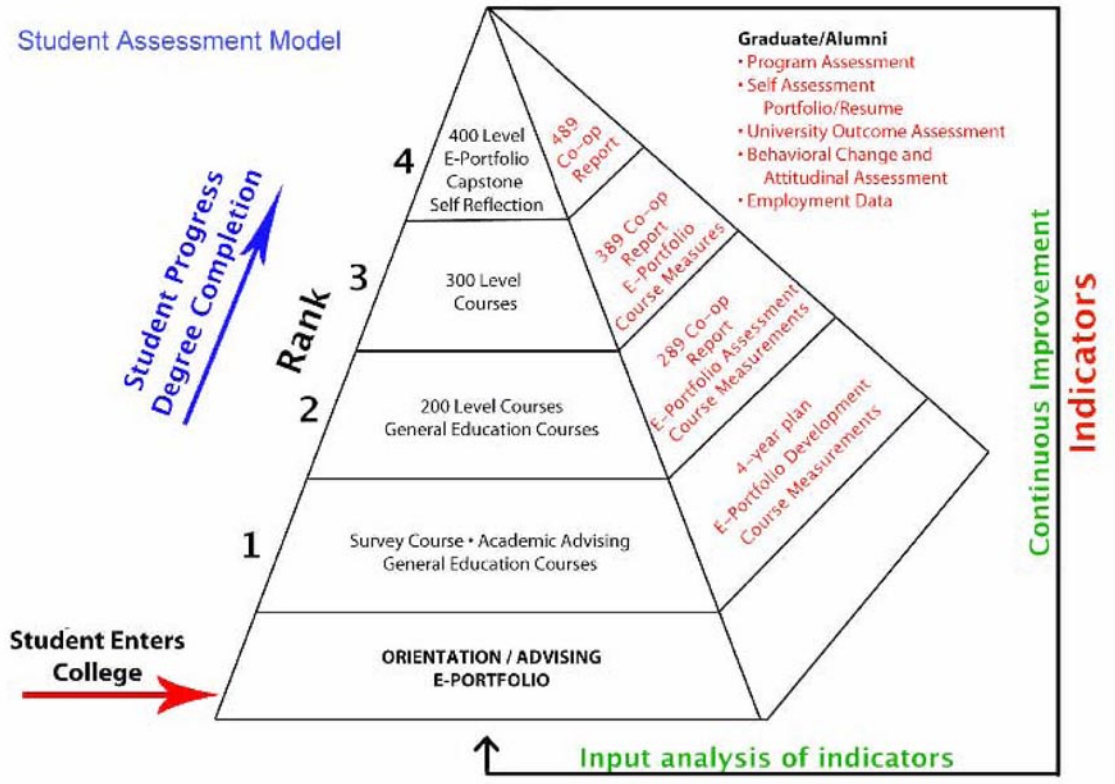

Figure 1. Student Assessment Model

Experiential learning is most effective when it is completely tied to the learning outcomes of a program. At times, faculty may not utilize the information gathered through experiential learning courses because they are not traditional courses. Because experiential learning courses are closely linked with learning theory, just as other courses are, the assessment information can expand the total educational experience. Figure 2 illustrates a program assessment model that takes into consideration the perspective of program development through program evaluation and how they feed off each other. Without a complete cycle, the model or target begins to show holes, weakening the program.

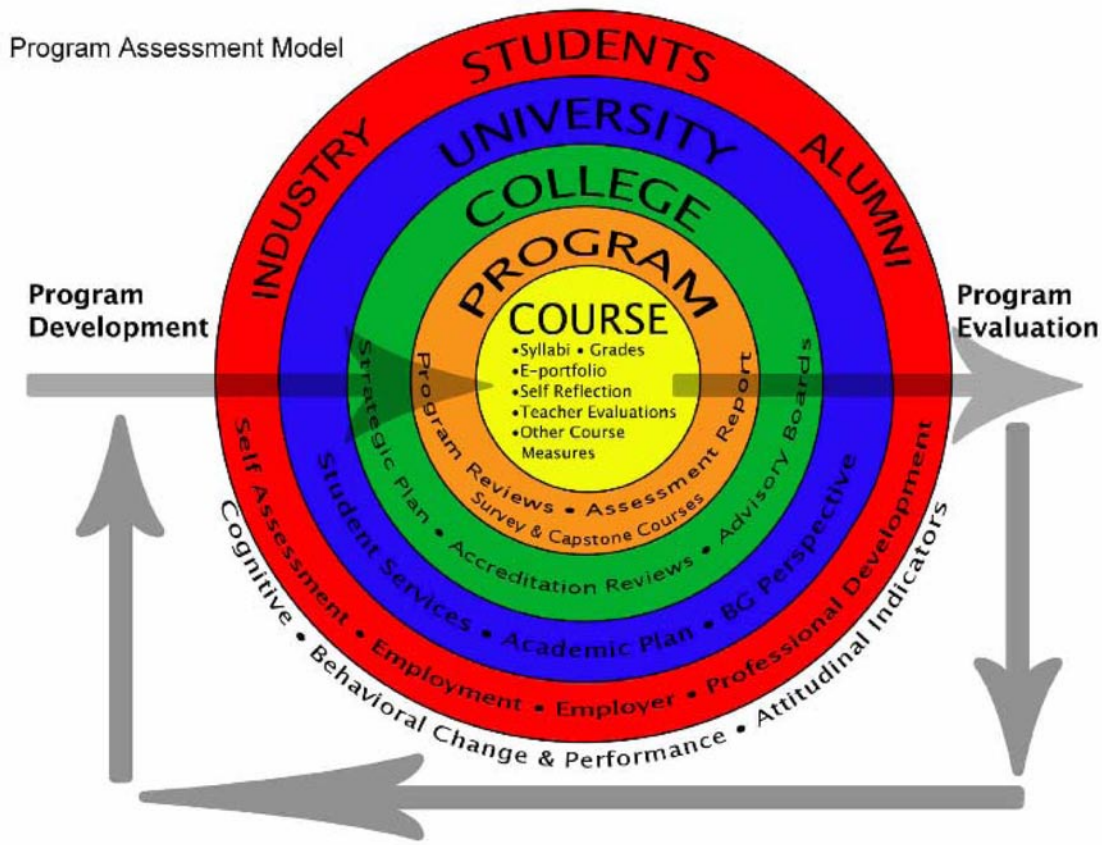

Figure 2. Program Assessment Model

Conclusion

Assessment only means something if the information is collected in a systematic, objective manner, the data is analyzed appropriately, and it is used to improve programs and the learning environment for all constituents. Assessing experiential learning components of any rogram, but especially technology-related programs, is essential and can provide behavioral change and attitudinal assessment input tha may be difficult to gather. These experiences should be a key par of program, department, college nd university asessment lan.

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APPENDIX A

Part I Instructions:

Please place a check mark beside the appropriate response to the following:

1. **Check the semester and year that you graduated from Bowling Green State University.**

Semester	Year
_____ May	_____ 2000
_____ August	_____ 2001
_____ December	_____ 2002
	_____ 2003
	_____ 2004

2. **Major.**

_____ Architecture/Environmental Design Studies
_____ Aviation Studies
_____ Construction Management and Technology
_____ Electronics and Computer Technology
_____ Mechanical Design Technology
_____ Manufacturing Technology
_____ Visual Communication Technology

3. **Gender.**

_____ Female _____ Male

4. **Did you transfer into the College of Technology with an Associates Degree?**

_____ Yes _____ No

5. **What is your level of education beyond your Bachelors Degree? Check all that apply.**

_____ I have already received a degree beyond my Bachelors Degree.
_____ I am currently pursuing a degree beyond my Bachelors Degree.
_____ I am planning on pursuing a degree beyond my Bachelors Degree in the future.
_____ I currently have no plans for pursuing a degree beyond my Bachelors Degree.

6. **How many different job positions have you held since graduation?**

_____ None _____ 1 _____ 2 _____ 3 _____ 4 _____ 5 _____ More than 5

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7. How much time after graduation did it take to secure your first position?

_____ Secured it before graduation
_____ Less than 1 month
_____ 1-2 months
_____ 2-3 months
_____ 3-4 months
_____ 4-5 months
_____ 5-6 months
_____ More than 6 months

8. How many companies interviewed you before you accepted your first position?

_____ 1 _____ 2 _____ 3 _____ 4 _____ 5 _____ More than 5

9. How many companies that you interviewed with offered you a position?

_____ 1 _____ 2 _____ 3 _____ 4 _____ 5 _____ More than 5

10. What was your hourly rate of pay for your TECH 489 co-op? $_____

11. Did your co-op experiences in the College of Technology assist you in obtaining your current or previous position(s)?

f you answer is yes, please answer and proceed to #12. If your answer is no, please skip to #13.

_____ Yes _____ No

12. Please specify how your co-op experience assisted you in obtaining your current position or previous position(s).

_____ I am/was employed by one of my co-op employers
_____ I obtained my position by networking with one of my co-op employers
_____ My employer was impressed that I had the co-op experience prior to graduation
_____ Other (please specify): _____

13. Are you currently employed? If your answer is yes, please answer and proceed to #14.

If your answer is no, please skip to #19.

_____ Yes _____ No

14. What is your job title? _____

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15. Check the salary range of your current position.

_____ Under $25,000
_____ $25,000-$29,999
_____ $30,000-$34,999
_____ $35,000-$39,999
_____ $40,000-$44,999
_____ $45,000-$49,999
_____ $50,000-$54,999
_____ $55,000-$59,999
_____ Above $60,000

16. Are you working in a field related to your major?

_____ Yes _____ No

17. Are you working full-time or part-time?

_____ Full-time _____ Part-time

18. How did you learn about your current position?

_____ Internet
_____ Newspaper
_____ College of Technology Cooperative Education Experience
_____ Bowling Green State University Career Center
_____ Employment Agency
_____ Other (please specify): _____

Part 2 Instructions

Using the following scale, please take a few minutes of your time to respond to the following statements by placing an "X" in the box that best describes your opinion.

19. My co-op experiences increased my….	SA	A	D	SD
• Motivation to learn				
• Enthusiasm for my field of study				
• Ambition toward my career				
• Self-esteem				
• Self-confidence				
• Problem-solving skills				
• Interpersonal communication skills				
• Ability to take initiative				

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20. My co-op experiences helped to develop my …	SA	A	D	SD
• Ability to apply classroom knowledge to the workplace				
• Relationships with men and women at work				
• Understanding of theory that was taught in the classroom				
• Responsibility for my actions				
• Trust in my own judgments				
• Professional work habits				
• Independence				
• Understanding of other people				
• Sense of purpose in life				
• Understanding of my field of study				
• Appreciation for the cooperative education process				
• Understanding of diverse work roles				
• Career assessment skills				
• Technical skills necessary for my career				
• Career identity				
• Ability to make informed career decisions				

21. My co-op experiences provided me with the opportunity to…	SA	A	D	SD
• Mature professionally				
• Mature personally				
• Successfully transition to full-time employment				
• Build a network within my industry				
• Explore a work experience that was beneficial to my career				

Part 3 Instructions:

Please answer the following questions.

22. In the space provided below, please describe the most valuable lesson you learned while completing your cooperative education experience.

23. What recommendations would you give to the current College of Technology students working toward completing their cooperative education experience?

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APPENDIX B

My Co-op Experiences Increased My…

	Strongly Agree	Agree	Strongly Disagree	Disagree	n
	%(n)	%(n)	%(n)	%(n)	
Motivation to learn	29.41(45)	56.86(87)	10.46(16)	3.27(5)	153
Enthusiasm for my field of study	37.25(57)	50.98(78)	8.50(13)	3.27(5)	153
Ambition toward my career	37.50(57)	52.63(80)	7.24(11)	2.63(4)	152
Self-esteem	30.72(47)	52.94(81)	13.07(20)	3.27(5)	153
Self-confidence	36.60(56)	51.63(79)	8.50(13)	3.27(5)	153
Problem-solving skills	39.22(60)	52.29(80)	5.88(9)	2.61(4)	153
Interpersonal communication skills	41.83(64)	49.02(75)	6.54(10)	2.61(4)	153
Ability to take initiative	35.95(55)	50.98(78)	9.80(15)	3.27(5)	153

My Co-op Experiences Helped to Develop My…

	Strongly Agree	Agree	Strongly Disagree	Disagree	n
	%(n)	%(n)	%(n)	%(n)	
Ability to apply classroom knowledge to the workplace	28.86(43)	49.66(74)	15.44(23)	6.04(9)	149
Relationships with men and women at work	18.79(28)	67.11(100)	7.38(11)	2.68(4)	149
Understanding of theory that was taught in the classroom	19.59(29)	55.41(82)	17.57(26)	7.43(11)	148
Responsibility for my actions	24.83(37)	62.42(93)	9.40(14)	3.36(5)	149
Trust in my own judgments	24.83(37)	63.09(94)	9.40(14)	2.68(4)	149
Professional work habits	40.27(60)	51.01(76)	7.38(11)	1.34(2)	149
Independence	36.24(54)	50.34(75)	11.41(17)	2.01(3)	149
Understanding of other people	26.85(40)	57.72(86)	12.08(18)	3.36(5)	149
Sense of purpose in life	10.20(15)	44.22(65)	33.33(49)	12.24(18)	147
Understanding of my field of study	37.58(56)	43.62(65)	14.09(21)	4.70(7)	149
Appreciation for the cooperative education process	34.23(51)	44.97(67)	10.07(15)	10.74(16)	149
Understanding of the diverse work roles	28.19(42)	55.03(82)	14.09(21)	2.68(4)	149
Career assessment skills	23.65(35)	56.08(83)	16.22(24)	4.05(6)	148
Technical skills necessary for my career	41.61(62)	46.31(69)	6.71(10)	5.37(8)	149
Career identity	19.59(29)	57.43(85)	19.59(29)	3.38(5)	148
Ability to make informed career decisions	28.86(43)	53.69(80)	14.09(21)	3.36(5)	149

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APPENDIX B

My Co-op Experiences Provided Me With the Opportunity to…

	Strongly Agree	Agree	Strongly Disagree	Disagree	n
	%(n)	%(n)	%(n)	%(n)	
Mature professionally	39.60(59)	46.31(69)	11.41(17)	2.68(4)	149
Mature personally	28.19(42)	54.36(81)	14.09(21)	3.36(5)	149
Successfully transition to full-time employment	39.04(57)	35.62(52)	17.81(26)	7.53(11)	146
Build a network within my industry	31.76(47)	38.51(57)	19.59(29)	10.14(15)	148
Explore a work experience that was beneficial to my career	44.59(66)	39.86(59)	9.46(14)	6.08(9)	148

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APPENDIX C

Number of Respondents by Category for Most Valuable Lesson Learned

	n=116
Application of Knowledge	10
Career Development	20
Communication	9
Company Environment	11
Co-op Comments	3
Experience	32
General Comments	7
Networking	3
Non-Technical Skills	8
Personal Development	3
Previous Jobs	4
Teamwork	4
Multiple Category Responses	2

Number of Respondents by Category for Recommendations for Co-op Students

	n=118
Be Open Minded	7
Be Selective	6
Career Development	15
Challenge Yourself	7
Communicate	4
Focus	6
General Comments	2
Get Experience	2
Get Involved	4
Go Above and Beyond	12
Goal Setting	1
Good Work Ethic	2
Job Searching Skills	11
Network	7
Start Early	3
Stay With It	2
Take Advantage	1
Take Co-op Seriously	7
Variety of Positions	19

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APPENDIX D

Revised Student Learning Outcomes

The intended student learning outcomes for students participating in cooperative education experiences are to:

- Develop an understanding of a target work environment.
- Develop an understanding for diversity of work roles.
- Build a network of industry contacts, which could be used for post-graduation employment.
- Explore a work experience that will be beneficial to the student's career.
- Develop a more focused career identity.
- Develop the technical skills necessary to be successful in industry.
- Increase the student's motivation to learn.
- Develop enthusiasm toward the student's field of study.
- Develop trust in the student's own judgments and strengthen skills to take initiative.
- Increase interpersonal communication skills.
- Make more informed career decisions leading to increased career maturity.
- Apply career assessment, resume writing, and interviewing techniques to post-graduation employment searches.
- Examine relationships between theories taught in the classroom to practices observed in the workplace.
- Develop mature relationships with men and women.
- Develop awareness to entrepreneurship.
- Develop independence.
- Increase self-esteem.
- Increase self-confidence.
- Develop good work habits.
- Enhance problem-solving skills.
- Appreciate the cooperative education process.
- Transition successfully into full-time employment.

Gender Generalization: Female Integration into Industrial Technology and Factors Contributing to their Recruitment and Retention

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Abstract
Educational institutions are increasing their efforts to integrate females into non-traditional technical programs. Adjustments, such as curriculum and recruitment and retentions efforts, are being made to ensure that females feel welcome and a part of the program's standard regimen. Industrial Technology stands at the vanguard of successful paradigms that prepare females in such non-traditional areas as managerial and technical degree programs. The results of this study indicated that gender generalization existed in Industrial Technology. However, methods of recruitment and retention were identified also to integrate more females into this field of study.

Introduction
Educational institutions are increasing their efforts to integrate females into non-traditional technical programs. Adjustments, such as curriculum and recruitment and retentions efforts, are being made to ensure that females feel welcome and a part of the program's standard regimen. Industrial Technology stands at the vanguard of successful paradigms that prepare females in such non-traditional areas as managerial and technical degree programs. Marshall (2000) contended that the common goals of Industrial Technology programs are to increase enrollments and to offer a curriculum designed to prepare students for management and technical careers. Areas of study, such as Industrial Technology, could provide possible managerial and technological career opportunities for females. The National Association of Industrial Technology (NAIT) defines Industrial Technology as a field of study designed to prepare technical and/or management oriented professionals for employment in business, industry, education, and government (McGowan, 1997). McGowan also added that Industrial Technology is primarily involved with the management, operation, and maintenance of complex technological systems while engineering and engineering technology are primarily involved with the design and installation of these systems.

Although female are increasing their representation in the non-traditional fields of study and are becoming more knowledgeable of the multi-facet components of technology, there still remains significant under-representation of females in technological areas such as Industrial Technology. Mayer's (1995) assertion that females comprise 30 percent of the industrial workforce, globally illustrating significant growth compared to past decades. The Chronicle of Higher Education (2001) reported that enhanced recruitment and retention strategies for females in technological and scientific areas would

assist in increasing representation in the industrial workforce. Enhanced recruitment and retention efforts of females in Industrial Technology will be one step toward offsetting the shortage of representation in this field of study.
The representation of female faculty in industrial technology reflects a serious lack of gender diversity. The National Association of Industrial Technology (NAIT) (as cited in Kasi, 1999) revealed that there was only 11.2 percent female representation in Industrial Technology faculty at the United States' university level. Under-representation has also been present in the industrial workforce as well.

In the actual industrial setting, there once appeared to be a major division between male and female job positions and responsibilities. Appiah (2002) indicated that traditional fields for males include: science, engineering, and other technical areas, while the traditional fields for females are education, history, and other social sciences. Bostic (1999) suggested that this might be a result of females allowing traditional roles to determine their career choices.
Since Industrial Technology is a technical and management oriented profession, Orr (1983) asserted that some females viewed this as uncharted territory, and may be reluctant to manage large organizations or their male counterparts. However, Williams, Stead, and Posner (as cited in Orr, 1983) conducted studies revealing that women manage as well as their male counterparts. Although such findings may have been influential in females securing more jobs in management, Farrar & Vogel (2001) suggested that representation in technology remains at a slow increase, and efforts should be made to encourage female students to enter non-traditional fields.

Research problem

This study revealed that under-representation of females existed in Industrial Technology programs. At five of the four-year institutions in the state of Mississippi with Industrial Technology programs, female under-representation was evident. During the 2003-2004 academic school year, Alcorn State University's Department of Industrial Technology currently had enrolled 45 female students of 125 undergraduate students (K. Agyepong, personal communication, September 05, 2003). Jackson State's Industrial Technology Department had an enrollment of 80 female students out of 276 undergraduate students (K. H. Jackson, personal communication, September 19, 2003). A. Stevens (personal communication, October 01, 2003) indicated that Mississippi State University's Industrial Technology program had an enrollment of one female student out of 63 undergraduate students. Mississippi Valley State's Industrial Technology department has an enrollment of 10 females out of 66 students (A. C. Favre, personal communication, October 20, 2003). In addition, C. Wentworth (personal communication, October 08, 2003) indicated that the University of Southern Mississippi's Industrial Engineer Technology program had an enrollment of 11 females (8 at the Hattiesburg-main campus, and 3 at the Gulf Coast campus) out of 75 students (see Table 1).

Table 1. Enrollment of Mississippi Industrial Technology undergraduates students

Institution	Male Students	Female Students	Total Enrollment
Alcorn State	80	45	125
Jackson State	196	80	276
Mississippi State	62	1	63
Mississippi Valley	56	10	66
Uni. Of Southern MS	64	11	75

While literature indicates the moderate increase of females in science and technological fields, the question for this study becomes whether colleges and universities are making effective efforts to recruit and retain females in Industrial Technology.

Kasi and Dugger (2000) stated, "despite the gains by women, their participation has leveled off in many areas including Industrial Technology, and they have not achieved demographic parity or occupational equality with men (p. 4)." Kasi (1999) further asserted that it is essential to conclude that gender generalization may have an impact on such under-representation by stereotypes, barriers, and perceptions of females in Industrial Technology. It is also significant to investigate any initiatives that may improve the overall environment for females enrolled in Industrial Technology programs.

The purpose of this study was to analyze efforts by the two NAIT (National Association of Industrial Technology) accredited Industrial Technology programs in the state of Mississippi, Alcorn State University and Jackson State University, toward recruitment and retention of females in this field of study. NAIT is the primary organization of Industrial Technology that provides direction and accrediting standards to programs and individuals. It is important to know whether gender generalizations exist within such programs. Also, it is essential to determine whether the learning environment promotes male/female equality. This study identified initiatives that Industrial Technology department chairs, program

coordinators, and faculty use to implement more meaningful recruitment practices for female students, thus, improving opportunities available to them.

Methodology

The study was conducted at Alcorn State University and Jackson State University. Alcorn State University is a land grant, historically black, institution located in Lorman, (southwest) Mississippi, with an enrollment of 3,100 undergraduate students (http://www.alcorn.edu). Alcorn State University's Department of Industrial Technology currently has 45 female students out of 125 undergraduate students along with 12 teaching faculty members (e.g. instructors, assistant professors, associate professors, and professors) (K. Agyepong, personal communication, September 05, 2003). However, Dr. B.W. McGowan (personal communication, September 16, 2003) noted that 1 of the 12 teaching faculty is a female who is substituting for a male faculty member.

Jackson State University is an urban, historically black, institution located in Jackson, (central) Mississippi. Jackson State University's current enrollment is 5,471 students (http://www.jsums.edu). Jackson State's Industrial Technology Department has an enrollment of 80 female students out of 276 undergraduate students (K. H. Jackson, personal communication, September 19, 2003). Dr. I.T. Mosley, (personal communication, September 06, 2003) affirmed that there are 9 teaching faculty members with no females.

The population consisted of a total of 146. Forty-six female students and 12 faculty members where from Alcorn State University's Industrial Technology department and 80 female students, and 9 faculty members where from Jackson State University's Industrial Technology. However, 29 (64%) female students and 12 (100%) faculty members from Alcorn State University, and 40 (50%) female students and 9 (100%) faculty members from Jackson State University participated in the study. The faculty from Alcorn State consisted of 11 males and 1 female. The faculty from Jackson State consisted of 9 males. Demographic information was obtained from the student survey.

Instrumentation

The design of the survey-questionnaire was guided by an instrument developed by Orr (1983). Orr classified his survey-questionnaire procedure as nonexperimental research, because "it is not possible to manipulate variables or to assign subjects or conditions at random" (p. 54). According to Patten (2002), nonexperimental research does not render treatment to subjects, and the results describe how subjects naturally exist. Patten added that a common type of nonexperimental study is the survey in which subjects are questioned, "to determine their attitudes, beliefs, and behaviors as they exist without experiment intervention" (p. 5). Therefore, this study implemented the nonexperimental research approach in order to determine attitudes of faculty and female students on female integration into Industrial Technology programs at Mississippi 4-year NAIT accredited universities.

The faculty survey-questionnaire was designed in accordance with guidance from Devier (1981). Each question on the survey-questionnaire was designed to answer the research questions 1 and 4 to meet the objective of this study: (1) What are the practices currently used to recruit and retain females into Industrial Technology at the two NAIT accredited four-year institutions at Alcorn State University and Jackson State University in the state of Mississippi, and (2) What recommendations can be made by both faculty and students to integrate more female students into Industrial Technology programs. This required the participation of the Industrial Technology faculty members from both institutions. Nonetheless, it was determined to be appropriate for data collection in this study.

This survey-questionnaire consisted of three sections (e. g. Section A. Recruitment, Section B. Retention, and Section C. Suggestions and Recommendations). Section A addressed the use and perceived effectiveness of the various recruitment methods. The description of 20 recruitment methods was ranked on a 5-point Likert-type scale. The responses were ranked as 5 = very effective, 4 = effective, 3 = ineffective, 2 = very ineffective, and 1 = not applicable. The last two questions in the section allowed the respondent to give an overall ranking of the recruitment initiative and their perceptions about other influential factors. Section B contained 5 questions in reference to retention. The items were focused on departmental and faculty efforts to promote inclusion and equality for both male and female students. Section C gave the respondents the opportunity to make any suggestions and/or recommendations concerning efforts to improve and modify recruitment methods of female Industrial Technology students.

The student survey-questionnaire consisted of 6 sections (e.g. Section A. Knowledge of Industrial Technology and Influences, Section B. Career and Salary Opportunities, Section C. Perception and Barriers, Section D. Recruitment and Retention, Section E. Demographics, and Section F. Suggestions and Recommendations). The questions were designed to answer research questions 2, 3, and 4: (1) What are the influences that help to integrate female students into Industrial Technology programs, (2) What are the barriers that female students perceive in studying Industrial Technology, an (3) What recommendations can be made by both faculty and students to integrate more female students into Industrial Technology

programs. Section A inquired about first time knowledge of Industrial Technology programs, and prominent factors that influenced entering the program. Section B inquired about knowledge of career and salary opportunities available to females in Industrial Technology. Section C sought to ascertain the female students' perception of their respective Industrial Technology departments. This section inquired about overall perception of Industrial Technology departments, greatest concerns about the programs, and apparent barriers female students have had to overcome. Section D allowed participants an opportunity to rank the initiatives that Industrial Technology departments have made to increase female enrollment on a 5-point Likert-type scale. The responses ranked as 5 = very effective, 4 = effective, 3 = ineffective, 2 = very ineffective, and 1 = not applicable. Section E contained demographic information (i.e. age, ethnicity, classification, and grade point average (G.P.A)). Section F provided the female students with the opportunity to make any suggestions and/or recommendations concerning efforts to improve and modify recruitment and retention practices.

Discussion

The examination of the data revealed the practices currently used to recruit and retain females into Industrial Technology at the two NAIT accredited four-year institutions at Alcorn State University and Jackson State University in the state of Mississippi as inquired from research question one. Collectively, both institutions indicated that effective recruitment practices included: distribute I.T. literature to high schools and community colleges reflective of male and female participation, make visits to high schools and community colleges, and make presentations at freshman orientation. Effective retention of female Industrial Technology students included: promote learning environment conducive for both male and female students, encourage female I.T. alumni to contact current female students, and keep female students well informed about I.T. career opportunities.

Secondarily, the results reported revealed the effective recruitment and retention practices from the individual institution's Industrial Technology department. At Alcorn State University, the effective recruitment included: establish mailing list to potential students, send letters describing I.T. opportunities, distribute I.T. literature to high schools and community colleges reflective of male and female participation, make visits to high schools and community colleges, make presentations during freshman orientation, and influence by family, friends, and female faculty of pursue I.T. Effective retention practices included: promote a learning environment conducive for both male and female students, encourage female I.T. to contact current female students, and keep female students well informed about I.T. career opportunities. At Jackson State University, effective recruitment practices included: distribute I.T. literature to high schools and community colleges reflective of male and female participation, make presentation of I.T. program opportunities to female students, make visits to high schools and community colleges, allow female students to arranging visits to tour I.T. Department, conduct recruitment conferences on campus, and make presentation during freshman orientation. Effective retention factors included: promote learning environment conducive for both male and female student, encourage female I.T. alumni to contact current female students, and keep current female students well informed about I.T. career opportunities.

Fifty percent of the Alcorn State's Industrial Technology faculty deemed their departmental recruitment practices were effective, and 58% deemed their retention practices for female students were effective. Fifty-six percent of the Jackson State's Industrial Technology faculty indicated that their departmental recruitment practices were effective, and 78% indicated that the retention of female students was effective. To develop the conclusions of this study, a further study with the present Industrial Technology enrollment of female students at Mississippi NAIT-Accredited institutions will be needed.

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Faculty Survey/Questionnaire

next page

Industrial Technology Recruitment and Retention Efforts

Faculty Survey/Questionnaire

Gender Generalization: Female Integration into Industrial Technology and Factors Contributing to Recruitment and Retention.

The survey/questionnaire intended to identify key recruitment and retention efforts of female student that are currently used in the Department of Industrial Technology at NAIT accredited, four-year institutions in the state of Mississippi. The data will be collected in a way that will provide insight into the exclusivity of the groups for meaningful comparisons. This study may propose initiatives for Industrial Technology department chairs, program coordinators, and faculty to implement more meaningful recruitment practices for female students and, thusly improve opportunities available for female students. Participation is confidential **and** voluntary**. If at any point you do not wish to continue in answering the survey, you may stop at any time. You may refuse to answer any specific question on the survey that may be asked. Responses will be used only for the purpose of statistical analysis. Please take 5-10 minutes to complete this survey.** *Thank you.*

Please indicate your Institution's Code (ASU=1, JSU=2) _____

Section A. Recruitment

Please review each of the following items. Please rank on the 5-point Likert Scale (5=very effective, 4=effective, 3=ineffective, 2=very ineffective, and 1= not applicable) of the most effective recruitment methods of female students. Circle the response that is most applicable to your department.

		Very Effective	Effective	Ineffective	Very Ineffective	Not Applicable
1.	Have potential females students identified by high school guidance counselors.	5	4	3	2	1
2.	Establish mailing list to potential female students.	5	4	3	2	1
3.	Send letters describing the I.T. program and careers opportunities to female students.	5	4	3	2	1
4.	Distribute literature on I.T. programs to high schools and community colleges reflective of both male and female participation.	5	4	3	2	1
5.	Allow female faculty to personally contact potential female students	5	4	3	2	1
6.	Allow I.T. faculty to indicate advantages of program to females to other departments.	5	4	3	2	1
7.	Send I.T. female faculty and students as reps. at college fairs.	5	4	3	2	1

		Very Effective	Effective	Ineffective	Very Ineffective	Not Applicable
8.	Make presentations of I.T. program offerings to female students.	5	4	3	2	1
9.	Make visits to high schools and community colleges.	5	4	3	2	1
10.	Sponsor open house activities, thusly, showing female representation within I.T. program.	5	4	3	2	1
11.	Allow female students to arrange visits to tour I.T. Departments.	5	4	3	2	1
12.	Conduct recruitment conferences on campus.	5	4	3	2	1
13.	Offer scholarships to females in non-traditional areas.	5	4	3	2	1
14.	Make presentation during freshman orientation.	5	4	3	2	1
15.	Sponsor "Women in Science and Technology" programs.	5	4	3	2	1
16.	Sponsor luncheons with female faculty and potential female students.	5	4	3	2	1
17.	Send female reps. and display booths to NAIT conferences.	5	4	3	2	1
18.	Have display booths at local shopping mall reflective of both male and female participation.	5	4	3	2	1
19.	Rank the factors (i.e. family, friends, female faculty, etc.) you feel influence females to participate in I.T. programs.	5	4	3	2	1
20.	Rank the overall effectiveness of recruiting females.	5	4	3	2	1

Section B. Retention

		Very Effective	Effective	Ineffective	Very Ineffective	Not Applicable
21.	Promote learning environment conducive for both male and female students.	5	4	3	2	1
22.	Sponsor luncheons for female faculty and students.	5	4	3	2	1
23.	Encourage female I.T. alumni to contact current females students.	5	4	3	2	1
24.	Keep current female students well informed about I.T. career opportunities.	5	4	3	2	1
25.	Rank the overall effectiveness of female students retention.	5	4	3	2	1

Section C. Suggestions and Recommendation

Please state any suggestions or recommendations you feel will increase the enrollment of female students within your Industrial Technology Departments.

Thank you for your participation.

Student Survey/Questionnaire
next page

Industrial Technology Recruitment and Retention

Student Survey/Questionnaire

Gender Generalization: Female Integration into Industrial Technology and Factors Contributing to Recruitment and Retention.

The survey/questionnaire intended to identify factor that influenced female students to participate Industrial Technology programs at NAIT accredited, four-year institutions in the state of Mississippi. The data will be collected in a way that will provide insight into the exclusivity of the groups for meaningful comparisons. This study may identify initiatives for Industrial Technology department chairs, program coordinators, and faculty to implement more meaningful recruitment practices for female students and, thusly improve opportunities available for female students. Participation is confidential **and** voluntary**. Responses will be used only for the purpose of statistical analysis. If at any point you do not wish to continue in answering the survey, you may stop at any time. You may refuse to answer any specific question on the survey that may be asked. Please take 5-10 minutes to complete this survey.** *Thank you.*

Please indicate your Institution's Code (ASU=1, JSU=2) _____

Section A. Knowledge of Industrial Technology and Influences

1. You were **first** introduced to Industrial Technology by:
   A. Middle school courses
   B. High school courses/Teacher lectures
   C. High school guidance counselor
   D. Family and/or friends
   E. College Recruiters
   F. Others (please specify) _____

2. What served as the means for your introduction to Industrial Technology? *(Circle all that apply.)*
   A. Text books
   B. Lectures
   C. Television Advertisements
   D. Displays booths
   E. Mailed literature (i.e. brochures, program description, college catalog, etc.)
   F. Computer Advertisements
   G. Others (please specify) _____

3. What do you know about the opportunities available in Industrial Technology? *(Circle all that apply.)*
   A. Available courses (i.e. mathematics, science, etc.)
   B. Graduate education
   C. Various disciplines (i.e. computer aided-drafting, computer technology, etc.)
   D. Career opportunities
   E. Salary projections
   F. Professional associations and affiliations
   G. Others (please specify) _____

4. What factors influenced you to enroll in an Industrial Technology program? *(Circle all that apply.)*
   A. Family and friends
   B. Female instructors
   C. Male instructors
   D. Female representation in the Industrial Technology
   E. Male representation in Industrial Technology
   F. "Gender-friendly" (appeals to both female and male students) curriculum
   G. Others (please specify) _____

5. What was valuable to you when considering enrollment in the Industrial Technology programs at your university. *(Circle all that apply.)*
   A. "Gender-friendly" (appeals to both female and male students) curriculum
   B. Desired to pursue a non-traditional field of study
   C. Desired to pursue a stimulating /challenging career
   D. Numerous career opportunities
   E. Good salary
   F. Chance for promotions in an industrial setting
   G. Other (please specify) _____

Section B: Careers and Salary

6. What are some of the career choices that you were aware of that are offered in Industrial Technology? *(Circle all that apply.)*
   A. Technicians
   B. Supervision, Management, and Administration
   C. Manufacturing Procedures and Controls and Standards
   D. Education
   E. Marketing, Distribution, and Sales
   F. Engineering
   G. Others (please specify) _____

7. What type of employment do you intend on pursing after graduation? *(Circle all that apply).*
   A. Technicians
   B. Supervision, Management, and Administration
   C. Manufacturing Procedures and Controls and Standards
   D. Education
   E. Marketing, Distribution, and Sales
   F. Engineering
   G. Others (please specify) _____

8. What do you anticipate as a starting salary?
   A. Below $20,000
   B. $20,500 to $30,000
   C. $30,500 to $40,000
   D. $40,500 to $50,000
   E. $50,500 to $60,000
   F. $60,500 to $70,000
   G. Above $70,000

Section C: Perception and Barriers

9. What is your overall perception of your Industrial Technology Department? *(Circle all that apply).*
   A. Male-dominated
   B. Conducive environment to both males and females
   C. "Gender Friendly"
   D. Threatening
   E. Challenging for female students
   F. Indifferent
   G. Other (please specify) _____

10. What was your concern (s) upon enter the Industrial Technology program? *(Circle all that apply).*
    A. Nothing
    B. The curriculum
    C. The mathematics, science, and computer courses required
    D. The male/female representation of students
    E. The male/female representation of faculty
    F. The lack of a female mentor
    G. Other (please specify) _____

11. What were some apparent barriers you had to overcome? *(Circle all that apply).*
    A. None
    B. Lack of preparation in mathematics, science, and technical courses
    C. Under-representation of female students in the classroom
    D. Sense of inferiority to male counterparts
    E. Sense of inferiority caused by male instructors
    F. The "hands-on" application in the classroom
    G. Others (please specify) _____

Section D: Recruitment and Retention

	Very Effective	Effective	Ineffective	Very Ineffective	Not Applicable
12. Distribute literature on I.T. programs to high schools and community colleges reflective of both male and female participation.	5	4	3	2	1
13. Allow female faculty to personally contact potential female students	5	4	3	2	1
14. Allow I.T. faculty to indicate advantages of program to females to other departments.	5	4	3	2	1
15. Send I.T. female faculty and students as reps. at college fairs.	5	4	3	2	1
16. Promote learning environment conducive for both male and female students.	5	4	3	2	1
17. Sponsor luncheons for female faculty and students.	5	4	3	2	1
18. Encourage female I.T. alumni to contact current females students.	5	4	3	2	1
19. Keep current female students well informed about I.T. career opportunities.	5	4	3	2	1

Please indicate the following by circling the response that is most applicable to you.

Section E. Demographics

20. Your age is:
    A. 17-18
    B. 19-20
    C. 21-22
    D. 23-24
    E. Over 24

21. Your ethnicity is (optional):
    A. African-American
    B. White-American
    C. Native-America
    D. Hispanic
    E. Other (please state) _____

22. Your classification is:
    A. Freshman
    B. Sophomore
    C. Junior
    D. Senior

23. Your grade point average is (optional):
    A. Below a 2.50
    B. 2.50 to 3.00
    C. 3.01 to 3.50
    D. 3.51 to 4.00

Section F. Suggestions and Recommendation

Please state any suggestions or recommendations you feel will increase the enrollment of female students within your Industrial Technology Departments.

Thank you for your participation.

This paper was named "Best Overall NAIT 2006 Selected Paper" after peer-review.

Making Industry Meaningful In College for Technical Students

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A multi-disciplinary project at Illinois Valley Community College provides electronics and engineering design students with training and practice with the entire process of manufacturing, continuous quality improvement, problem solving, leadership, teamwork and communication in a simulated industrial setting. Entitled Making Industry Meaningful In College (MIMIC), the entrepreneurial project places students in electronics, engineering design and various business fields into teams, called "companies," to design, produce, market and sell products. With support from a National Science Foundation grant, the one-semester capstone project is utilized for integrating continuous quality improvement throughout the technical students' two-year programs. In their first three semesters, the electronics and engineering design students design, prototype, and redesign products for MIMIC. In their fourth semester, the technical students are teamed with business students to produce and sell the reengineered products. The students' courses meet at a common time so the student "companies" can meet, for training in such areas as group dynamics, and for communication experiences typical of the workplace. MIMIC not only exposes students to the world of industry within the confines of the classroom, it is a replicable, cost-effective model that can include industry partners and can be integrated into various programs and college settings.

Similar Projects at Other Institutions

Entrepreneurial team projects are relatively common in university engineering programs. They vary in focus, participants, and length, but none appear to exactly match the MIMIC model. Some projects emerge from programs encouraging entrepreneurship, like Pennsylvania State (Bilen *et al*., 2005). Some projects, like the University of Maryland (Barbe, *et al*., 2001), are a part of incubator-like environments where prospective entrepreneurs live together. Some universities facilitate start-up ventures: Florida Institute of Technology (Ports, *et al*., 2005) and Stanford University (Stanford Technology Ventures Program, n.d.), for example. A high tech manufacturing facility is available for teams to produce a product, for example, at the University of Missouri-Columbia (Zayas-Castro, *et al*., 2002). A business plan competition is the focus at the Massachusetts Institute of Technology (MIT $50k Entrepreneurship Competition, n.d.)

At some universities, the teams work with industry partners, i.e., at Lehigh University (Ochs, *et al*., 2001) and Michigan Technological University (Raber and Moore, 2005). At some universities, multi-disciplinary project teams include MBA students, i.e., at University of Nevada-Reno (Wang and Kleppe, 2001) and University of Florida (Stanfill, *et al*., 2004). Other projects include undergraduate business students, i.e., University of Missouri-Columbia (Zayas-Castro, *et al*., 2002) and Lehigh University (Ochs, *et al*., 2001). Some projects are capstones, i.e., at the University of Nevada-Reno (Wang and Kleppe, 2001). Other teams exist several years, i.e., at Rowan University (Engineering Clinics, n.d.) and Michigan Technological University (The Enterprise Program, n.d.).

At community colleges, technical team projects are also relatively common (Mott, 2002; Gordy and Ezzell, 2004), and agreements with universities allow some community college students to participate in projects at a university (Liou, *et al*, 2003). However, multi-disciplinary entrepreneurial projects, which include business students, are either rare or not well publicized.

Origin of the MIMIC Concept

In 1995, the engineering design instructor and a business instructor at Illinois Valley Community College developed a creative plan to provide their students with workplace experience. As a project in one of their courses, the instructors integrated their students into teams to develop, produce and sell a product. Shortly after MIMIC's successful debut, the project expanded. Electronics students joined the student companies, and product specifications were revised to require electronic components. Additionally, a MIMIC business course was developed as a capstone for students in Associate in Applied Science degree programs in marketing, accounting, management, computer systems and information systems.

MIMIC's Current Role

Today, with support from National Science Foundation Grant #0501885, the one-semester MIMIC project is being used as a catalyst to embed continuous quality improvement methodology (CQI) throughout the two-year electronics and engineering design curricula.

For the first ten years of MIMIC, the entire process was completed in one semester, including team assignments, product decisions and designs, training in teamwork and other skills, prototyping, production, marketing and sales. The one-semester time frame successfully provided teamwork, problem solving, entrepreneurship and communication experiences, but it limited the design experience of the technical students and the viability of the products. Expanding the program to introduce electronics and engineering design students to CQI in their first semester courses solves those problems. In the first semester of their two-year programs, students learn CQI principles and receive hands-on experience with reengineering in Computer Aided Drafting I, which is required in both electronics and engineering design. The students analyze previous MIMIC products and make recommendations for improvements. In their second and third semesters, technical students continue to study CQI, design products, build prototypes, analyze the prototypes, redesign, and so on. Just before the fourth semester, the instructors select the products for the MIMIC project from the redesigned products. The instructors evaluate the quality of the design, ease of production on campus, cost and marketability.

The fourth semester is the MIMIC project semester, when products are manufactured and sold. Students enrolled in the following courses participate:

- Design Projects, a capstone engineering design course,
- Motors and Controls II, a sophomore electronics course, and
- Integrated Business Operations, a capstone business course.

The courses are scheduled at a common time to allow for company meetings and training.

At the beginning of the MIMIC semester, the instructors assign students to companies and a product to each company. Enrollment determines the number of companies and number of students from each discipline assigned to each company. Typically, a company includes two engineering design students, two electronics students, and a mix of business students. Companies meet immediately for orientation and training and continue to meet at least once a week throughout the semester. Instructors from other disciplines are brought into company meetings or into the individual courses to teach workplace skills such as teamwork, goal setting, and problem solving, as consultants would be hired to provide training in a business or industry. Communication channels, including e-mail and an electronic discussion board, are established to allow students to conduct their company business realistically.

In their early meetings, the student teams decide how to produce and market their product and develop a product and corporate name. Students assume responsibility for a portion of the project based on their discipline, and they facilitate company meetings on a rotating basis.

The teams research and purchase materials and determine the selling price. A minimum of one week is devoted to producing the products with students in all of the disciplines participating. The number of units to be produced is set by the instructors. Marketing students design packaging and prepare the instructions for assembly and/or operation. Business students plan and promote an on-campus fair where the products are sold. All students are required to assist in the sale of their product. After the fair, accounting students prepare a cost analysis and make a recommendation on the commercial viability of the products.

MIMIC Products

Products created by student teams have included security devices, desktop water fountains, electronic games, lamps, and clocks. The flashing drink holder, Figure 1 and Figure 2 below, is a MIMIC product. Marketed under the name Kan Kuzzie, this drink holder incorporates fiber optics with a tri-color LED and a printed circuit board. The top, bottom and battery holder were produced in a rapid prototyping machine. This product was produced and sold from the original design; it has yet to undergo reengineering.

Figure 1: Flashing drink holder, exterior

Figure 2: Drink holder, interior

The strobe light, in Figures 3 and 4 below, illustrates how reengineering is improving product quality. Figure 3, on the left, shows the side and top view of the original product that was designed and sold a few years ago. Given the limited time the students had from concept to production, the original is relatively well designed. The original light also predates the students' access to rapid prototyping and mold making capability. Newer technology and reengineering allowed students to create the more commercially viable and professional product in Figure 4.

Figure 3: Strobe light original

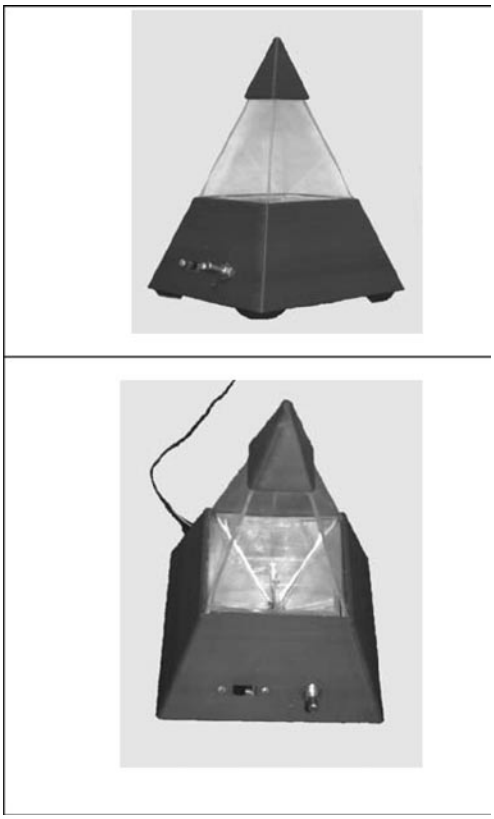

Figure 4: Strobe light reengineered

The new design is also more effective. The original design concentrated light in one direction, upward from the box. The new design distributes light more evenly throughout a room because the entire upper section is made of clear plastic. The RC time constant in the new design was also altered to affect the time charge rates, affecting the flash rates.

Learning in the MIMIC Project

MIMIC is a learning-centered project, providing training and practice in leadership, teamwork, problem solving and critical thinking, in addition to requiring students to apply their technical skills. MIMIC also provides students with opportunities to learn about and experience:

- the entire process of manufacturing,
- technologies outside of their discipline,
- thinking and communication styles of other disciplines,
- scheduling and time management,
- oral and written communication modes appropriate to their discipline.

At every stage in the process, all team members participate in making company decisions, such as purchasing of components, pricing, producing, and selling the product. That participation helps them to understand how their role fits into the entire process.

Throughout their programs, technical students become experienced with technology they will utilize in the workplace; MIMIC exposes them to technology outside of their fields. For example, electronics and engineering design students become familiar with Excel while the business students are introduced to AutoCAD and rapid prototyping. Understanding different technologies helps them to work together productively.

The students also encounter diverse thinking and communication styles as they interact in their companies and, with the assistance of training in group dynamics and communication, they interact more productively. The need for training to improve interaction, especially between technical students and business students, is illustrated in the following feedback from students:

- An electronics student: "We can't get money out of the accountants to buy parts."
- An accounting student: "The engineering and electronics students won't give me any numbers."
- An engineering design student: "Marketing students said we'd never be able to sell it. The accountants said our idea was no good – too complicated."

Obviously, these issues are typical of the workplace.

In their companies, students receive training in goal setting and time management. Their hands-on teamwork makes the students aware of deadline responsibilities in a way that individual classroom assignments do not. In exit interviews, students routinely advise future MIMIC participants not to relax even if they are on schedule.

A number of communication exercises are integrated into MIMIC. In addition to small group communication required for student companies to function successfully, the students participate in communication situations that would be required of them on the job. All students give oral presentations in a 120-seat, multi-screen, electronic lecture hall to members of the faculty and administration in addition to the student teams. Presentations are scheduled throughout the semester with students from each discipline explaining their portions of the project; engineering design students, for example, defend their product designs early in the semester, and electronics students explain electronic components before production begins. The types of written materials produced by the students are also discipline-specific; technical students detail their design and component choices in formal, technical reports.

Assessment in the MIMIC Project

The MIMIC project, students, and products undergo extensive evaluation. MIMIC instructors, consulting instructors, students, product buyers and business/industry leaders evaluate plans, designs, prototypes, products, written materials, oral presentations, teamwork, and student participation. A full assessment of the four-semester focus will not be possible until the first students complete their two-year programs, but past assessments of MIMIC have been very positive. Business and industry leaders have been supportive because MIMIC gives students hands-on experience dealing with workplace problems. Student feedback has also been very positive. Typically, students are skeptical about the benefits of the project as they begin and frustrated during the project. By the end, they recognize the value of the experience in preparing them for the world of work. An advisory committee of business and industry representatives has been formed to provide guidance as the technical programs incorporate reengineering. The committee also provides an ongoing, formal structure for feedback on MIMIC itself.

Cost for a MIMIC-like Project

MIMIC has been very cost effective. Although a National Science Foundation grant is currently providing some funding, MIMIC has been offered for ten years on a budget of approximately $3,000 a year:

- $1,200 for the three instructors ($400 stipend each),
- $1,000 for product supplies, divided equally among the student companies,
- Under $1,000 for stipends to instructors for training in teamwork and other workplace skills.

Since it began, MIMIC has been sponsored by the college's Tech Prep team, with funding provided through Carl D. Perkins federal legislation. Students have helped to control costs by locating low-cost supplies and soliciting donations from lumberyards and hardware suppliers. Product sales have covered some additional expenses.

A similar project would require start-up funding or industry sponsorship but could be nearly, if not entirely, self supporting through product sales.

Adaptability of the MIMIC Model

MIMIC is an adaptable model for integrating students from diverse disciplines, as illustrated by a spin-off project at IVCC. Students in engineering design, electronics, theatre, English, art, graphic design and business designed and built a portable puppet theatre and puppets; developed and administered a budget; and wrote, promoted and produced a play. The project required the technical students to work with theatre students to learn about theatre materials and stage lighting effects and zones. Integrating technical students with liberal arts students provided even more teamwork and communication challenges than the original MIMIC project. As the theatre instructor said, "Design and electronics students approach a project differently compared to theatre students."

Integrating teams of students from diverse areas to produce products can also be accomplished at various educational levels and can involve industry partners. The MIMIC model can be adapted to various college settings, including university programs, by adjusting the complexity of the products to match student backgrounds and expectations/standards of the instructor, course or program. A number of universities offer projects that incorporate aspects of the MIMIC model, as the literature review listed previously illustrates.

At IVCC, MIMIC has truly made industry meaningful, and the MIMIC project can be used as a blueprint for other universities to make industry meaningful to their students.

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Undergraduate and Graduate Enrollment and Graduation Trends in Industrial Technology from 1995-2005

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Introduction

As the National Association of Industrial Technology (NAIT) matures and refines its critical role in promoting the discipline of Industrial Technology (IT), it is important to track those vital few measures of discipline health so association leaders and members will have some indication of whether a celebration or a strong sense of concern is warranted. This paper is written to provide a summary of the enrollment trends in National Association of Industrial Technology undergraduate and graduate programs. Although far from the only indicator of organization health, program enrollments and numbers of graduates are certainly one of the vital few measures that reflect to a large degree the health of the discipline and the health of the organization.

Enrollment and graduation rates of NAIT baccalaureate and masters programs will provide a means for all Industrial Technology professionals to compare their programs with a national average, understand whether the discipline is following an upward or downward trajectory, and identify which programs have had the greatest success. As in the case of other disciplines, a comprehensive look at these trends have led to association-led initiatives that have reversed national downward trends and strengthened the disciplines that have taken such data collection and analysis procedures seriously. Hence, this paper is intended to provide the readers with information as well as suggestion as how NAIT may improve the quality of the data being generated. It is essential that we as NAIT professionals ask relevant questions and gather data to provide the answers to questions about discipline and association health. This question formulation and data gathering must happen if the IT discipline and the respective programs are to be successful in this competitive educational environment.

Similar efforts in other fields

There have been similar efforts to gather and report enrollment and graduation data by researchers in other disciplines. Mulvey and Nicholson (2003) reported on the health of physics programs by gathering and sharing graduation data for baccalaureate and graduate programs in physics in the United States. Siegfried (2003) reported in the *Journal of Economic Education* that a precipitous decline in graduates in economics had been reversed but there had been little success in increasing the percentage of females completing degrees in economics. Conant (1992) reported on national enrollment trends of schools of public affairs and administration. In each case, either the determination of the overall health, the outcomes of a specific national effort, or both were the focus of the article. The next section was prepared to answer the question "how valuable will baccalaureate level degrees be to the next generation of college students?"

Value of B.S. Degree

According to the Bureau of Labor Statistics, total employment is projected to increase by 21.3 million jobs over the 2002-12 period, rising to 165.3 million (Hecker, 2004). It is projected that the economy will continue generating jobs for workers at all levels of education and training, although growth rates are projected to be faster, on average, for occupations generally

requiring a postsecondary award, than for occupations requiring less education or training. Hecker (2004) also stated that computer and mathematical occupations are projected to add the most jobs, 1.1 million, and grow the fastest among the eight professional and related occupations subgroups. The demand for computer-related occupations will continue to increase as a result of the rapid advances in computer technology and continuing demand for new computer applications, including those for Internet and intranets. Engineering related jobs are projected to grow slowly and about 2 out of 5 new jobs in architecture and engineering occupations are projected for the professional, scientific, and technical services industry (Hecker, 2004).

The implications for industrial technology programs are that industries will continue to see the need to have an increasingly strong supply of graduates possessing a postsecondary degree or award. It can also be surmised that computer and math intensive IT programs may fare better than other NAIT programs. Finally, with help from regional, state and national business and industry leaders, greater incentives should be put in place to help promote post-secondary programs in areas where shortages exist and which negatively impacts the capacity for industries in the region to be competitive.

Methodology

The National Association of Industrial Technology publishes a directory every year that lists all the universities and colleges offering NAIT accredited or non-accredited programs related to Industrial Technology. To examine the enrollment trends in the under graduate NAIT programs from 1995-2005, the data contained in the NAIT directories for the target years was analyzed. According to Volk (1993), the appropriateness of using directories for quantitative analysis has been demonstrated by Edmunds (1990), Moss (1989), and Wright (1986). Hence, the use of such a secondary source appeared to be relevant for this study.

The main concern in using the NAIT directory as a source was the reliability of the enrollment and graduation data reported by the universities and colleges offering Industry Technology programs. A review of the individual schools reports included in the Directory for 2004, 2005 and 2006 revealed that a small number of institutions have reported an identical enrollment and graduation numbers for each of the past three years. The likelihood of such a coincidence occurring naturally is extremely small which brings into question the accuracy of the reports. In at least one case, associate and baccalaureate degree numbers were aggregated which has the effect of inflating the baccalaureate numbers. It is also unclear as to how second or third majors are counted and as to how program enrollment is determined. For example, do program enrollment numbers include only students enrolled in that Fall semester or those that have declared a major but may be taking off a semester?

In several other instances, an institution failed to report for a particular year. In order to minimize the impacts of these missing data, a careful examination of the enrollment and graduation numbers across the years for each institution was made. Missing data for a particular institution was estimated by using the mean from prior and subsequent directories, following the recommendation of Borg & Gall (1989, as cited in Volk, 1993, p.46).

Information from the Integrated Postsecondary Education Data System (IPEDS) has been included in this paper to allow for comparisons of NAIT trends with nationwide trends in bachelor's degrees conferred and degrees conferred in engineering and engineering technologies. The IPEDS data are taken very seriously and are reported by each college and university each year. The slice in time for enrollment is on the tenth class day when most students who are going to add or drop out have done so. When the data were available, relevant comparisons with other disciplines such as engineering and engineering technology have been provided.

Baccalaureate Level Enrollment and Graduation Trends

The following figure (Figure 1) shows the trends in enrollment for the baccalaureate programs as reported in the NAIT Directory. It can be observed from the figure that there was a 13% (approximate) drop in enrollment during 1995-1998. The enrollment then started to increase and was at its maximum in 2003 of 33, 612students. The enrollment in 2004 declined from 2003 by approximately 8.5 percent but increased 2.7 percent as reported in for 2005 in the 2006 Directory. The numbers indicate that NAIT program enrollment has undergone a relatively small increase (3.3 percent) from Fall 1995 through Fall 2005.

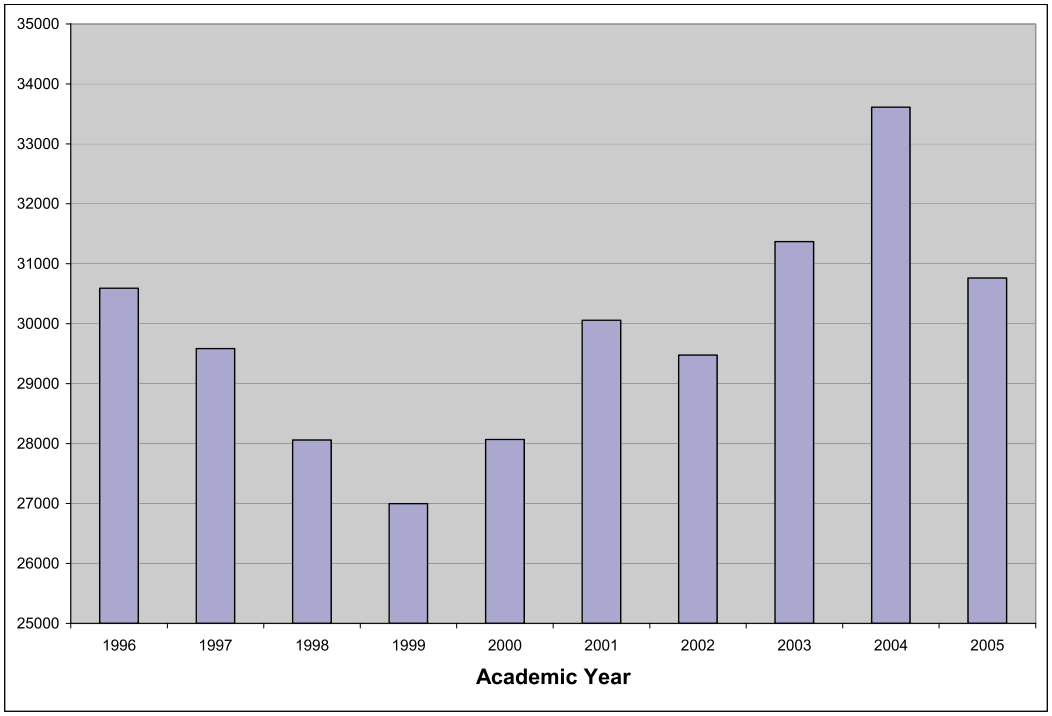

Figure 1. NAIT baccalaureate enrollment from Fall 1995-Fall 2005

Figure 2 shows the number of graduates with baccalaureate degrees from NAIT programs. It can be observed from the enrollment and graduation data that out of an average of approximately 30,000 students who are enrolled into NAIT programs approximately 21% of these enrollees graduate with NAIT baccalaureate degrees. These data raise many questions as to whether this percentage is largely due to attrition or due to students taking more than four years to graduate.

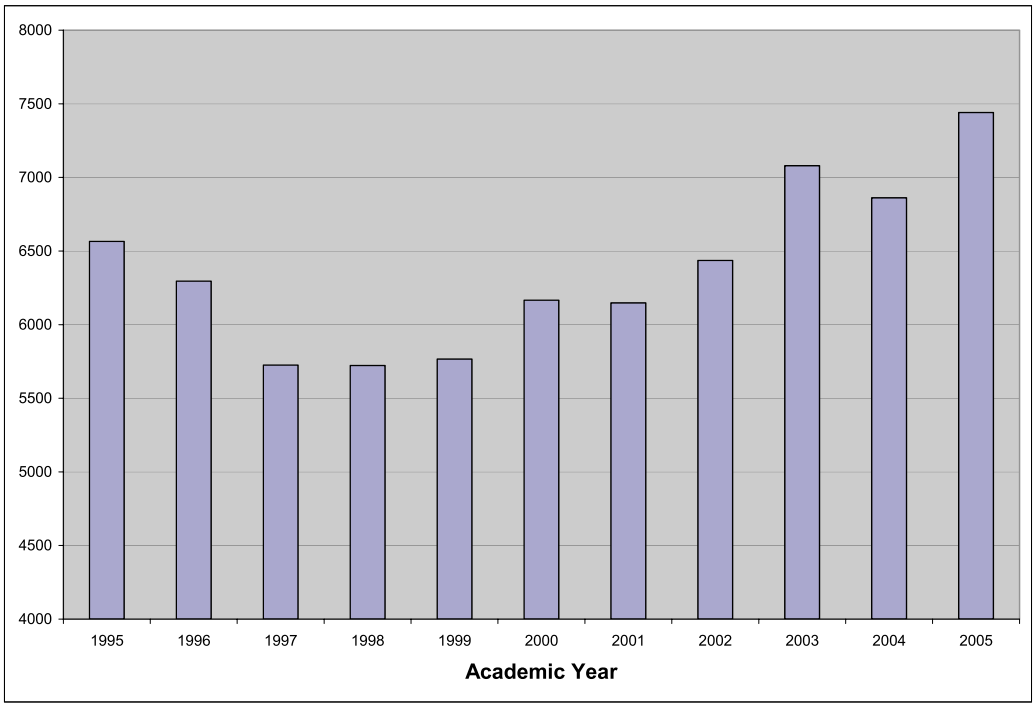

Figure 2. NAIT Baccalaureate Graduates for the 1995-2005 Academic Years

Regarding the numbers of graduates, the news is better than that of enrollment. The number of students completing IT programs has increased more than 13.3 percent from 1995 until 2005. If we examine the period from 1998 to 2005 the increase is slightly more than 30 percent. As we examine subsequent years, it will be interesting to see if the large increase in IT enrollment in 2003 yielded even larger numbers of graduates in 2005.

When we compare the increase in IT graduates to the national trend in numbers of graduates of baccalaureate programs (Table 1), we must account for an almost two year delay in IPEDS reporting. Therefore, the comparisons in Table 1 only include the years 1995 through 2003. Over the same period, there was a 14 percent increase in baccalaureate degrees awarded in the United States while IT degree awards increased by only 7.82 percent. When one compares 1998 through 2003, the percentages look quite different with the national average gain in baccalaureate graduates at 13.9 percent while the IT gain in baccalaureate graduates is 23.7 percent.

Academic Year	US BS Graduates	NAIT BS Graduates
1995	1,160,134	6,565
1996	1,164,792	6,296
1997	1,172,879	5,726
1998	1,184,406	5,723
1999	1,200,303	5,766
2000	1,237,875	6,166
2001	1,244,171	6,148
2002	1,291,900	6,437
2003	1,348,503	7,079
Percentage Increase	14.0 %	7.82%

Table 1. A comparison of national baccalaureate graduation rates with NAIT graduation rates for a nine year period.

Engineering and Engineering Technology numbers reflect even lower throughput for the same time period. Figure 3 depicts the numbers of graduates for these two groups of programs as reported by IPEDS. Engineering Technology programs reported 15,829 baccalaureate graduates in 1995 and 14,656 graduates in 2003 or a decrease of 7.4 percent. Baccalaureate engineering programs fared somewhat better during the same time period. There were 62,257 engineering graduates in 1995 and 62,611 graduates in 2003 for a small increase of .57 percent. Baccalaureate programs in business experienced a 29.5 percent (226,623 reported in 1995 and 293,545 reported in 2003) increase in the number of graduates over the same time period.

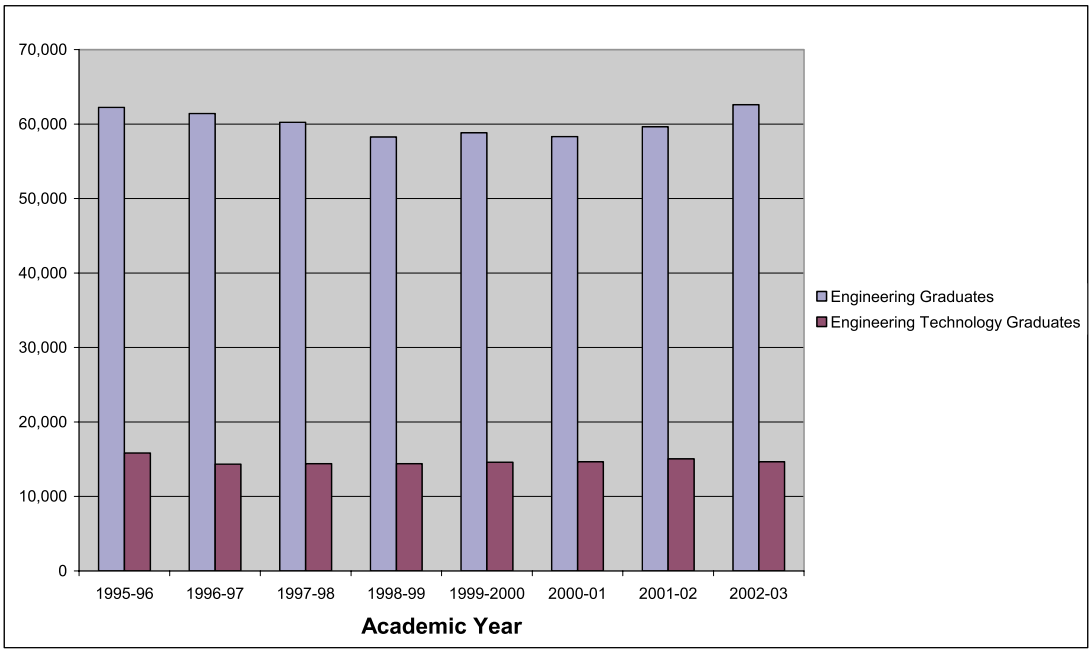

Figure 3. US Engineering and Engineering Technology graduates from 1995 through 2003.

Master's Level Enrollment and Graduation Trends

Master's degrees awarded in the United States have increased 26.2 percent from 1995 to 2003. The number of graduates has increased annually from 406,301 in 1995 to 512,645 in 2003. The numbers of students graduating with master's degrees in business increased 36.3 percent from 1995 to 2003. Engineering technology masters degrees increased more than 13.5 percent over the same period while engineering master's degrees increased 5.4 percent. It is important to note that individuals are seeking master's degrees at an increasing rate.

Figure 4 displays the numbers of master's students enrolled and the number of degrees conferred as reported in the NAIT Directory. When compared to the IPEDS data from 1995 through 2003, NAIT master's program enrollment dropped more than 29.3 percent and the number of graduates dropped more than 54.3 percent.

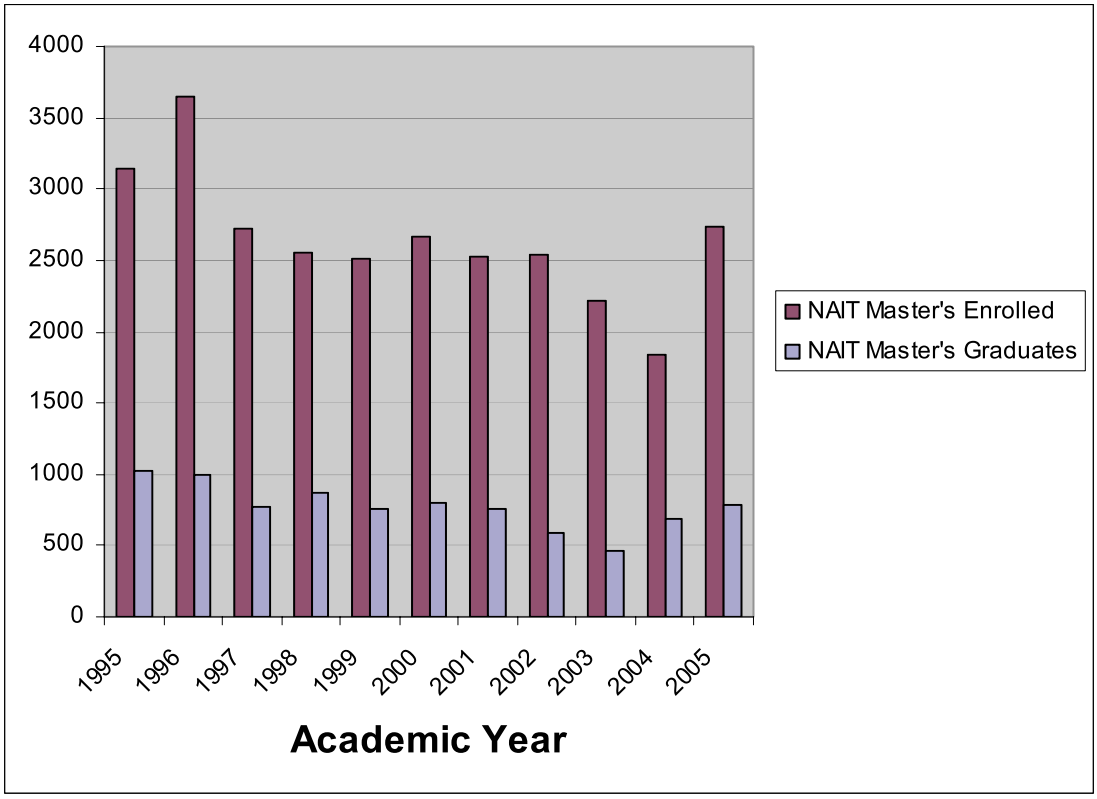

Figure 4. NAIT master's enrollment and graduation numbers from 1995-2005

From 2003 to 2004, NAIT master's degree enrollment decreased 17.1 percent as reported in the 2005 Directory for 2004 but experienced a dramatic increase (48.4 percent) as reported in the 2006 Directory for 2005. When the 1995 through 2005 period enrollment is examined, there was a decrease of 13.1 percent.

While NAIT master's program graduation numbers decreased 54.3 percent from 1995 through 2003 there have been increases for 2004 and 2005 as reported in the Directory which total slightly more than 69 percent. An examination of the number of NAIT Master's program graduates reveals that from 1995 to 2005 there has been a 22.8 percent decrease in the number of master's graduates. The data reveals that NAIT master's programs are lagging far behind the national trends. The increases for 2004 and 2005 suggest that some positive steps are being taken but the overall picture is quite troubling.

Summary and Recommendations

The graduation numbers for NAIT Baccalaureate programs reveal some slight increases but they do not approach the overall growth of the numbers of graduates of all baccalaureate programs in the United States. Industrial Technology graduation numbers are higher than those of Engineering and Engineering Technology programs when all engineering and all engineering technology programs are aggregated. Selected engineering technology or engineering programs will differ significantly from one another. For example, bioengineering may be increasing at a very high rate while mechanical and chemical engineering may be stagnant or decreasing.

The graduation numbers for NAIT master's programs have experienced some growth in the past two years but this area is in a crisis when compared to other disciplines. The dramatic decreases and fluctuations indicate that there may be reporting problems or other issues that cannot be determined with an effort such as this using currently available data.

Some interesting facts that provide some indication as to the level of impact of industrial technology baccalaureate and master's programs follow:

1. NAIT baccalaureate programs produce approximately 11.3 percent of the number of graduates that are produced by engineering baccalaureate programs in the United States.
2. NAIT baccalaureate programs produce approximately 48 percent of the number of graduates that are produced by engineering technology programs.

3. Business colleges produce more than 41 times the number of baccalaureate graduates than NAIT baccalaureate programs.
4. When compared to NAIT master's programs, Engineering Technology master's programs produce more than five times the number of graduates.
5. Engineering master's programs produce more than 62 times the number of graduates than NAIT master's programs.
6. Business master's programs produce 274 times the number of graduates than NAIT master's programs.

As indicated earlier, while examining the data for individual schools that were reported in the NAIT Directories, the validity of the data reported in the Directory has come into question. There is a need to ensure more accurate reporting since this information is the best that the National Association of Industrial Technology can gather regarding the health of the overall discipline. It is recommended that the procedure for collecting data from the various NAIT programs be modified to include the following steps. It is envisioned that support for these changes will be needed from the NAIT board and from the NAIT office staff.

1. Create a database file such as an Access file that is linked to the word document that forms the basis of the Directory.
2. Provide definitions of enrolled student that address second and third majors and whether students must be enrolled during the reporting semester to be counted.
3. Establish a timeframe for enrollment data that closely follows the tenth day enrollment data collected by IPEDS.
4. Provide a higher degree of specificity as to time frame and majors (how are second and third majors handled) when requesting the numbers of graduates of programs.
5. Require an approval of all submissions by the registrar of each university or college.

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CONTRUCTION

Learning Experiences for Professional Ethics in a Construction Curriculum

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Introduction

Construction Management (CM) graduates encounter situations that require professional ethical expertise. Ethical decisions are frequent in all businesses, including the construction industry. Unless students are exposed to codes of professional ethics prior to graduation, they may not have the opportunity to sufficiently reflect upon professional standards that can guide these workplace decisions.

In general, ethics courses are not designed to create specific beliefs or values; it is surmised that students have an ethical basis. These courses present options for making ethical decisions, and offer a methodology that helps decision making for the ethical dilemmas which the student will face. Creating or expanding student understanding of the need for ethical standards in construction is necessary in construction management programs, given the ethical dilemmas which occur in any business operation. The consequences of large disasters caused by poor ethical decisions such as the levies around New Orleans are reported in newspapers, magazines, and on television. Smaller deviations from ethical standards are seldom reported and students are less familiar with the consequences.

The intent of this study is to determine whether exposure to professional ethical codes and reflection on their application in real-world situations can prepare students to better solve real world problems. This study investigates both quantitative and qualitative methodologies of traditional undergraduate CM students solving ethical questions. In order to examine the efficacy of decision making, three different pedagogical approaches to teaching ethics in a construction curriculum is explored. All three techniques encourage learner centered problem solving, critical thinking about ethical issues in the workplace, and reflection on real-world situations. Therefore, this study explores the introduction of students to ethical problem solving using three different methods: quantified principlism, industry panel discussion, and traditional in-class case study. This study seeks to determine which methods improve the moral decision making of students in a traditional undergraduate setting.

Literature Review

Need for Ethics in the Construction Environment

The construction environment is one of the largest industries in the world, with a high degree of complexity and multi-faceted problems. As such, those working in the industry are sometimes faced with ambiguous circumstances that require decisions based on ethical standards. In his paper, "Foundations of Ethical Judgment in Construction," Ohrn (2002) outlined the ethical codes of two professional organizations: the Construction Management Association of America (CMAA) and the American Institute of Constructors; and two construction organizations: the Bechtel Group, and the Barton Marlow Company. Each code demonstrates that ethical standards and reputation within the construction industry are important in both the construction profession and construction organizations.

Ethical decision making in construction curriculums

In addition to Codes of Ethics, curriculums that educate constructors and construction students emphasize ethical decision making as an important concept for managers to understand and employ. For example, construction management program

accreditation from the American Council for Construction Education (ACCE) requires that students receive education focused on ethics throughout the construction-specific curriculum (ACCE, 2004). Similar standards can be found for accreditation of construction engineering programs from ABET.

Therefore, both industry and education acknowledge the importance of ethics in the construction environment. However, Riley, et al., (2004) found that several students expressed the opinion that current education does not prepare students to approach ethically ambiguous situations. Others said that they lacked the analytical tools and training to frame the situation and respond to it appropriately.

Tools for ethical decision making

Efforts are underway in different sectors to provide tools and guidelines for ethical decision making. The Center for the Study of Ethics in the Professions at the Illinois Institute of Technology (IIT) created a web site which provides guidance on using codes of ethics. It also lists an index of professional codes of ethics (http://ethics.iit.edu/codes/). The IIT site emphasizes that codes of ethics are only created in response to actual or anticipated ethical conflicts. Considered in a vacuum, many codes of ethics would be difficult to comprehend or interpret. It is only in the context of real life and real ethical uncertainty that the codes take on any meaning. The site also points out that case studies provide practice at thoughtful moral decision making, which is what makes the codes seem both necessary and real (http://ethics.iit.edu/codes/Users_Guide.html). Using case studies brings reality into the curricular design and overcomes some of the pedantic objections of CM students.

At the University of Puerto Rico, Cruz and Frey (2003) attempt to address ethical decision making by providing day-long workshops for other university faculty. During these workshops, faculty developed innovative ways to solve ethical conflicts, showing that studies and research can inform the design of curriculum which centers on ethics. By studying the research, instructors are exposed to many facets of ethics. Glover et al. (1997) followed their early research with a study that considered societal and demographic aspects that impact ethical decisions. Weber and Wasieleski (2001) state that most researchers "often focus on what the decision maker might do rather than focusing on the moral reasoning used by the decision maker (p 80)." Christabel and Vincent (2003), after discussing the status of ethics research in surveying and construction, also emphasize moral theories and how "different subgroups of quantity surveyors placed their emphasis on these … criteria differently (p 45)." They statistically demonstrate that "the more ethical training quantity surveyors have, the better their ethical perceptions of contemporary ethical theories can be explained (Christabel, 2003, p 47)."

Harris and Moral Theories

Harris, in his book Applying Moral Theories, suggests that a person can approach ethical dilemmas more confidently and consistently if there is an underlying understanding of moral theory. After an in-depth study of ethics and moral theories, Harris analyzes strengths and weaknesses of some basic moral theories, and then applies the theories to several cases. Harris also explains that people can disagree on the ethical correctness of a decision based moral theories they hold to most strongly. Harris (2002) suggests that, when dealing with controversial issues, each individual chooses which theories are the most relevant to the issues.

Literature review conclusion

Ethics in the business world has been well documented. Loe et al. (2000) assembled a review of ethical decision making studies. There was a paucity of studies concentrated within the construction arena, signifying the need for further research. Cruz and Frey (2003) discuss the importance of having ethics in all classes, the ease of doing so, and the support an overall emphasis on ethics offers a stand alone ethics course.

Teaching Methodology

Three different methodologies were used to introduce students to ethical problem solving. The methods are characterized as 1) analytical presentation with qualitative survey and case studies; 2) external industry panel with qualitative ethics survey and case studies; and 3) traditional lecture/class discussion about ethics in construction, case studies and qualitative response. All three methodologies presented guidelines to help students determine what constitutes professional ethical behavior.

Quantified Principlism

Quantified principalism includes a discussion of ethical principles, and construction organization codes of ethics,; in addition, a numeric weight is given to the principles providing a quantification of the final decision. Students were introduced to three traditional ethical theories: means-based, ends-based, and virtues-based. Rather than discussing utilitarian, or teleological, ethics (where the ends justify the means), ends-based decision-making was used. Deontological ethics was defined as means-based (where life is lived by an unchanging set of principles, moral rules, or duties). Virtues-based ethics focuses on what are good character traits as opposed to good actions.

Students were not unfamiliar with these principles. Economic perspectives in society often use utilitarianism as their normative base. An example of this is the cost/benefit analysis; it does not take into consideration how the gains and losses are distributed. Religion often uses deontological ethics as a normative structure. Both a pre- and post-survey were given to students given the quantified principalism treatment. In addition to ethical theories, a rubric was applied to student answers to establish whether the AIC code of ethics was met in the solution.

External Panel

The treatment for this class was an external panel of construction industry professionals who discussed case studies specific to construction. Students listened to the discussion. These students were given the same pre and post-survey given to the class with the analytical presentation after the panel discussion. In addition evaluating the survey for adherence to ethical theories, a rubric was applied to student answers to establish whether the AIC code of ethics was met in the solution.

Traditional Lecture

A traditional lecture/class discussion format was used to introduce the AIC Code of ethics and one case study was analyzed in class using the Code as a standard. Justification for a decision was stressed. The students were given an assignment directly from ACI's Program of Construction Ethics. Six case studies, questions about those cases, and the ACI Code of Ethics were included (ACI, nd). Students submitted written responses to the questions. During the class period that the responses were due, a class discussion was held. Students responded orally to questions about the case studies. After the discussion, final question was asked of the students: What did you learn from the assignment.

Evaluation of ethical constructs in student responses

Students in the qualified principlism treatment and in the external panel treatment, completed a pre- and post-survey using the "Visions of Morality Scale" (Shelton and McAdams, 1990), which measures three constructs of the students' private, interpersonal, and/or social morality. The survey composes examples in the following categorical constructs: Private is defined as an ethical act with no known beneficiary; an example of this was volunteering at your school to be a greater or a parking attendant. Interpersonal is defined as an act with a known beneficiary; an example is volunteering for a fundraising to benefit someone injured in an automobile accident. Social is defined as a benefit to the public or society; an example of this was conserving energy (Bringle, et al, 2002).

In addition, grades were apportioned using rubric to evaluate student's responses to four construction case studies. The rubric listed ends-based, means-based, and virtue-based decisions, and the AIC Code of Ethics, as part of the evaluation. The traditional lecture/class discussion methodology exposed students to other student's opinions when the class discussion was held. The instructor often took the unpopular side of the controversy, encouraging students to explain how they arrived at their decision. The discussion was used to model engaging in respectful discussions with others holding different views; examining the meaning and application of professional codes of ethics was also encouraged. The class period was used to establish how students can carry their beliefs into their professional lives by ethical actions. Emphasize was made that some of the actions were on the part of management; some were on the part of employees. Further discussion was focused on increasing student understanding of how to develop codes of ethics for their individual firms when they enter the construction industry.

The traditional lecture/class discussion treatment used constructs from the AIC category designations of: 1) contractors and owners, 2) contractors and architects/engineers, 3) contractors and subcontractors, 4) contractors and vendors, 5) contractors and other contractors, 6) contractors and their employees, 7) contractors and the general public (AIC, nd).

Commonality of three methods

In all classes, and with all treatments, students were asked to make a decision using a standard or a theory as a justification for that decision. By stating a standard based justification, it is believed that CM students will be able to make consistent decisions across a broader spectrum of ethical challenges.

Analysis

This study was structured to determine 1) how students responded to different methods of teaching ethics 2) if students accepted the need for an external justification when making their professional ethical decisions, 3) if students applied the external justification when making their ethical decisions, 4) if the students learned anything which they believed they would later apply.

Analysis of the survey results from the participants who received the quantified principlism treatment and the external industry panel treatment produced no significant results. This may reflect the small number of participants (n = 90), or

discussions between the two groups outside the classroom. Students given the traditional treatment were not given the same survey. However, students' grades on the case analysis, using the above describe rubric, were found to be significantly higher for the quantified principlism group over the external industry panel group.

One factor stood out when the responses to all classes were analyzed: Students did not readily accept the need for external justification when making professional ethical decisions. Although students given the traditional treatment were given specific instructions to list their justification for their decision by citing the code which applied to this situation from the AIC Code of ethics, less than 20% referenced the code as instructed. All students, however, completed the assignment and made a decision about the ethical question.

The some student's resistance to applying the code may be summed by one comment

> I think everyone has their own opinions when it come(s) to ethical decision making. The way they were brought up and the morals they were exposed to will ultimately decide their personal values. This exercise did not sway how I would respond to ethical decision making, but it did reveal situations I had not thought of.

Many students echoed how surprised they were about the complexity of some of the situations, and the lack of a clear right and wrong. Comments similar to "I found out the ethical may not be so ethical", "I learned that ethics are not black and white", and "I gained an understanding that there is a lot of gray area in deciding what is ethical and unethical, therefore when I get into the field I should watch what I do and make sure it is ethical" were common.

Perhaps the most rewarding comments from an instructor's standpoint reflected the sentiment that "I gained a little bit of knowledge about myself. These were difficult circumstances and finding how I reacted was pretty interesting,"; "From this exercise I learned that I need to think about how important my decisions are. My decisions can affect so many … other things."; and, perhaps the best of all, "It gave me a lot to think about."

The most common comments were the student's appreciation for other's opinions. Over half of the 46 student's in the traditional/discussion class expressed appreciation for hearing other's opinions. The discussions forced students to reconsider their answers, even if they did not change them. One comment was "I gained the knowledge that some of the issues that I thought were unethical could be looked at in a different light and seen as ethical. Also some issues that I thought were ethical might not be." The discussions also allowed the instructor to model tolerance for others outlooks and opinions. The assignment itself, according to student comments, exposed students to situations which they had never encountered, and did not know existed, such as front-end loading.

Conclusion

Ethical studies in construction management education is mandated, not only by accrediting agencies, but by the society in which we live and the companies that employ CM graduates. It is believed that exposure to professional ethical codes and reflection on their real-world situations can prepare students to better solve real world problems. The researcher's belief that students have an ethical basis when they reach the classroom was reinforced by this study; however, further research is recommended to determine what code is applied to construction scenarios and if that code can be modified by undergraduate pedagogy. If students are reacting to "the way they were brought up, and the morals they were exposed to," and if that code remains entrenched in spite of educational efforts, are they applying a theoretical moral code, a religious standard, or some informal casuistry (case analysis)? Because casuistry occurs when a problematic situation is compared to a clear situation, and reasoning is done by analogy, it is possible that students were comparing the situation to some other case in their past which had a clear justification and outcome.

Encouraging discussion remains a positive way to teach applied moral concepts in various situations, and case studies remain a valid method of introducing real world scenarios. Teaching respect for other's opinions, encouraging reflection, and promoting consideration of ethics in CM graduates remains a valid reason to engage in ethics education.

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Linking the Construction World through Technology

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Introduction

Linking construction education with construction practices is an important and necessary pursuit required when teaching in any professional school. The foundation of the education must be relevant, current and viable. The more one can bring the world of practice together with education the more relevant the education and the better prepared students will be for the profession when they graduate. This has always been the mission of professional school and this has always been a struggle within professional schools.

In times past, schools drew their faculty from the professions and many faculty were both practicing and teaching simultaneously. In more recent times and with the expansion of school and the varied locations of professional schools the problem of relevant professional education has become even more evident. This issue is more significant today because the gap between education and practice has widened. The continuous trend for faculty members to be more research oriented has made it more challenging for professionals from the field to become teachers in traditionally professional schools lacking the skills in inquiry and dialectics required in today's educational setting. In trying to reconcile this dilemma the Department of Construction Management at East Carolina University is using technology to link the distance between education and practice, between theory and knowledge. Linking these two worlds can be accomplished through the use of various composite technologies that bring the field into the classroom and the field to the office in live and interactive audio and video formats. The linking process not only enhances learning opportunities for students and faculty beyond the traditional education but they open doors to places most have never been (Panettieri, 2006).

Links in Construction

Linking is the means by which we can bring together the separation between construction field activities to office or classroom settings. These links are applicable in the educational and professional setting. How are these links made? *Communicating* links have been in used with cellular telephonic and facsimile technologies. These tools have dramatically changed the speed and accessibility of information (Sawyer, 2004). Shortening the information lag can be accomplished with the use of the Internet. Web based applications such as McGraw-Hill Construction (http://www.construction.com/) uses the internet as a repository and allows individuals to access recourses from across political, physical and cultural boundaries that can and will expedite construction and education.

Wireless networks placed on a job site can bring immediate construction activity to the attention of project managers, teachers, students, and others who can benefit from real time observation of field activities. Observing a concrete slump test, inspecting steel, documenting a testing procedure can save time, money and improve the quality of the final building project. A wireless network will serve to reduce accidents from being on site, reduce decision time and document the decisions in a natural and immediate time frame.

Documentation of these activities is easily managed with file exchanges and shared applications. This technology allows changes to be made in real time on location immediately that once took weeks to circulate among the respective parties. The RFI process can significantly reduce time and miscommunications and in the process improve productivity and quality.

Interactive audio and video teleconferencing technologies are available and easily managed for desktop or laptop applications. These technologies simulate faced to face communications with live video and audio capabilities. With up to 16 FPM on standard quality desktop cams the imagery is close to TV quality making the meetings more life-like and natural. Sound quality is highly reliable and has little to no lag in across the internet discussions. The ability to initiate and conduct a meeting with engineers, architects, consultants and clients, simultaneously can reduce or eliminate the need to travel and meet in a singular location. Linking work related colleagues from office to field, office to office, field to classroom are made possible using NetMeeting, Polycom, Click-to-Meet or other programs designed for these purposes.

Benefits of Linking Construction to the Classroom

Teaching and linking to the site will make the construction knowledge exchange immediate and interactive when utilizing a field cam and field conferencing node. The field conferencing node is a network of wireless mesh links that allow information points that are dynamic Utilizing a wireless mesh permits the audio/video interaction to move with the construction activity that will vary in location over the different construction phases. Providing this information immediacy from the construction site to the classroom will enhance the educational experience of students in a professional program. Students become more animated and engaged in the learning process (Rivero, 2006). In the practice context, a project manager can resolve problems in less time and keep the construction schedule on time and/or reduce it in comparison to the conventional approach. If time constraints are reduced then mistakes are less likely to occur, a safer work place will be maintained and a higher quality product should be the result.

Bringing field activities to the classroom, such as testing materials, conducting pours, quality inspections, safety observations, bid openings and deliberations of unique construction processes are all within the scope of the technology. Visiting a job site can now be accomplished remotely with the technology and permit interactive discussions as the work takes place and not only alleviate the safety hazards of large numbers of visitors on the job site but also permit those with accessibility issues visit the site and gain knowledge in real time. Providing real-time knowledge of the field makes learning relevant and provides a connection to the work place that students will take place in the future.

These benefits are not limited to the educational arena only but have parallel validity in the construction practice. Immediate access to real-time activity in the field is pertinent to on-time schedules, documentation of decision making and managing the construction project more thoroughly.

Building the Link from Field to Classroom

To link classrooms and the field effectively, many obstacles have to be overcome. Access to the Internet either through wired or wireless have to be available in the field. A video conferencing system with sufficient capabilities is required to serve as the platform of video and audio communications. Conducting live video conferencing could be challenging to the novice user, especially in educational settings with larger number of students at multiple locations.
Internet connections are currently available through 3G mobile phone network with most major carriers. This type of connection usually provides coast to coast coverage with a monthly subscription fee. Due to the fee structure, it is not the most cost effective option if service is only sporadically used. The connection has limited bandwidth and is composed of less than flexible configurations. These factors make this type of Internet connection a less favorable choice for our case in particular.

On the other hand, a Wi-Fi based wireless network attached to a fixed broadband Internet connection solves most of the problems aforementioned. Our efforts established a wireless mesh network in the field with an off-the-shelf product from Firetide (Firetide, 2006) and achieved a fairly satisfactory result. The network was highly configurable and able to deliver acceptable connections in terms of stability and bandwidth within a limited coverage area. This type of system has the capability to cover a middle size, 50,000sf construction site and deliver both video and audio streams with quality acceptable for classroom interaction.

Lessons Learned

In any instance where one the area of inquiry in new and applications are adapted or newly developing, there are always issues that cannot anticipate. Often when working within this context failures are frequent, however we are certain that without failure progress is not possible. In taking an experimental position, most of what we have done may not have a precedent. In this context, we offer these few but personally experienced lessons. Our lessons are based on the recent

efforts conducted over the period of past three years. The earliest lesson came from the development and implementation of a multi-site interdisciplinary online class using a myriad of technology systems for interactive audio and video teaching. We followed that effort with a series of exercises, a wireless mesh connecting a job site to a remote conference, a faculty meeting with multiple remote participants and the most recent was a live class from Beijing, China in which students were interacting live from their lecture hall class with the instructor using desktop A/V and web based servers to link the two distant places in real time. From that experience, we have summarized a few key points that we think are worth noting:

- Most software applications were functional on most computers, but some parameters must be minimally established for collaborations in using shared files and various interactive communications applications. In some instances, we only learned from trial and error about these issues. The implication for experimental approaches is that it is a requirement for participants, faculty, managers, and students to seek solutions when none seem to exist; failure is not an option. For example to support video conferencing a minimum of high speed internet connection are a must. Feeding into a video conferencing program with high resolution can collapse/crash a meeting; therefore, at times it actually works more effectively to use lower resolution, i.e. cheaper equipment than the more expensive equipment.
- Computer configuration and settings across collaborating members of an audio/video conference must be coordinated. Incompatibilities sometimes cause extra burdens to technical support.
- Greater participation requires a higher degree of cooperation (protocols) and planning. The natural flows of communications that are the goal of the technologies require high level of activities that begin to connect participants together in the virtual medium (Smith, 2005). A social trust must be established between participants whether having equal or hierarchical communications. The online setting requires that participants, teacher and student alike, manager and labor, believe they are working as a team in order to have successful interactions. (Aviles, 2005)
- Failure must be anticipated with back up plans and systems to maintain the communication links, e.g. Firetide mesh is inherently redundant to keep communications continuous and natural, and the same must be for all communication and shared applications. How about keeping more than one channel of communication open, such as a text chat.
- A progressive proactive attitude that looks beyond the conventional thinking, applications, a type of "out of the box" thinking, where an intentional paradigmatic shift is necessary. Using any and all means to achieve a goal is a productive and appreciated attitude that leads to improved learning situations (Stahmer, 2006). Collaborative and dialectic thinking is conducive to more innovative solutions and a diversity of thinking is advantageous in this new context.
- We have spoken in general terms of various activities and capabilities but how are these specifically accomplished? There are many competing software and hardware manufacturers and they are continuously emerging. Our experience has suggested that no singular option offers all solutions and one must use the tool that best fit the task. Some tasks require a composite of technologies and some of these may not be compatible and yet there are no other current options.
- Equipment cost and emerging new technology must be anticipated. The Firetide equipment we used was not the most current yet we were able to adapt to achieve satisfactory results.

Conclusion

Linking construction to the classroom is just one of many possibilities that technology can help achieve. Linking construction education with construction practices is important to the success of a construction management program. With a reasonable amount of effort, we are able to establish links that provide experiences gained from the technology process. The classroom will have no bounds (Villano, 2005). The application of technology for practical and useful purposes demands that we use technology with results. Developers and users of technology have different purposes, but when the two intersect a synergistic event occurs. When the previously separated are 'linked', technology has emerged as we knew it could.

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Task Diminishment: Construction Value Loss Through Sub-Optimal Execution

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Introduction to Task Diminishment

Ledbetter & Burati (1989) defined quality as "conformance to requirements." This definition assumes that a 'requirement' has been specified and mutually accepted by the contract purchaser (owner, agency, prime contractor, etc.), and the contract holder (vendor, consultant, contractor). This definition also presumes that any non-conformance to a contracted requirement would diminish quality, or diminish the value of the mutually accepted contract requirement.

The contract purchaser's requirements or 'expectations' are defined and implied by project specifications, plans, terms and conditions, and other assorted contract documents. According to Bertelsen and Koskela (2002), these construction requirements or expectations represent a generated value for the client. Bertelsen and Koskela (2002) describe how the construction process generates value for the client: "a series of processes; forming a workflow drawing on transformations delivered by the trade contractors under a contractual arrangement with the client – either direct or through a GC."

If construction generates value through the execution of contractual requirements, then any variance to those specified requirements would diminish value. In this manner, variance to requirements provides poor quality in Ledbetter and Burati's (1989) definition, or value loss according to Bertelsen and Koskela (2002).

By the definition above, value loss would occur whenever the actual delivered task is at variance to the specified, contracted, or purchased task. Task diminishment identifies the value gap generated by the sub-optimal execution of a specified task. Although value loss can result from productivity loss, and design errors, and governmental interference, etc., this research will focus on value loss generated by the sub-optimal execution of specified tasks. With regards to a required contract task, any variability between the value of the expected task, and the actual value of the delivered task, can be described as task diminishment. A construction task that is not completed per the contract specifications, terms, conditions and plans, or other contractual infringement – and not restored -- is task diminishment.

Tasks can be diminished in all trades, independently. Therefore, task diminishment by contractors is not due to task diminishment in design. Task diminishment in the defect liability period is not the results of task diminishment in the construction phase, etc.

Diminished tasks are not discovered by normal methods of process control and QAQC. The task diminishments are non-restored, and linger to degrade the value of the delivered project. This is an important distinction, and diverges from previous research. This point was underscored in Abdul-Rahman's (1997) survey on quality cost loss. A QA manager for a construction service provider responded to a survey question with the crux of the premise behind task diminishment: "Site management will record the failure of others [subcontractors], it's the unrecorded [failures] that holds the key." Similarly, Barber et al, (2000) described the inability of normal process control and QAQC to identify all sub-optimally executed tasks, another key tenet of task diminishment: "… the sheer size of the construction site … meant that, while the researcher was focusing on some activities with one managing engineer, it was highly likely that failures were occurring elsewhere … ". Although previous research has thoroughly discussed rework, and the costs of correcting quality defects, this research describes the persistent value loss from diminished tasks in the delivered project.

Findings - Case Study: Big Box Retailer

In the fall and winter of 2005, an audit analysis was conducted on $120 million worth of capital construction projects for a retail/commercial development company. The host company spends approximately $4b in capital upgrades annually. The audit identified and analyzed all non-recovered loss examples, their causes, reasons, documentation and comments from the project stakeholders. The audit identified 16.44% in task diminishment value loss.

This audit was not a financial audit, nor was the audit exhaustive in any manner. The researcher examined archived files from 2002, 2003, and 2004. In addition, 2005 active files and site activities were examined during this audit. Specifically, defect notices, change orders, quality reports, bid documents, photo journals, arbitration transcripts, pay applications, close-out punch-lists, warranty logs, defect claims, quality reports, and open work order reports were reviewed. In addition to file audits on historical projects, site visits outside of normal protocols were conducted on works in progress. Variability in any site visits, or analyzed documents were annotated and investigated. The variance investigation ultimately led to a vetting process, which included stakeholder interviews, and costing exercises. The investigated item was identified as a value loss – or not – and costed as appropriate. The amount of the contract associated with the loss was either retrieved from the file, or from the prime contractor, or estimated using standard construction costing methods. A per cent to total value loss was then assigned. The losses were then logged into an audit log. The audit and interviews vetted 261 examples of task diminishment through 2005, although hundreds of identified task diminishment examples are still pending investigation and vetting.

Diminished tasks are execution errors that were discovered exceptional to normal project controls and processes. If a defect is discovered within normal QC processes, or through the normal process control procedures, and restored, then this is not lost value, and was not logged. If a loss was discovered by the quality control contractor, and the project manager and the contractor were notified through a defect report, and the item was corrected (even though it caused rework), this was not task diminishment.

The 16.44% in losses associated with task diminishment were more significant than the original assumptions, but conservative in light of their potential magnitude. It is important to remember that the audit was largely inchoate. The total losses mean that the owner receives about 83 cents of value for each 100 cents expended. If previous productivity research is correct, then before the execution phase starts, the contract is already starting at a greatly diminished value.

Task diminishment resulted in value loss in five principal categories: quality/non-conformance to specified work tasks; administrative/process non-conformance losses including fraud; loss associated with failure to collected warranty; non-recovered credits owed from all parties; and inefficient legal deployment costs. Table I is a summary of these loss categories.

Table I. Summary of Loss Categories

Non-Conformance to Quality Specifications	$6,900,155	34.72%
Admin/Process non-conformance including fraud	$5,580,161	28.08%
Warranty Recovery loss	$4,235,654	21.31%
Unrecovered credits owed from all parties including EO.	$2,480,164	12.48%
Inefficient legal deployment	$677,472	3.41%
Total Loss	$19,873,606	100.00%

Measuring Task Diminishment

Quality non-conformance during task execution was the largest contributor to the total observed value loss from task diminishment. Quality losses of $6,900,155 (34.72%) were observed during the project audit analysis. Quality task diminishment occurs every time a construction task was performed in variance with the specified task.

There were 261 examples of non-restored defects provided in the audit defect log (includes all categories). Random examples of quality defects include: improper utility backfill procedures; failure to replace joint material prior to the warranty period expiration; improper joint filler installation; sub-optimal sub-grade construction; incorrect welding; poorly trained quality control inspectors; improper slab construction; poor roof installation procedures; improper electrical

installation procedures and material; highly variant asphalt concrete paving thickness; non-conforming painting procedures; skipped welds; roofing membrane not adhered according to the contract; and oversight errors, etc. Quality breakdowns were accrued all along the execution spectrum.

Taking an example from the log, we can see how a value loss was measured. When the utility line backfill specification is diminished, what is the value loss to the contract purchaser (client)? The cost could be measured during the facility's life cycle by the costs it requires to repair the subsiding trench. In one case in West Fredrick, Maryland in 2004, a utility trench subsided so much that forklift traffic was impeded while trying to off-load delivery trucks. A warranty claim was not perfected because the defect was noticed beyond the defect liability period. Therefore, a service provider was called to enact the repair at a cost of $13,644.00 on the subsiding trench. This was task diminishment for the utility contractor, the prime contractor, and the quality control contractor. The initial value of this task diminishment is $13,644.00 from a total contract amount of $344,817.00 to the site/utility contractor. If this was the 'only' diminished task on the utility contractor's contact, the task diminishment would be 4%. However, it could be assumed that the entire utility trench was installed in a non-conforming condition, even though a failure was noticed only in the area of forklift operation. Therefore annotating this diminishment across the entire trench cost could be justified. In this case study, however, only the actual cost of the repaired area was annotated. West Fredrick was partially audited during the audit phase with forty-one examples of task-diminishment for a total value loss per cent of 9.38% for this project. A partial excerpt from the audit log is provided in Table II.

Table II. West Fredrick, MD.

15-Acre Development with 140,000 sf Structure.

Responsible Party	Type	Original Contract Value	Diminishment Value	Per Cent Loss	Discussion	Attachment
Sub-contract; Floor	NCQ	$166,400	$62,400	37.50%	Specifications (3900) require eight steps of progressive concrete cutting and polishing. Only five steps were provided. Lack of sheen after delivery of project caused interviews with contractor and QC firm. QC firm did not observe or provide oversight, and contractor stated that the slab only needed five steps, rather than eight. Sub-contractor refused to provide remedy because site has been accepted, and defect notice wasn't issued.	Fotos
QC Contractor	NCQ	$38,000	$2,600	6.84%	Specifications (1400) require ITC to observe all eight steps of progressive concrete cutting and polishing. ITC oversight was not provided, which may have lead to task diminishment. QC firm did not observe or provide oversight, and contractor stated that the slab only needed five steps, rather than eight. Sub-contractor refused to provide remedy because site has been accepted, and defect notice wasn't issued.	Fotos
Sub-contract; Utility	NCQ	$13,644	$344,817	4.0%	Poor compaction on a utility trench in the rear of the store (see photos) caused the trench to subside. The subsidence impeded forklift operation and the store called the MSC. The general contractor was given the call, and the temporary patch they provided failed and greated a worse condition. Finally, the GC corrected it on 7/12/05	Fotos

Prime	Warranty Loss	$25,266	$111,455	22.67%	Total warranty missed on Wfredrick. There were 83 warranty calls out of a total of 218 calls in the 11months of this store's life. Of the 83 warranty calls, 41 warranty items were missed at a total cost of $23,160.90	Work Order History rpt
QC Contractor	NCQ	$38,000	$1,400	3.68%	QC contractor did not provide mil thickness test as required. (section 1400, 9900) Review of quality reports on this project showed that there was no mil thickness test completed. $1400 is amount of retest cost.	QC Reports
PM	Admin	$146,600	$1,400	.95%	PM was responsible to review all quality reports and manage 3rd party QC company, and contractors on site. The mil thickness test results are a specific review requirement for the Project Manager. Mil thickness test was not performed.	QC Reports
Sub-contract; Utility	NCQ	$32,661	246,711	13.24%	Poor compaction on a utility trench in the rear of the store (see photos) caused the trench to subside. The subsidence impeded forklift operation and the store called the MSC. The general contractor was given the call, and the temporary patch they provided failed and greated a worse condition. Finally, the GC corrected it on 7/12/05	Fotos
Sub-contract Energy	NCQ	$23,000	$3200	13.91%	Only two visits from Entek are in the contract. GC is responsible – theoretically --- for any follow up visits in order to fire up life safety systems. In this case, as in most cases, THD paid the bill and no back charges to the GC were made.	Entek 3rd Invoice.
Sub-contract Mechanical	NCQ	$23,000	$3200	13.91%	Only two visits from Entek are in the contract. GC is responsible – theoretically --- for any follow up visits in order to fire up life safety systems. In this case, as in most cases, THD paid the bill and no back charges to the GC were made.	Entek 3rd Invoice.
PM	Admin	Incl	$3200	2.18%	Only two visits from Entek are in the contract. GC is responsible for any follow up visits in order to fire up life safety systems. In this case, as in most cases, THD paid the bill and no back charges to the GC were made.	Entek 3rd Invoice.
AE	EO	$133800	$1442	1.07%	Change order 10 was required because the City of Fredrick Bldg inspector required a floor drain in a room where there was previously not one. This was made from RFI #59. The inspector made the request because of the backflow preventor that was added to the system on TVA's dwgs. This was part of the code and should have been picked up by the AE.	Change Order

Prime	Admin	$322,710	$11,024	3.42%	Change order #16 is a great example of good PM oversight and correct mark up on material vs. labor.	Change Order
PM	Admin	Incl	$11,024	7.52%	Change order #16 is a great example of good PM oversight and correct mark up on material vs. labor.	Change Order
Prime	Admin	Incl	2759	.0038%	Several Problems, a.) back up losses; b.) approved back up in CO, not included in total billing; but PMs revisions put the missing charges – though edited -- back in the billing.	Change Order
PM	Admin	Incl	2759	.85%	Several Problems, a.) back up losses; b.) approved back up in CO, not included in total billing; but PMs revisions put the missing charges – though edited -- back in the billing.	Change Order
PM	Admin	$54,000	$32,000	59.26%	Duplicate contracts issued for land surveying to two different consultants. Both contracts were billed against, and no credit provided. On 1-27-03 a contract was issued to Bohler engineering for surveying based on BE's proposal of 10/11/02. This was for 6 acres. A revised proposal surveying 7. 5 acres was issued on3/23/03. An revision of the original contract should have been made.	Contract

There does not need to be a specific cost associated with non-compliance work for value loss to be realized. If contractual specifications are circumvented, or subverted or otherwise not followed, then the value of the delivered project is at variance with the expected project value. The owner expects the utility trenches to be back-filled per the specifications in the bid/contract documents. When the backfill specifications aren't followed, the owner receives less value than he paid for, regardless if the diminished task leads to manifested latent defects, or not.

Industry Significance

The contract purchaser (typically an owner, prime contractor, or municipal agency) purchases value by letting a construction services contract. The various construction service providers, or contract holders (vendors, consultants, contractors, etc.), on the other hand, are obligated through the exchange of fiduciary consideration to provide the value expressed in the contract documents.

The accumulation of task diminishment losses over the life of the project can be significant. According to the case study in this research, the value of task diminishment was 16.44% on audited contract values of $120 million. In 2000, the U.S. construction industry let contracts for a total of $US900B. Therefore, from a 2000 construction industry level, task diminishment could lead to over $US148B in lost value (Bogdan, 2000).

Unfortunately, and usually unknowingly, the contract purchaser receives a value less than what the contract documents stipulate. If the contract purchaser tenders a contract for one million dollars to build a bridge, then the expectation at project delivery is for one million dollars worth of constructed bridge value, pursuant to the specifications in the contract documents. This research will show that in fact, the bridge will be delivered devalued to the contract purchaser. This variability is persistent value loss due in part to task diminishment.

Deviations from Previous Research

Several researchers have veered closely to the premise of task diminishment by describing impediments to task completion. Koskela (1999) outlines seven preconditions to a construction task, and how variability in these preconditions prohibits task completion. In concert with Koskela's theoretical view, Ballard and Howell (1998), discuss how execution problems and quality failures prohibit task completion. Ballard and Howell (1998) estimate productivity losses can be around 40% for

assigned tasks. A staggering number, but very similar to the conclusions found in the annual Proudfoot global productivity study (Proudfoot, 2005). However, these researchers describe a productivity loss problem. Task diminishment, as described in this research is not typically related to productivity loss. Task diminishment describes the value degradation on tasks that are executed sub-optimally, rather than the loss incurred due to not accomplishing a scheduled task.

Further, previous research has viewed losses in construction from the perspective of the construction service provider (contract holder), and deal mostly with cost of quality, rework, and productivity loss. The general analysis of quality loss in previous research states that 'some reason' causes the construction service provider (contractor holder) to have to do certain work tasks more than once, or less efficiently than originally planned. The 'some reasons' vary widely from researcher to researcher. Basically, rework required more labor and material to restore the task to its specified condition, and therefore additional cost was unnecessarily expended. Ledbetter and Burati (1989), Love and Li (2000), Aoieong, Tang, and Ahmed (2002), Love and Sohal (2003), Abdul-Rahman, (1996), Barber et al. (2000), Alwi et al., (2003); Bertelsen, and Koskela (2002), and Josephson et al (2002), all discussed value loss in the terms of rework, cost of quality, wasteage, quality loss and productivity loss in relation to the construction service provider (contract holder).

In addition, task diminishment is independent of other causes. Therefore, task diminishment in the construction phase is typically not the result of anything in the design phase. The impact of design is a common component of most previous research into quality and productivity loss. In fact, Cnuddle (1991), Love and Sohal (2003), Alarcon and Mardones (1998), Burati, et al. (1992), Willis and Willis (1996), Howell and Ballard (1998), and Abdul-Rahman (1997), all attribute a significant amount of rework to design. The theory of task diminishment observes that design tasks may be subjected to their own diminishment, but does not cause diminishment in other construction phases.

Conclusion

The construction process includes multiple phases, and hundreds of tasks. Task diminishment can potentially degrade the value of any task, which in turn ultimately degrades the delivered value of the project. Task diminishment creates or exacerbates the variance between the specified task, and the delivered task. Task diminishment is a result of sub-optimal execution of the respective task, or tasks. Task diminishment can occur in every phase in the construction process including planning (entitlements), design and permitting, construction, defect liability and close-out. The expectations implied in the contract documents are supported by the exchange of financial consideration. Therefore, if the execution of the task is sub-optimal, or otherwise does not meet the expectations in the contract documents, then value is not delivered.

Contract purchasers need to understand how value is diminished on a delivered project. Contract purchasers should understand that QAQC programs do not prevent all quality breakdowns, and warranty recovery programs do not recover all warranties. Within these programs, sub-optimal execution degrades the effectiveness of these programs through task diminishment, and value erodes as a result.

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EECT

Applications of Wireless Sensor Networks in Industrial Environments

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Abstract
A wireless sensor network empowered with the ability to coordinate on large sensing tasks in a self-organization mode will provide unprecedented potential in monitoring, instructing and controlling our world and environment. This paper presents wireless sensor networks and their industrial applications. Characteristics and architecture of wireless sensor networks are first discussed and the benefits of their potential use in industrial environments are presented. Design issues and specific requirements of the industrial applications are investigated and possible solutions to the design challenges are discussed. Wireless technologies that may be adopted in wireless sensor networks are also discussed and their advantages/disadvantages are compared. Several examples of the experimental industrial applications, including wearing part detecting, power monitoring, part assembly, and cold chain management, are demonstrated.

Introduction
The consecutive progresses in microelectronics and wireless networking technologies have led the development of low-cost, low-power, and multipurpose wireless sensor networks. The advance on MEMS (Micro-Electro Mechanical Systems) and other microelectronics technologies enable the miniaturization of sensor nodes that integrate sensing, computing, and wireless communication capabilities. Sensor networks are envisioned to consist of a large number (hundreds to hundreds of thousands) of small-sized inexpensive sensor nodes. These wireless sensor nodes can be deployed across a certain

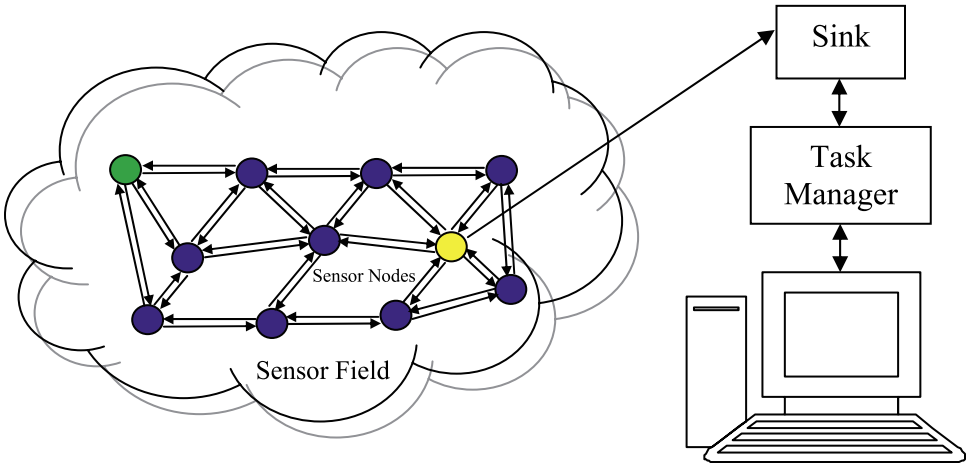

Figure 1: Wireless sensor network architecture

environment and work together between themselves to collect, process, analyze and distribute data within the network. The system may start to operate without human intervention in a robust and autonomous manner, and also may provide the capability to adapt to diverse environment and unforeseeable situations. The general view of a wireless sensor network is illustrated in Figure 1. The information collected at sensor nodes can be sent locally or to one or more collection points through wireless links. Through their ability to monitor their surroundings and to provide detailed data in a self-organized mode, sensor networks have tremendous potential applications to benefit a broad range of sectors. Wireless sensor networks (WSNs) are anticipated to promote a diversity of application domains that essentially depend on low profile real world observations in industrial environments.

WSN in Industrial Environments

The applications of wireless sensor networks in industrial environments may bring many benefits, including cable free easy installation, easier maintenance, lower cost, selective installations, and easy information process and management. WSNs can be used to keep the work environment safe and in healthy condition, particularly in nuclear reactors, and chemical production plants etc.

Nowadays various types of sensors are in use for almost all industries. They are used for all sorts of applications, from monitoring a machine instrument in a manufacturing plant to organizing a chemical process in a hazardous environment. Usually, cables are required to connect these sensors back to a centralized screening/control station. In this situation, each cable may enclose several wires for both power supply and data transmissions. Proper cabling of sensors is sometimes a bottleneck because it is tedious to find and install the right type of cables for various types of sensors and maintain wire chains. When functioning with a small quantity of sensors, this does not look like a troublesome task. However, if a large number of sensors are considered, it would be a difficult task to select, install and maintain cables. For instance, dozens of sensors may be used to monitor various thermal parameters in a manufacturing facility; thousands of sensors monitor the radiation level in nuclear power plant; tens of thousands of sensors monitor temperature changes and conditions in chemical plants (Gilsinn & Lee, 2001). Using WSNs, the received data can be transmitted through the wireless network, therefore not only the troublesome cabling job can be totally eliminated, but also a much flexible solution is provided for many applications. For example, remotely evaluating the condition of devices like rotating machinery or automated assembly lines in manufacturing using the comprehensive data collected by a sensor network can help to plan maintenance tasks and develop preventive maintenance. Because industrial activities often operate in hazardous or remote locations, WSNs offer a safer and easier way to perform monitoring and control tasks.

In the following, we will introduce the architecture of sensor nodes and discuss the features of WSNs. Then we will investigate the specific requirements of industrial applications on WSNs.

Architecture and Characteristics

As we mentioned before, the progress of hardware technology in low-cost, low-power, small-sized processors, transceivers and sensors has facilitated the development of WSNs. A sensor node consists of three main components: the processing module, sensing module and the communication module. Figure 2 demonstrates the typical architecture of a wireless sensor node.

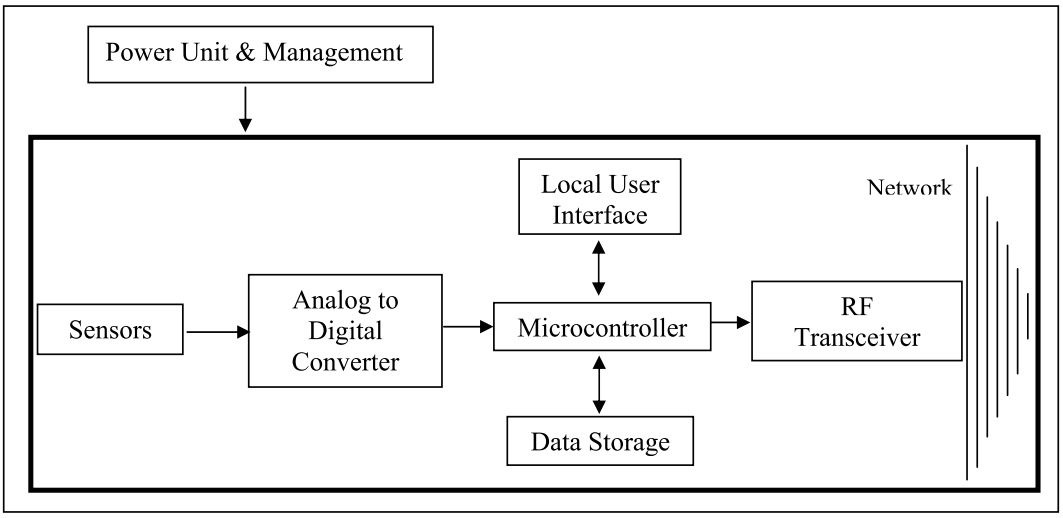

Figure 2: Wireless Sensor Node Architecture

The nodes in the emerging wireless sensor networks will be un-tethered, with limited energy resource from power units (usually batteries), rather than power lines. Power units must be attached to them before the sensor nodes are deployed in the specified environments. Another promising way to power sensor nodes would be to have them receive power from their surroundings. This type of device is named as ambient-powered sensor nodes. A power alteration component would be designed to take energy from heat, light, sound, vibration, or any other source of energy available from the environment. Advances on energy technology along with the availability of the ultra-low-power devices, will make ambient energy source support possible for the future wireless sensor networks. It can be envisioned that the wide use and deployment of maintenance-free wireless sensor networks in various environments.

One of the features of WSN is for its extended coverage and easier deployment. The number of sensors may be hundreds or even hundreds of thousands and the coverage provided may be much larger comparing to that by a single-sited sensor system. The overall coverage of a sensor network is the union of many small coverage areas of low-cost sensors, so the coverage is more flexible and can be adjusted conveniently by adding new nodes or moving nodes.

A WSN may also provide much more flexible and reliable service due to its self-organization characteristic (Aakvaag, Mathiesen, Thonet, 2005). Self-organization refers to the ability of the system to maintain the necessary organization to perform operations without requiring outside intervention. The flexibility and reliability reflect in several aspects. The tradeoff between delay and accuracy, the power balance between different nodes can be made via the collaboration among sensors. The sensing coverage can be adjusted easily by moving or adding nodes because of the self-organization attribute. Large number of sensor nodes may also provide coverage redundancy so that when some sensor node fails, other nodes can automatically cover the work of the node.

Through the data gathering and processing among plenty of nodes, WSN can monitor the parameters better that present both spatial and temporal variances, and therefore provide more valuable inferences about the physical world to the end user. Wireless feature of a WSN also makes it suitable for the applications that require mobility, for example, the moving or rotating components (such motors) of a machine under monitoring.

Design Challenges for Industrial Usage

Industry has pointed interest in wireless sensor networks either making investment or giving close attention to the research projects (Shen, Wang & Sun, 2004). Although wireless sensor networks have many advantages over traditional systems, specific design issues in several aspects have to be addressed so that they can be used in the industrial environments. WSNs designed for other applications, such as home automation or habitat monitoring, are often inadequate for industrial applications. Applications in industry require high levels of reliability while the extensive electromagnetic interference (EMI) and radio frequency multi-path propagations would cause a number of problems.

The radio frequency and the EMI are the first challenge in order to design and deploy WSNs in the harsh industrial environments. Unlike the customer-grade applications, industrial applications may experience considerable unpredictable EMI from various equipments. The operation temperature and conditions are also more rigorous. The radio frequency propagation models in industrial environments are also not clear and few researches have been done. The equipments or pipes may block communication paths and cause severe multi-path and fading problems. In addition, the radio frequency interferences from other existing wireless devices, such as walkie-talkies, cell phones, RFID, and pagers, especially from those that use the same frequency bands, have to be carefully considered to make sure the proper operations of WSNs.

The lifetime of a battery powered sensor node is limited and replacing batteries is unfavorable, especially when the thousands of wireless sensor nodes are deployed ubiquitously; replacing batteries is impractical, if not impossible. Therefore, energy-efficient design is critical. The energy efficiency should be investigated at both the hardware design and protocol design. As we mentioned before, ambient power sources, as replacement of batteries, come into consideration, to minimize the maintenance. Studies showed that several sources (including vibrations and air flow) capable of providing power on the order of 100$\mu w/cm^3$ for very long lifetimes are feasible (Roundy, Steingart, 2004). Power scavenging may enable wireless nodes to be completely self-sustaining and maintenance can be eventually freed. These potential ambient power sources, such as vibration, light, acoustic, airflow, heat and temperature variations, are abundant in industrial environment and need to be exploited.

Small sized sensor nodes have many benefits from the aspects of cost efficiency, easiness of deployment and installation. For example, the pressure sensor node for tire monitoring should be as small as possible to be fit valve of the tire, because the external effects would damage the sensor node. Moreover, these sensors must measure the tire pressure regardless of whether the vehicle is on motion or not, in the undulating land or hill, and new or old without being manually reprogrammed for all these different conditions. On the other hand, the individual sensor nodes generally present several limitations, (to achieve cost-effectiveness and tiny size) such as limited energy and memory resources, small antenna, and limited processing capability. The design tradeoffs between the size and other elements for WSNs have to be investigated.

Another crucial design requirement for industrial monitoring and control applications is the extremely high reliability and robustness of the system. In case of failure of a few sensor nodes, the system operation should still remain valid and functional. However, traditional point-to-point wireless networks are prone to failure. A wireless sensor network is fundamentally a distributed system and has the capability against the node or communication link failures and achieves the high reliability through careful deployment and the automatic coordination among sensor nodes (Sivrikaya and Yener, 2004). The industrial applications are usually time-critical, which means that the required data have to be received within a certain period and outdated data are useless, therefore the end-to-end delay is an important concern.

For large-scale WSN, scalability and effective deployment is also an issue. While structured deployment with careful placement of nodes and pre-configured topologies is a possibility in some applications, other applications may require unattended, ad-hoc deployment in remote or hostile environments. Serious consideration has to be made before a large number of sensor nodes are deployed or scattered in some "operational area." The topology affects many network characteristics such as latency, robustness, and capacity. The network size, the amount of nodes taking part in a WSN, is primarily determined by network connectivity and coverage (the size of the area of interest) requirements (Römer and Mattern, 2004).

Wireless Technologies for WSNs

The potential capabilities of WSNs to add values in industrial monitoring, control and system configuration are tremendous. Since WSNs need to adopt appropriate wireless technologies to transmit data, the authors discuss several popular or emerging wireless communication technologies and standards that may be applicable to WSNs.

Consumer application demands have driven development of low-power wireless communication (the air interface) standard. For wireless applications, the air interface mainly defines the lower layers of the network communication protocol stack, physical (PHY) and medium access control (MAC). IEEE 802.11 (or Wi-Fi) is the most popular air interface standard for Wireless Local Area Network (WLAN). Several revisions for the high data transmission rate of up to 54Mbps (802.11a/b/g) have been ratified. It is developed for customer-grade wireless data transmission and does not target to WSNs. The PHY and MAC layers of a sensor network may be compared to those of a personal area network (PAN) and wireless technologies for wireless PAN may be considered for wireless sensor applications. Examples of PAN standards include those of Bluetooth (IEEE 802.15.1), UWB (IEEE 802.15.3), and ZigBee (IEEE 802.15.4). Each of these standards is accompanied by limitations for sensor networks. For example, currently available Bluetooth devices show power consumption that is excessive for many classes of sensor network applications. The network size it supports is also very limited. Alternatively, ZigBee can support a much larger number of nodes than other systems such as Bluetooth.

ZigBee is a published specification set of high level communication protocols designed to use small, low-power digital radios based on the IEEE 802.15.4 standard (2003). ZigBee also operates in the ISM radio bands, at 868 MHz in Europe, 915 MHz in the USA and 2.4 GHz worldwide. ZigBee's current focus is to define a general-purpose, inexpensive self-organizing mesh network that can be shared by industrial controls, embedded sensors, medical devices, smoke and intruder alarms, building and home automation. The network is designed to use very small amounts of power, so that individual devices might run for a year or two with a single alkaline battery.

Ultra wide band (UWB) technology is another potential wireless technology for WSNs. Impulse-radio-based UWB systems have noise-like signals and are resistant to severe multi-path and jamming, and thus have very good time domain resolution, allowing for location and tracking applications (Oppermann, Stoica, 2004). To realize the benefits of UWB in sensor networks, careful consideration must be given to the design of the medium access control (MAC), conservation of power, and efficient radio technology. There are also other wireless technologies, including wireless USB, IR wireless and Radio Frequency Identification (RFID), etc.

Most wireless specifications adopt spread spectrum methods of transmitting data, using Direct Sequence Spread Spectrum (DSSS), or Frequency Hoping Spread Spectrum (FHSS). The reliability and robustness of different wireless technologies can be analyzed in industrial environments. The appropriate technologies should be chosen based on the requirements of applications in throughput, data rate, topologies, reliability and transmission range, etc. Table 1 compares the specifications of wireless standards that have the potential to be adopted for WSNs (Software Technologies Group, 2006)

Table 1 Comparison of Specifications of Wireless Standards

	ZigBee	802.11 (Wi-Fi)	Bluetooth	UWB	Wireless USB	IR Wireless
Operating Frequency	2.4 GHz 868 MHz (Europe) 915MHz (NA)	2.4 and 5 GHz	2.4 GHz	3.1-10.6 GHz	2.4 GHz	800-900 nm
Data Rate	20, 40, and 250 Kbits/s	up to 54 Mbits/sec	1 Mbits/s	100-500 Mbits/s	62.5 Kbits/s	20-40 Kbps 115 Kbps 4 & 16 Mbps
Range	10-100 meters	50-100 meters	10 meters	<10 meters	10 meters	<10 meters (line of sight)
Networking Topology	Ad-hoc, peer to peer, star, or mesh	Point to hub Ad-Hoc	Ad-hoc, Point-to Point Point-to Multipoint	Point to point	Point to point	Point to point
Complexity	Low	High	High	Medium	Low	Low
Power Consump-tion	Very low	High	Medium	Low	Low	Low

Industrial Application Examples

There are many potential applications in industry to improve the productiveness and reduce costs, by taking advantage of using WSNs in their facilities. As discussed earlier, WSNs are offering great flexibility and cost efficiency during installation, deployment and maintenance.

Eliminating wires also supports an augmented decentralization of computerization functions across the whole plant. Collecting data or sensor measurements in manufacturing is noticeable task of an industrial wireless sensor network. Especially, preventive maintenance programs for key plant equipment are critical to industrial processes. Remotely evaluating the condition of devices like rotating machinery or automated assembly lines can yield additional status information and help plan maintenance tasks. Because industrial activities often operate in hazardous or remote locations, wireless sensor communications offer a safer and cheaper way to assist monitoring and control. Extending network reach is then easily achieved through multi-hop transmissions. Furthermore, the self-organization offered by mesh technologies allow for flexibility of deployment at a level that was not available with previous technologies. We depict several experimental works as examples in this paper to inform readers about industrial utilization and adaptation of WSNs. For this, we have chosen industrial applications that are well recognized and have advanced beyond a simple vision. However, since the WSN and its use in industries are still on its early developing stage, the scale of these experimental networks is small and we expect that more large-scale WSNs and applications will be explored in the near future.

Manufacturing Facility

The goal of this experimental design is to discuss technical issues, in particular those related to timing and power, relevant to building up a WSN in an industrial automation environment. In order to illustrate both opportunities and hurdles, an experimental network has been installed at a mining facility in Sweden (Aakvaag, Mathiesen, and Thonet, 2005). The sensing application consists of detecting wear part in the plant's pumps in order to optimize the overall process. The seven-node network is placed on the factory floor and the network synchronizes and exchanges data once every minute. Data are logged for a period of one month. Upon transmission the data packets are time-stamped with the node's perception of real time. At the gateway node this time is compared with the "official" time in order to get a measurement of the time skew induced by the algorithm. In the ideal case, this should be a fairly constant time equal to the delay through the stacks the packets traverse in the network. It illustrates that the new ZigBee standard performs well even in heavy industrial environments.

Power Monitoring
A WSN is being used to monitor power consumption in large and widespread office buildings (Kappler and Riegel 2004). The goal is to sense places or devices that are consuming lots of power to provide warnings for potential decreases in power consumption. Sensor nodes are connected to the power grid (at outlets or fuse boxes) to measure power consumption and for their own power supply. Sensor nodes directly transmit sensor readings to transceivers (Römer and Mattern, 2004). The transceivers form a multi-hop network and forward messages to the central unit. The central unit acts as a gateway to the Internet and forwards sensor data to a database system in order to be processed.

Part Assembly
A wireless sensor network is being used to assist people during the assembly of complex combination of objects such as do-it-yourself furniture (Antifakos, Michahelles, and Schiele, 2002). This saves users from having to study and understand complex instruction manuals, and prevents them from making mistakes. The furniture parts and tools are equipped with wireless sensor nodes. These nodes are equipped with a variety of different sensors: force sensors (for joints), gyroscope (for screwdrivers), and accelerometers (for hammers). The sensor nodes form an ad hoc wireless network for detecting certain actions and sequences thereof, and give visual feedback to the user via LEDs integrated into the furniture parts.

Cold Chain Management
The commercial Securifood system is a WSN for monitoring the temperature compliance of cold chains from production, via distribution centers and stores, to the consumer. Clients receive an early warning of possible breaks in the cold chain (R. Riem-Vis, 2004). The system consists of four major components: sensor nodes, relay units, access boxes, and a warehouse. Sensor nodes are embedded in and transported with the products and collect temperature data. Relay units, which are more powerful nodes with a permanent power supply, gather temperature data from sensor nodes. Multiple relay units form a multi-hop ad hoc network. An access box is an even more powerful embedded Linux device that acts as a gateway between the network of relay units and the Internet, one access box per production site. An Internet-hosted data warehouse acts as a central server, collecting data from all the access boxes. The data warehouse provides an online image of all the sensor data in the system and acts as a central data repository for applications.

Conclusions
The feasibility of applying WSNs to industrial applications is discussed. The features of WSNs and the design challenges for the industrial application have been investigated. The development of WSNs is still in its early experimental stage, but we can envision its wide use in various industrial environments and great benefits they may provide. The design and implementation of WSNs have to be application-oriented due to its tight coupling with the physical world. Therefore, a single hardware platform will most likely be insufficient to support the wide range of possible applications. It would be desirable to have available a set of platforms with different capabilities that cover the design space. A modular approach, where the individual components of a sensor node can be easily exchanged, may help to increase the flexibility of system design and shorten the design period. Making the application of WSN a reality, still, requires substantial and coordinated research in a variety of disciplines, including computer science, electrical engineering, communications, microelectronics and MEMS technology, industrial technology, manufacturing and power engineering technologies.

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Electrical 1/f Noise Characterization of Magneto-Resistive Read/Write Head

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Introduction

Many of the past improvements in disk-drive capacity have been a result of improvements in the read-write head, which records data by altering the magnetic polarities of tiny areas, called domains (each domain representing one bit), in the storage medium. Early products used read-write heads made of ferrite, but beginning in 1979, silicon chip design technology enabled the precise fabrication of thin-film inductive (TFI) heads (Daniel, Mee & Clark, 1996). The TFI read-write head consists of wired wrapped magnetic cores, which produce a voltage when moved past a magnetic hard disk platter. In TFI, it became impractical to increase areal density of recorded data in the conventional way - by increasing the sensitivity of the head to magnetic flux changes by adding turns to the TFI head's coil. This method increases the head's inductance to levels that limited its ability to write data.

In 1991, IBM's work on anisotropic magneto-resistive (AMR) technology led to the development of magneto-resistive (MR) heads capable of the areal densities required to sustain the disk-drive industry's continued growth in capacity and performance (IBM; Mallinson, 1995). The physical characteristics of an MR read-write head are shown in Figure 1. In an MR read-write head, simply called as MR head, the write element is a conventional TFI head, while the read element is composed of a thin stripe of magnetic material (Ashar, 1997). Rather than reading the varying magnetic field in a disk directly, an MR head looks for minute changes in the electrical resistance of the overlying read element, which is influenced by that magnetic field. The greater sensitivity that results allows data-storing domains to be shrunk further.
The use of MR heads also introduced a new challenge not present with TFI heads: thermal asperities, the instantaneous temperature rise that causes the data signal to spike and momentarily disrupt the recovery of data from the drive (Tian, Cheung & Wang, 1997). Thermal asperities are transient electrical events, usually associated with a particle, and normally do not result in mechanical damage to the head, but can lead to misreading data in a large portion of a sector. Thermal asperities can be caused due to self-heating in MR heads due to writing currents (Iben, 2003; Ju, 2005). Head protrusion caused by the thermal expansion of its constituent films alters the head media, which may also lead to thermal asperities and mechanical damage (Wang, Wu, Weresin & Ju, 2001).

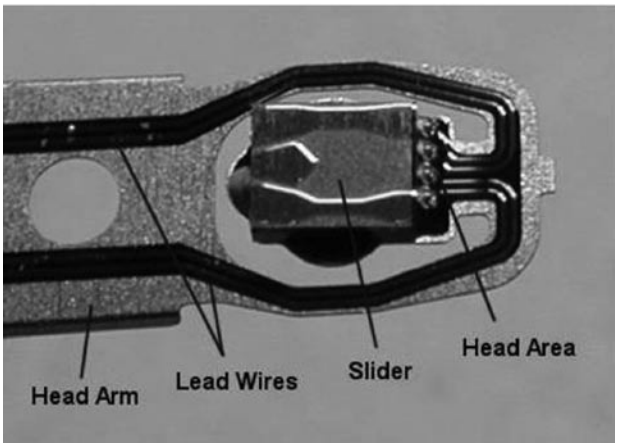

Figure 1: Magnetoresistive (MR) read-write head element.

Under normal operating conditions the changes in MR read-write head sensor (stripe) properties are undetectable. To estimate failure conditions, sensors need to be exposed to elevated temperatures and currents and changes in relevant physical parameters to be measured (Ju et al., 2001). In this study, we have made use of the low-frequency one-over-f ($1/f$) noise also known as excess noise measurement technique, which has been extensively used to study reliability in metal thin films, wafer level reliability issues and reliability of various other solid-state devices (Zeynep & Wiyi, 1990; Rawat & Massiha, 2004). Research has shown that low-frequency noise and resistance measurements can be used as a sensitive tool for detecting stress induced damage (Zeynep & Min, 1992). In addition, it is widely accepted that $1/f$ noise shows a significant increase during the process of failure due to heat induced stress, and that the noise magnitude is related to the time of failure of the sample (Zeynep & Wiyi, 1990).

The excess noise measurement technique is much faster than the conventional mean-time-to-failure (MTTF) method and is nondestructive in nature, which makes this technique an ideal tool to study failure issues in thin film-based materials (Ghate, 1982). In a noise measurement experiment it is necessary to monitor the excess noise produced by the sample while it is subjected to the electrical and thermal stress in order to make a correlation between the noise voltage spectral density or noise power and the sample failure conditions. This was made possible by using a dual channel dynamic signal analyzer-based low-frequency noise measurement system. Physical parameters such as stripe resistance and noise spectral density were measured as functions of temperature and current density. In this paper, the results were obtained by applying low-frequency noise measurements on MR head samples subjected to electrical and thermal stress.
In the next section, a brief introduction to electrical noise theory and low-frequency noise measurement system is presented. The later part of the paper focuses on the experiments performed, experimental results and significance of the study conducted. Finally, the relevant conclusion is presented.

Electrical Noise Theory and Measurement System

1. Electrical Noise Theory:

Noise in a broad sense can be defined as an unwanted signal or disturbance. Three main types of noise mechanisms are referred to as thermal noise, shot noise, and low-frequency excess noise. Thermal noise is caused by the random thermally excited vibration of the charge carriers in a conductor. Shot noise is found in tubes, transistors, and diodes. Shot noise is associated with current flow across a potential barrier. The low-frequency or excess noise was first observed in vacuum tubes; this noise was called flicker noise (Haus, 2000). Studies of low-frequency noise have shown that the major cause of this noise in semiconductor devices is traceable to the surface of the material (Ciofi & Neri, 2000). In general, depending on the spectral shape of the noise power spectrum, these studies can be divided into two groups: one that concentrates on $1/f$ noise and ones that deals with $1/f^2$ noise. At low frequencies, $1/f^{\alpha}$ noise with $0.7 \leq \alpha < 1.4$ is referred to low-frequency $1/f$ noise or simply $1/f$ noise.

2. Low-Frequency Noise Measurement System:

The complete system used in the noise and reliability lab to teach students noise measurement had four important parts: SR785 Dynamic Signal Analyzer, EG&G 5184 Ultra Low Noise Voltage Preamplifier, and SR715 LCR meter and biasing circuit. In addition a computer workstation installed with the data analyzing software, is also used to view and analyze the study data. A block diagram of low-frequency noise measurement system used in the project is shown in Figure 2. The detailed discussion on the measurement system can be found in (Rawat & Massiha, 2004).

SR785 Dynamic signal analyzer is a dual channel spectrum analyzer and makes use of Fast Fourier Transform (FFT) to obtain the spectral density of an input voltage signal. One of the useful features of this signal analyzer is different type of averaging modes. Averaging is necessary in a given frequency range to reduce the variance of the final plot. Furthermore, the trace storage, retrieval, and math function are used to store and subtract background noise transformation from the final measurement. A very low noise amplifier is used to amplify the noise signal to amplitude large enough to drive an input of the signal analyzer. A R meter is used to monitor the change in capable of measuring the resistance, inductance and capacitance when current is flowing through the device.

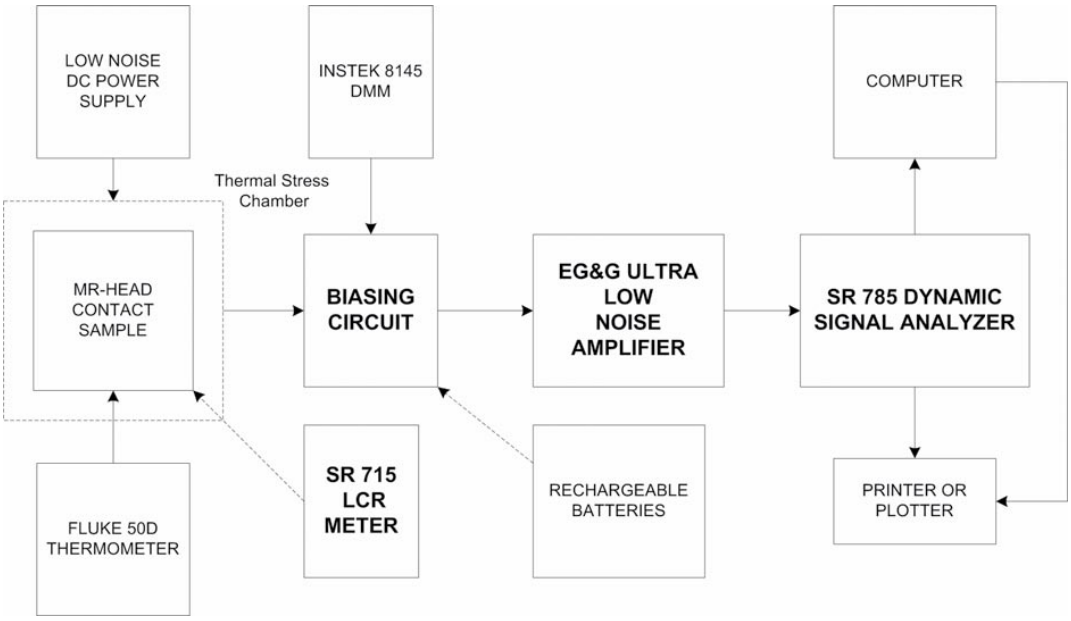

Figure 2: Low-frequency noise measurement setup.

To achieve a fixed range of current density across the sample, a biasing circuit is designed and fabricated. Connecting a few batteries in series with resistances provides the biasing voltage. The design of the biasing circuit is critical for the required current density across the MR stripe. The batteries are used instead of a power supply to avoid electrical noise, which adds to the 1/*f* noise to be measured. An ultra low-noise power supply can also be used, if available. In addition to this measurement setup, a heating chamber shown in Figure 3 was also constructed to induce thermal stress to the MR samples. A thermocouple probe was used to keep track of the sample surface temperature.

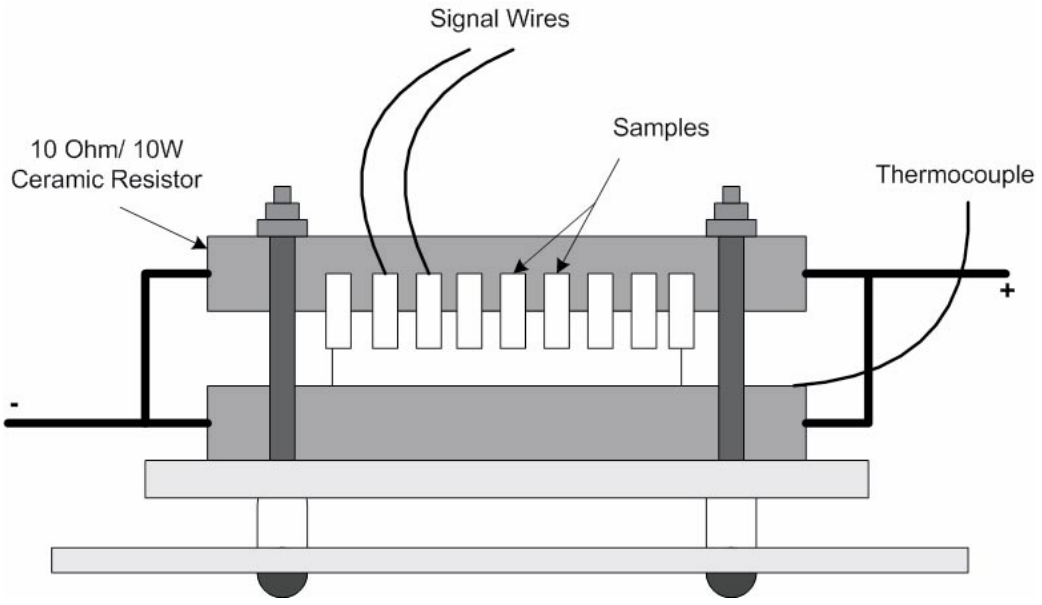

Figure 3: High temperature chamber.

Performing Low-Frequency Noise Measurements

In this research, the low-frequency noise measurements were carried out on five MR samples. The layout of the selected sample with MR contacts is shown in Figure 4.

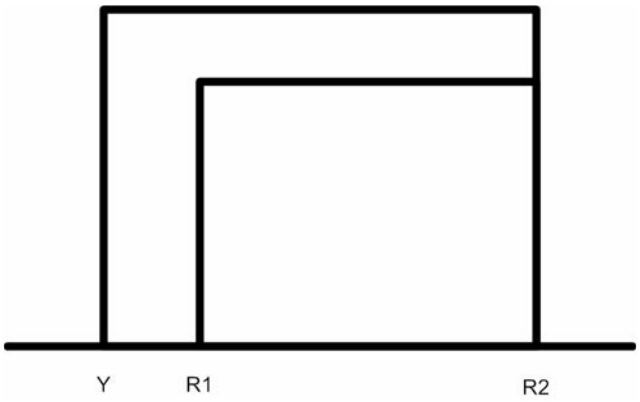

Figure 4: The MR contacts of the read-write head sample.

Each sample has a set of three MR contact stripes (Y-R1, R1-R2, and Y-R2). The material composition was Nickel-80% and Iron-20%. All of the metals in the stripe are ion-beam deposited. The selected samples were inspected using a Scanning Electron Microscope (SEM) for dimensions and any damage. The resistance of each strip is measured at regular intervals with aide of LCR meter used in the noise measurement system.

The stress conditions were created through a combination of elevated temperature and excess current. The thermal and electrical stress was applied to all the MR contacts simultaneously. The MR contacts were subjected to current densities between 2.0×10^6 A/cm^2 and 2.4×10^7 A/cm^2 and the ambient temperature up to 400 °C. To capture $1/f$ noise spectra across the MR contact we first measured the background noise power when the entire system was operating with no DC current passing through the MR contacts. This spectrum was captured and stored in the dynamic signal analyzer. Next the sample was kept under current density $J = 3.0 \times 10^6$ A/cm^2 and the ambient temperature was raised from 23 °C up to 400 °C. The MR samples were also subjected to higher current densities between 2.0×10^6 A/cm^2 and 2.4×10^7 A/cm^2 at a constant temperature. The noise spectrum corresponding to these conditions were also captured and stored in the dynamic signal analyzer. Using the math features of the dual channel dynamic signal analyzer, background noise was subtracted from the total noise with the remainder being the excess noise exhibited by the MR sample. The time period (stressing period) for each set of noise measurement was documented, so that the changes in the level and slope of the spectrum of excess noise could be traced as a function of test time duration.

Experimental Results

In this paper, the results for Y-R1 MR contact only are reported. The dimension of this MR contact was 4.0 micron × 0.25 micron × 0.1 micron. The noise spectral density S_v versus current density J at 50 Hz for three different temperatures is shown in Figure 5. As observed in Figure 5, the current dependence of the noise magnitude shows that there seems to be a threshold below which the noise voltage has a lower degree of dependency on the bias current. Above this threshold, value the noise magnitude (power) increases at a higher rate.

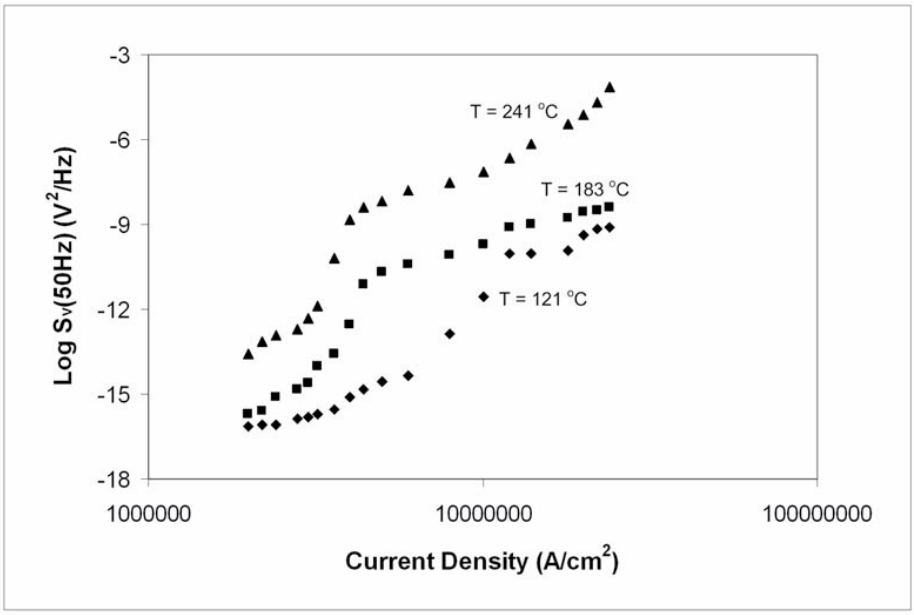

Figure 5: Dependence of the noise spectral density S_v (at 50Hz) on the current density J.

In the experimental result shown in Figure 5 the MR contact exhibited higher noise power above 3.6×10^6 A/cm^2. The increase in noise power above this point is an indication that stress or failure conditions have started to set in. The change in resistances was monitored throughout the experiment and the relative values (deltaR/R_0) were calculated for all the MR contacts. The change in resistance versus temperature at current density $J = 3.0 \times 10^6$ A/cm^2 and $J = 8.0 \times 10^6$ A/cm^2 is shown in Figure 6. In Figure 6 we observe that the resistance of the strip first increases gradually until ~248 °C. After this initial period the resistance of MR stripe increases rapidly as thermal runaway occurs. This could be caused due to electromigration-induced microsegregation of Ni and Fe atoms followed by oxidation of Fe which is due to elevated temperature and exposure to air.

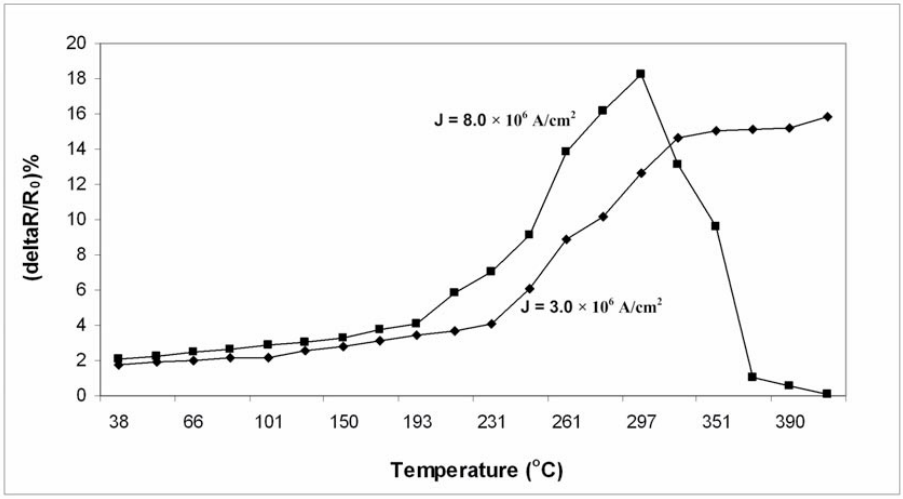

Figure 6: Change in resistance versus current density J.

In Figure 6 we also observe that at a much higher current density, the resistance of MR stripe reaches a peak and then falls abruptly. This rapid resistance increase followed by an abrupt fall observed in this experiment is reflective of stress-induced damage that leads to the failure of the MR head contact.

Conclusion

A faster and nondestructive low-frequency electrical noise technique was used to study reliability conditions in MR heads. Using a dual channel dynamic signal analyzer-based measurement systems low-frequency noise signals in MR head samples subjected to stress conditions were measured and the relevant results were reported in the paper. To this effect 5 sets of MR head samples were used. The experimental results showed that the noise signal spectrums were found to be a function of the subjected heating temperatures and of the higher current densities. The MR samples showed no sign of damage even when subjected to extreme current density up to 2.0×10^7 A/cm^2 and temperature up to 380 °C. Only when subjected to temperatures above this, the MR contact stripe started decaying and exhibited an increase in higher noise power, thereby indicating its maximum reliability condition. Also the MR head contacts showed large resistance drift after being subjected to higher temperatures (>250 °C) and higher noise power above current density over 8.0×10^6 A/cm^2. From the results we can conclude that the damaged MR stripes are found to exhibit excess noise at low temperatures and currents.

The results showed that the noise measurement technique could be applied to study the reliability of MR heads, which are constantly introduced to thermal asperities due to the disk, read and write activities. We can also deduce the sustainability of the MR head against excess use due to frequent read and write operations and also under any other thermal conditions. The experiments conducted during the study were sufficient to analyze the conditions that can lead to MR head failure.

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Extend the Motor Controls in the PIC Microcontroller Applications

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Abstract
Using microprocessor/microcontroller in various control applications is not only one of the major topics in Engineering Technology (ET) curricula, but also of interest in industry applications. To accomplish it correctly the process of designing application programs starts from the individual module development through extensive testing, verification, and modification. Applying these developed modules in a useful manner requires the links and integrations that lead to the practical project implementation. Frequently, in students' senior project designs and faculty's research plans, the microprocessor/microcontroller resources become scarce or cause conflicts during the modules' integration stage. In order to accommodate the shortfall of the resources and resolve any conflict state, several choices are forced to consider: (1) revise the module design, (2) rework most of the design, or (3) add additional circuit to the module. This article presents a proven concept that implements the simple serial communication protocols in a multi-processor environment, which aims to keep the pre-developed modules intact with the least possible modification during project implementation in an efficient and economical way.

Introduction
A project was implemented under a contract between a private company and Old Dominion University, Technology Applications Center in 2004. This project was to design and develop a training robot that is to be used in the boxing training exercises. Its original design relied on a single CPU (Motorola 68HC11) to control 8 DC motors, 8 position sensors, and some other peripheral and safety features.

After the prototyping and examination of the mechanical functions, it was determined that the control circuits had to be revised. The requirements for this 68HC11 had grown to 9 DC motors and 18 position sensors with the same safety features. Due to the limitation of the 8 bit 68HC11 CPU, the processor's resources were exhausted (Motorola, 1991). The mechanical designers desired to have a total of 20 or more position sensors to gain adequate controls of the training model, but this list was forced to cut down to accommodate the CPU.

The 68HC11 is a microcontroller that has been in the market since 1980 (Cady, 1997) and Motorola has discontinued the manufacture of this product. It became difficult to find the supplier for this chip and its price is higher than expected. After a study of the specifications and potential applications on SPI (Serial UART Tutorial, 1996), I^2C (Philips, 1997) and SMBus (SMBus1.1, 1998; SMBus2.0, 2001), an idea has surfaced to revise the designs on the electronic hardware and software to use multiple and cheaper CPUs, such as Microchip's 16F84A in a form of serial communication links (Philips, 1997; Serial UART Tutorial, 1996; SMBus2.0, 2001). The 16F84A is a popular 8 bit microcontroller in many places and the vender suppliers are plentiful (Bates, 2004). From an economic point of view, it is the one of the best choices of all the available low end microcontrollers.

The selected design is to have multiple slave processors that everyone is in the same format, which uses one 16F84A as a dedicated CPU to control one DC motor. A single master 16F84A CPU controls and links all the slave CPUs. This design is to modularize the processor environment that has a single master which takes the control commands from a user and passes the necessary control functions to an appropriate slave to perform the operations. With this design concept, there will be virtually no limit on the number of slaves in the system. The limitations on a single CPU approach are automatically resolved.

Certainly, this approach requires a well planned software protocol design, and the hardware requirement becomes a fixed module that is less complex (Philips, 1997; SMBus2.0, 2001). This article focuses on hardware, software designs, and their implementation as a proof of concept of a multiple processor in multiple DC motors control application. The use of multiple PIC 16F84As in a system design is doable, low cost, and efficient.

Software Design

Since there are multiple slaves and a single master in this control system design, two kinds of software are needed for this project. The major proof of concept in this project heavily relies on the software design. In order to better clarify the design of this concept, subsequent sections of this paper will describe the master, slave protocol, and communication.

Software on Master

The master is the controlling microcontroller which handles all the controlling sequences, such as taking interaction between a user and the system, making sure the right motors are running in the specified time and position. The master controller oversees major system components such as the keypad, LCD, and slave microcontrollers that run the motors.

In operation, the master starts with the keypad and LCD display module, handling interactions between the user's inputs and system's response. The keypad routine is a standard scanning, debouncing, and decoding of the four rows and four columns to detect the user's input. The LCD routine implements serial communication between the master CPU and display module via a 74164 shift register (TTL, 1998).

A major portion of the software design in this project is the communication between the master and the multiple slaves. All the communications are initiated by the single master. Once the master has processed an action selected by the user input, it determines which action was chosen and transmits the information/instructions to the appropriate slave using serial synchronous communication (Serial UART Tutorial, 1996). Both read and write on the master side are implemented in the same subroutine. This routine is in charge of generating the clocks, and sending and receiving the bits of information. Since 16F84A does not have any hardware support for serial communication, the clock and data bits rely entirely on software bit banging. The time between the clock edges is preset at 0.2 ms for the whole system. In order to control the multiple slaves, every slave has a unique address that is embedded in the master software. There are pre-defined five bytes protocols that a master sends to all the slaves in the system. Two dedicated I/O (Input/Output) pins on the master and slaves synchronize the intended action between the parties.

Every communication sequence consists of the master broadcasts five bytes (four information bytes and one 0XFF byte to read from the slave) on the shared bus lines (Serial UART Tutorial, 1996 & SMBus2.0, 2001) consisting of a clock (CLK), data out (DOUT), data in (DIN), and framing I/O bits. The first byte is the slave address, the second byte is a master read, the third byte is the speed of the motor, the forth byte is the motor direction, and the last byte is the motor running time period. Once the master receives the acknowledgement (ACK) from the intended slave, it sends the remaining three bytes. When that is done, it goes on to the address of the next action line of bytes that needs to be sent and continues on until the control sequences are finished. When all instructions are sent to the slaves, the master will return to start and wait for the next control sequence from the user through the keypad.

Software on Slave

The slave is in charge of executing what the master has commanded. It does not start processing information until the master is ready to send. However, the slave has a few tasks it must complete before it is ready to start the communication. To make the individual motor controller as a fixed modular design, it should have the same hardware and software but perform different action. A unique address has to assign to each slave to differentiate them. This becomes the only difference between the slaves in the system. To start, the slave first pulls its address from the EEPROM and stores it into its DRAM (PIC16F84A, 2004). Once this is accomplished, it waits for the master to signal the start condition with a framing of "00" as an initiate of the sending information. The first byte is going to be the address byte. The address byte that is received is compared to the address of the particular microcontroller. If they are different, the microcontroller does nothing but waits/polls for the next action address. Once it receives the correct address, the slave waits/polls for another framing condition "01" and sends the ACK.

After the ACK, the slave waits/polls for a different framing condition of "10" to receive three more motor control bytes information. All the bytes will be stored in the predefined DRAM locations (Bates, 2004; PIC16F84A, 2004). When the slave is finished receiving the rest of the instructions, it activates the motor accordingly.

The motor speed byte is used to determine the prescalor to the 16F84A TMR0 timer interrupt interval that is used to generate the PWM signal to regulate the motor speed (Bates, 2004; PIC16F84A, 2004). The motor running period byte is used in conjunction of the sensors to determine when to shut down the gate of the PWM signal that eventually stop the motor. When that is accomplished, the slave is ready for the next set of information from the master.

The Protocol Design

There are basically three I/O lines (clock, data in, and data out) used in this communication. These are all shared as a serial bus between a master and multiple slaves (Philips, 1997; SMBus2.0, 2001). In each action of the serial communication bits streams, there are total of five bytes either transmit or receive between a master and any particular slave CPU. The pre-defined bytes are: (1) address byte, (2) slave acknowledge byte, (3) speed byte, (4) direction byte, and (5) time period byte.

There are several set of rules for this communication (Philips, 1997; Serial UART Tutorial, 1996; SMBus2.0, 2001): (1) only one master is allowed in the system, (2) only the master can generate the clock, (3) only the master can start/stop the communications, (4) only the master is responsible for the framing I/O bits, (5) there are multiple slaves allowed in the system, but each slave shall have a unique address recognizable by the master, (6) the slave can only monitor the framing I/O bit for communication responses, (7) the slave is required to respond to its address call by sending an ACK byte, (8) after the initiation of a start from the master, every slave has to read the address that master broadcasts, (9) the slave is not permitted to respond if its address is not called, and (10) the only time that the slave sends a byte is when it is required to ACK.

To ensure the safety of the system performance, an alarm condition is implemented in the event of violation of the protocol. The alarm condition is defined as: when the master sends a legitimate address to the slaves and does not receive an ACK or the ACK is not recognized for any reason. As soon as the master detects this alarm condition, it will disable the de-multiplexer that is used by the slaves to activate the motors.

The Communication

At the beginning of the protocols testing stage, it was difficult to keep the master and slave synchronized with each other. Therefore, the protocol rules mentioned above were introduced and the framing I/Os were added. These two additional I/O pins were developed to frame the states of the communication bytes to fix the problem. They are the states that the master controls and slaves poll during each action. The framing I/Os are inputs to the slave. They are used to indicate to the slaves that the master is ready to do the next set of instruction. There are four different states (00, 01, 10, 11) the master sends to the slaves. Since the slaves don't perform as much work as the master, these states let the slaves recognize where the master is in the communication sequence. "00" informs the slaves as a start that the master is getting ready to send the first byte (address). Following the first byte, the master sends a "01" to notify the slaves it is ready to receive the ACK. When the I/O pins switch to "10", the slave knows that the master has received the ACK and is about to send the last three bytes. Finally, the master will send an "11" through the I/O pins, indicating it is done with the transmitting action. The summation of the framing I/O control is presented in Table 1.

Framing I/O	Master Control	Slave Response
00	Start Transmission of Address	Ready to read the address
01	Start Receiving of ACK	Ready to send the ACK
10	Start Transmission Command Byte of Motor Speed	Ready to read the Motor Speed Control
10	Start Transmission Command Byte of Motor Direction	Read the Motor Direction control
10	Start Transmission Command Byte of Motor Run Time	Read the Motor Run Time Control
11	Signal End of Transmission	Recognize End of Transmission

Table 1. Framing I/O Controls

The synchronous serial communication shares the same clock (Philips, 1997; Serial UART Tutorial, 1996; SMBus2.0, 2001), and every party relies on the clock edges to either read or write the bits. The framing implementation resolves the timing issues and differentiation of the start, end/stop, address, and command bytes. The presentation of the protocol bytes and associate framing I/O is presented in Figure 1.

Hardware Design

Although the hardware design appears complex, it has a lot of duplications due to multiple CPUs in the system. There are three major parts in this design: (1) the master that handles the user's commands and communications via keypad and LCD module, (2) the multiple slaves that actual generate the PWM signals to drive the motors via DC motor interface board, and (3) the motor driver board circuit that handles the high current to activate the DC motors.

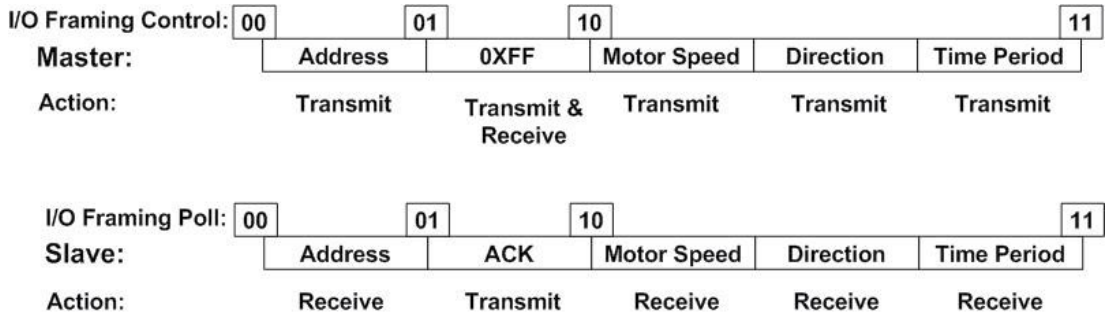


Figure 1. Master & Slave Protocols

Master Control Circuit

The master interface circuit has a standard 4x4 keypad, a LCD module, a shift register, and three software controlled I/Os for the serial interface buses to the slave CPUs.

The keypad is direct interfaced to PORTB RB0-RB7 with eight 10K pull up resistors (Bates, 2004; PIC16F84A, 2004). RB0 (IO_1) and RB1 (IO_2) are dually used for the slaves' serial communication framing I/O controls. These two logic lines will generate four different states that are used as guidance to the slaves to follow the predefined protocols. RB2 (MA_E) is also used as a control of the slave's de-multiplexer enable that serves as an alarm condition for master to shut down all the motors when an emergency condition is encountered.

The LCD module is connected to a 74164 shift register in a parallel format, but its interface to the CPU is in a serial form. This is needed because of the limited number of available I/Os on the master CPU. RA2 (LCD_E) and RA3 (LCD_RS) are used for E and RS controls on the LCD display module (LCD, 2004).

The entire serial interface is done through PORTA. RA0 (marked as CLK) is used to generate the clock, RA1 (marked as DOUT) is the control data output from a master to the slaves, and RA4 (marked as DIN) is a return data line from the slaves to a master. RA4 is an open drain I/O. Its required pull up resistor (10K) connection makes it the best choice for this type of interface communication (Bates, 2004; PIC16F84A, 2004). There are three serial communication lines that are not only used in master-slave, but also in CPU-LCD interactions. There is no unused pin on the master circuit. Figure 2 presents the master hardware circuit design.

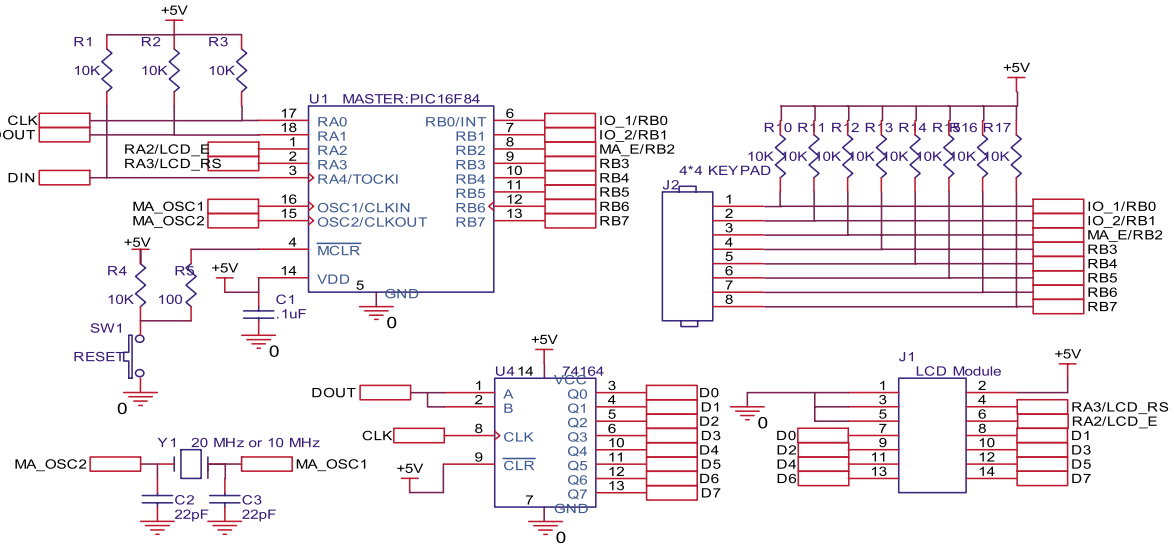


Figure 2. The Master Hardware Circuit

Slave Control Circuit

The serial communication interface is implemented on PORTA where RA0 (CLK) is used to accept the clock signal from the master, RA1 (DOUT) is used to read the command bytes from the master, and RA4 (DIN) is used to send the ACK to the master. The PWM signal is generated from the TMR0 timer via interrupt control on RB0 pin (PIC16F84A, 2004). It is used to control the de-multiplexer output that eventually is used to regulate the energy to the DC motor. The PWM signal is generated constantly since it is an interrupt driven event. To gate this PWM to a proper channel (either forward or reverse control of the motor), RB3 (marked as SLX_E) is used as an enable control. Both RB1 (marked as SLX_RB1) and RB2 (marked as SLX_RB2) are used as channel select on the 74138 3-to-8 decoder that is functioned as a de-multiplexer. The X on SLX stands for the number of the motor in the circuit.

There are two position sensors on each slave. The signals are monitored on RB4 (SLX_SENSOR1) and RB5 (SLX_SENSOR2) pins to provide feedbacks on the motor's position. The framing logic states are monitored on RB6 (IO_2/RB1) and RB7 (IO_1/RB2), which controls the slave's communication protocols sequences. There are two unused I/O pins, RA2 and RA3 on the slave circuit design. The multiple slaves are a duplication of the following slaves' circuits that have two slaves as presented in Figure 3.

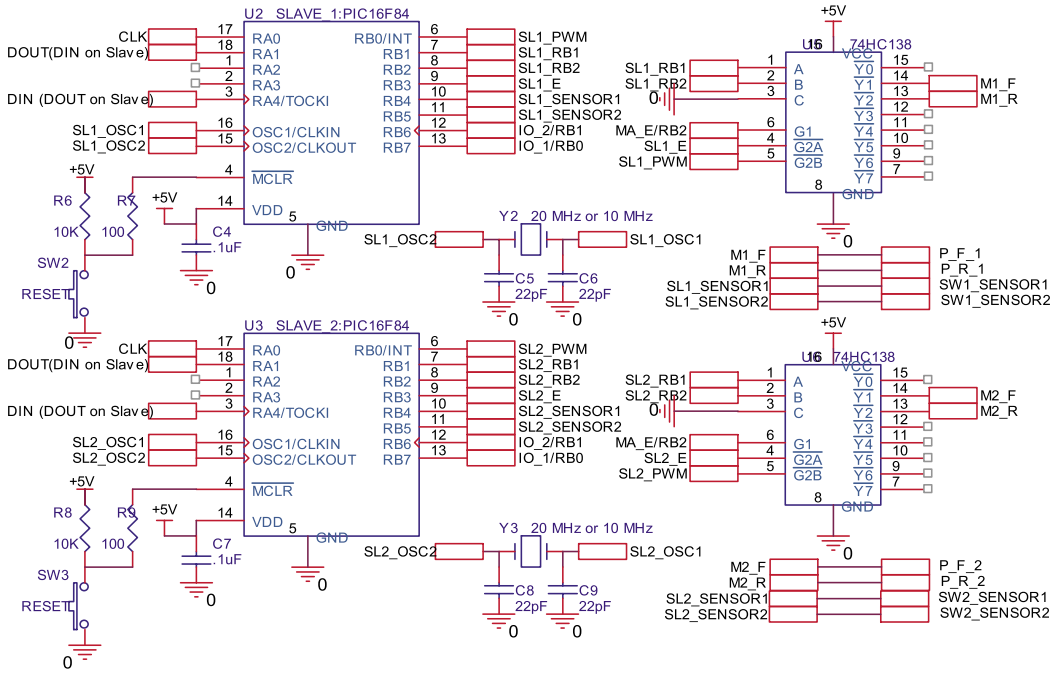


Figure 3. Two Slaves Hardware Circuit

Motor Control Circuit

The motor driver circuit is a standard H-bridge design. These bridge on-off controls are made through an IRF530N power MOSFET that can easily handle 10A DC current (IRF530N, 2006). The circuit can control a motor in either forward or reverse direction depending on the PWM signal that is coming in at its P_F_1 or P_R_1 terminal. The two position sensors have a RS latch debounce circuit to produce a clean feedback signal to the slave CPU. The motor circuit design is presented in Figure 4.

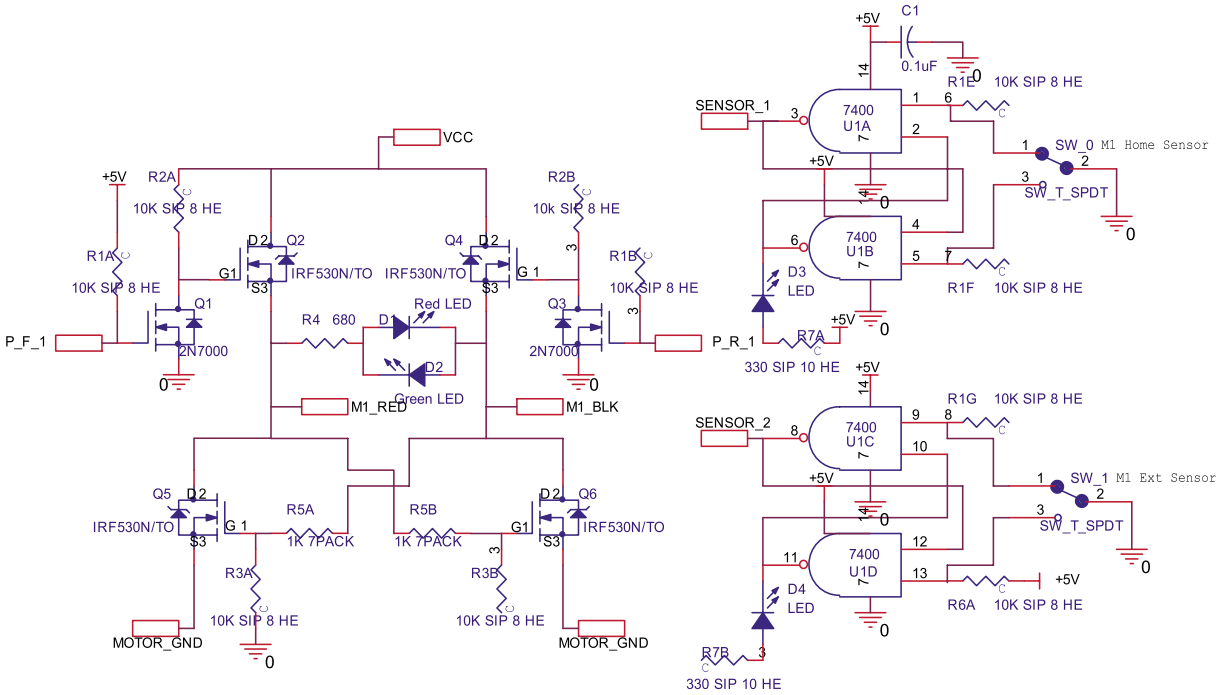
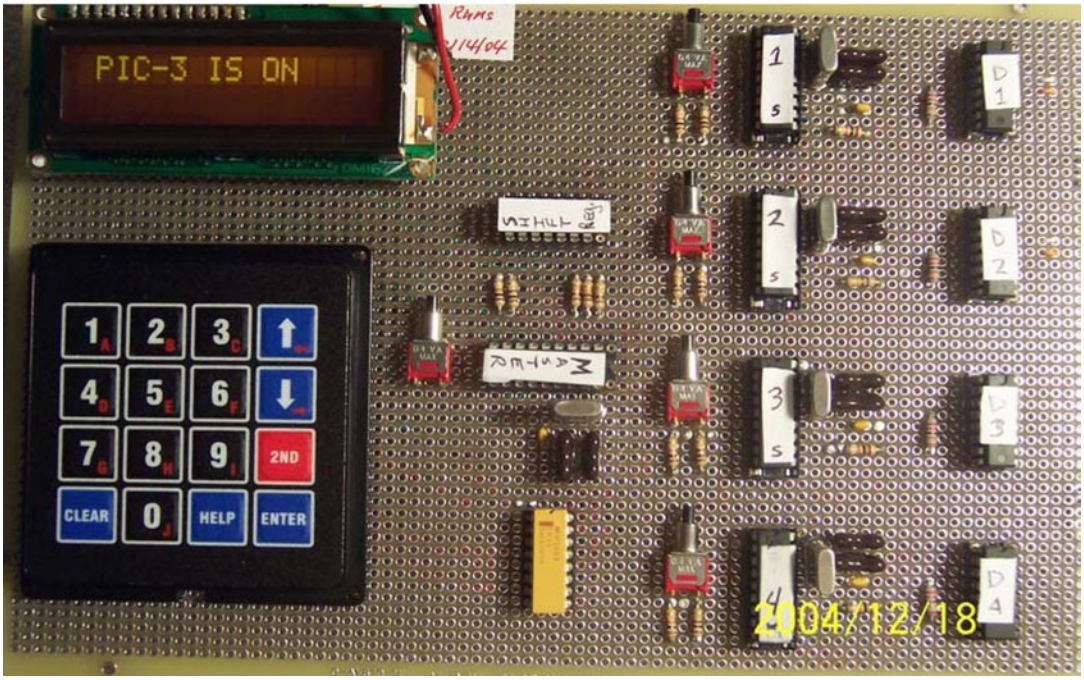


Figure 4.The Motor Control Hardware

The Implementation

This multi-processor control application that uses simple protocols has been proven functional. The testing of this concept was carried out in one master and four slaves to control four different DC motors. The setup is presented in Picture 1.

The addresses distributions and their control functions of the 9 slaves are presented in Table 2. The predefined command bytes and their associated functions are in Table 3. Picture 2 shows the real sample communication bits streams on clock (CLK), data out (DOUT), data in (DIN), and framing I/O (I_O1 & I_O2) lines that were captured by a logic analyzer. The prototype demo system that has one master and four slaves with two DC motors is presented in Picture 3. The overall operation of this demo system is presented in a block diagram format in Figure 5.



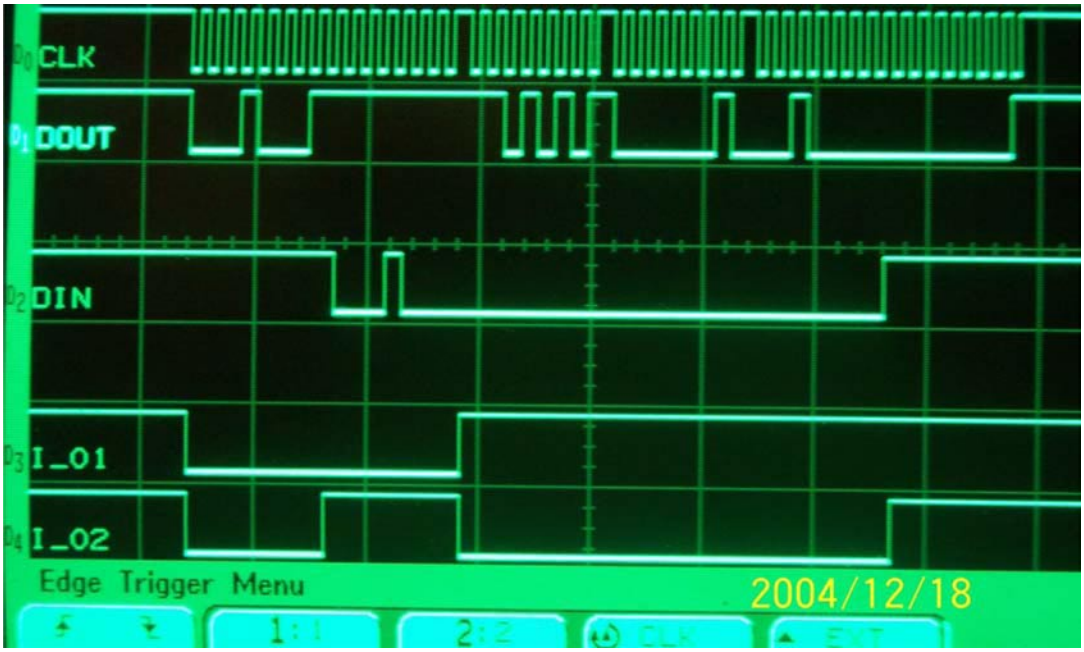
Picture 1. One Master & Four Slaves Setup

Slave #	Slave Name	Address	Function Control
1	PIC 1	0X11	Right Elbow
2	PIC 2	0X22	Right Shoulder up/down
3	PIC 3	0X33	Left Elbow
4	PIC 4	0X44	Left Shoulder up/down
5	PIC 5	0X55	Pivot Torso
6	PIC 6	0X66	Back/Forth Torso
7	PIC 7	0X77	Right/Left Torso
8	PIC 8	0X88	Right Shoulder Left/Right
9	PIC 9	0X99	Left Shoulder Left/Right

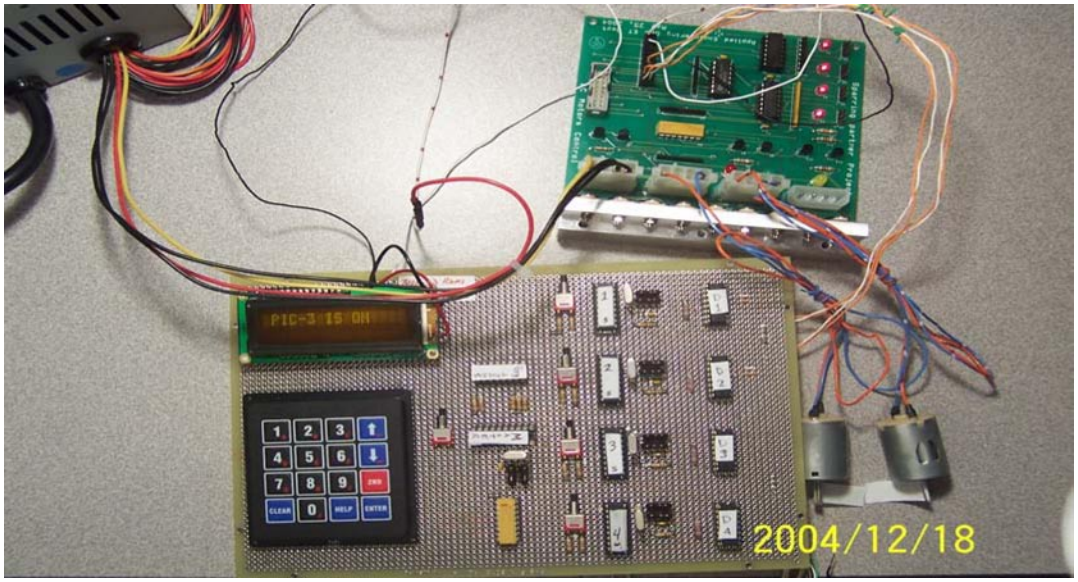
Table 2. Slaves' Addresses & Functions

#	Command Byte	Control Function
1	0XD4	Fast Speed Motor Control, 80% Duty Cycle (PWM)
2	0XD5	Medium Speed Motor Control, 50% Duty Cycle (PWM)
3	0XD6	Slow Speed Motor Control, 20% Duty Cycle (PWM)
4	0X01	Motor Direction Control: Moving Backward
5	0X02	Motor Direction Control: Moving Forward
6	0X20	Time Delay Between Motors Action: Short = 2.04 Seconds
7	0X33	Time Delay Between Motors Action: Medium = 4.02 Seconds
8	0X65	Time Delay Between Motors Action: Long = 78.965 Seconds

Table 3. Command Bytes & Functions



Picture 2. The Serial Communication Signals



Picture 3. The Multiple-Processor System Setup

Table 4 represents the estimated cost of the multi-processors system that uses PIC16F84As is compared with the original design using a single MC68HC11 processor. The cost for both systems is very similar, but the flexibility that multi-processor system provides is beyond this assessment.

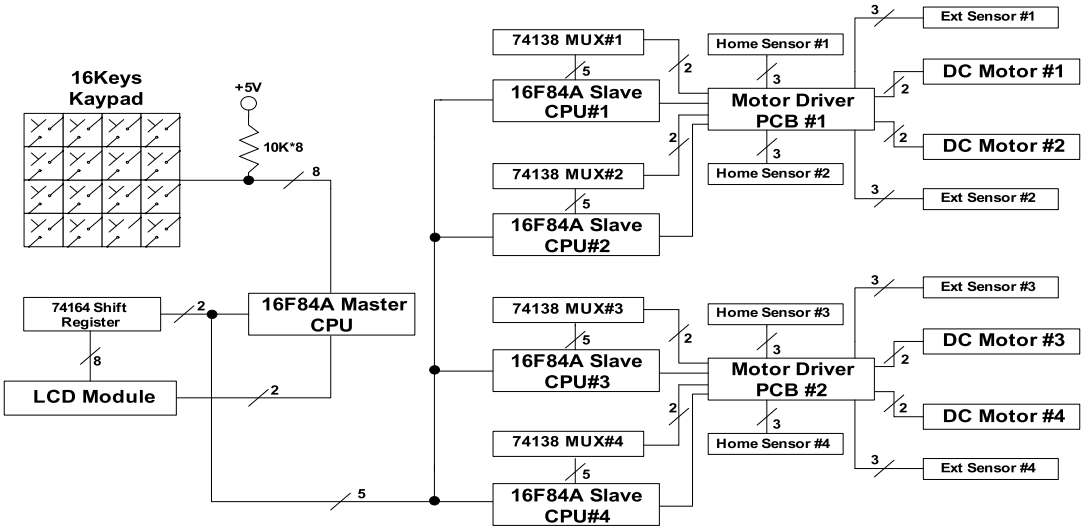


Figure 5. The Demo System Block Diagram

Single CPU System	Cost	Multi-CPUs System	Cost
MC68HC11 & EVB	$80	PIC16F84A*10	$40
Motor Driver PCB & Accessories	$100	Motor Driver PCB & Accessories	$100
Misc. Components	$30	Misc. Components	$50
Total	$210	Total	$190

Table 4. The Estimated Cost Comparison between Two Systems

Conclusion

This project was actually implemented in the students' (Tyson McCall and Corinne Ransberger) senior project design. The concept has been successfully proven to be suitable in real multiple motors control applications. There are several valuable lessons that were learned in this proof of concept project design.

The designed serial communication protocols with only byte address can have up to 254 slave processors (that exclude 0X00 and 0XFF). This can easily be extended to any number of slaves by adding multiple bytes of the address definitions. The three control bytes in the existing protocols can also be extended to fit any project needs. The two bits I/O protocol framing controls from the master may be eliminated by using the clock edge sensing interrupt to synchronize the communications. Certainly, an upgraded CPU such as the 16F877A that has a built in SPI hardware block would relieve the software bit banging load on the CPUs to improve communication efficiency, but would also increase the cost of the project design (PIC16F877A, 2004). An implementation of the SLEEP in all the CPUs software will make the system more energy efficient (Bates, 2004). If security is a concern, adding the CRC-8 implementation in the protocols will be one of the solutions (CRC8, 1999).

This capstone project brought the theory and protocol design (Serial UART Tutorial, 1996; SMBus2.0, 2001) of the synchronous serial communication in the chip level into a practical application has made a good impact on the students' understanding of the potential in their ET career. Regarding their accomplishment, here is what the students said, "As the project nears to an end we have learned so many things. We learned how to communicate with each other as team members, which we think is important when we move on and start our careers. We also learned how to communicate with multiple microcontrollers, and how to design a project that can be useful to the environment. We were able to take our knowledge and apply it to one project. We were able to see that each one of us thinks completely different, which makes the project unique and different. The boxing robot no matter how simple it may sound, it was a great way for us to apply our knowledge of communication, electronics, and teamwork." (Tyson & Ransberger, 2004, p18)

The concept of the serial communication is simple and has been utilized in different areas in the real world. This integration of the existing concept in a custom-made application that brings real-life applications into classes, has served one the important missions of the ET education: Applied Engineering. This proof of concept provides the student with an interesting application idea and a better understanding of the links between hardware and software along with their potential applications in the workplaces.

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Linking the Microcontroller Lab with Hands-on for Web-Based Distance Learning

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Introduction

This paper explains the procedure to set up a distance learning microcontroller laboratory with hands-on experience for the students. Students are given traditional access to a microcontroller laboratory environment in the Electronics and Computer Technology Department at Indiana State University. With fast internet connectivity and growing needs for distance learning, it makes sense now to develop a learning management system to train and teach microcontroller laboratory other than actually being on campus.

Distance learning is planned learning in which teaching and learning normally occur at different places and so require special techniques of course design, special instructional techniques and special methods of communication by electronics and other technologies. Students who may not be able to participate in the regular classroom proceedings due to inflexible working schedule, poor health or disabilities will choose distance learning. Distance learning could also be a solution for the universities that do not have enough room for students, or for students who can not take classes at certain times. This paper addresses the question if it is possible to offer microcontroller class for distance students.

Assie-Lumumba (2003) pointed out that information and communication technologies and their application to distance education are being increasingly adopted as they are cost-effective and this responds to the high demand for university and other types of tertiary education both in developing and developed countries. The programs of many electronic universities, for instance, consist of a two-mode design in which distance learning is designed as a supplement to, or side-by-side with the regular face-to-face learning within traditional institutions. In addition, there are an increasing number of single-mode programs of distance learning in open universities that operate entirely as virtual institutions.
A microcontroller laboratory based distance learning course using Moodle, an open source learning management system, has been developed. This learning management system facilitates teaching a microcontroller course with hands-on experiments, tracks student progress and enables online interactivity between students and their faculty.

Overview and Background

During the introductory period of distance learning, trials were made to offer lab courses with laboratories that included hardware like microcontrollers through internet for distance students, and some of these trials are considered below.

In his paper titled 'Advanced Microcontroller Interfacing Laboratory', Bryan Infanger (1988) says that the set up of an Advanced Microcontroller Laboratory is a networkable terminal, a network or a host that allows multiple logins, a terminal server, and an evaluation board along with a suitable assembler that can be ported to the host. Then he adds that the majority of institutions have a networkable terminal like a PC with telnet capabilities, a network in campus and a host, so that they need only the terminal server, evaluation board and assembler, whose cost is less than $500.00.

Later he describes the use of his laboratory by assuming a situation in which a student has to write a microcontroller assembly language program without interfacing. The student in this case, would first telnet to the campus host from a computer. Then, he would compose a program utilizing the hosts' on-line editors and then assemble the program. The student then telnets from the host to one of the evaluation boards through the terminal server to upload the assembled code and then executes the program to see if it gives the desired result. If the program does not give the desired result, the student can debug as necessary. The second case is when students must finish an assignment that includes interfacing. In this case, the arrangement of the evaluation boards needs additional assumptions. Students use a computer and telnet from their location to the campus host. They then take their assembled code and upload it to the evaluation board that is

hosting their interfacing experiment. Students then execute their code by issuing commands to the evaluation board. In general, there are two drawbacks to Bryan Infanger techniques for a microcontroller laboratory based class to be offered through distance learning on the programming and interface sides. The first aspect is to offer the microcontroller simulation software on university's servers so that students can compose assembly language programs and then execute them in a simulated environment. The second option would be a microcontroller simulation offered on the lab computer then students can reach it by using the remote control desktop software to do their experiments on the simulated environment. However, this method will not give the students a full experience in terms of dealing with the actual hardware and restricts students to programming that doesn't involve interfacing with hands-on experience. One of the drawbacks of running code on simulators is that students might assume that their code is correct as the simulated result is correct. However, students may overlook timing issues for the slow I/O components and once the code is attempted with an actual evaluation board the I/O synchronization failure will be evident in this method.

The second approach is to let the students connect to the microcontroller lab and to the actual evaluation board from anywhere by using the remote desktop software. In this way students will not be able to touch the hardware. In addition to this, the evaluation board has some switches and push buttons that need to be switched or pushed, and in advanced experiments, the evaluation board needs to be connected to interfacing equipment. Also, this board needs to be observed by students to know what is going on it. These are some disadvantages in the previous two ways of offering the microcontroller class through distance learning. However, these disadvantages can be avoided and it is still possible to offer this class through distance learning.

This paper provides a solution to students who wish to get practical exposure with the actual hardware as well as take the class through distance learning. In order to do that, students need to get the *Fox 11 Trainer Board* (Wytec Evaluation Boards, 2005) that is specially designed for them to be able to use outside the class settings and get Moodle, a free open source software package installed on their schools' web server to take the classes online. The *Fox11 Trainer Board* is shown in Figure 1.

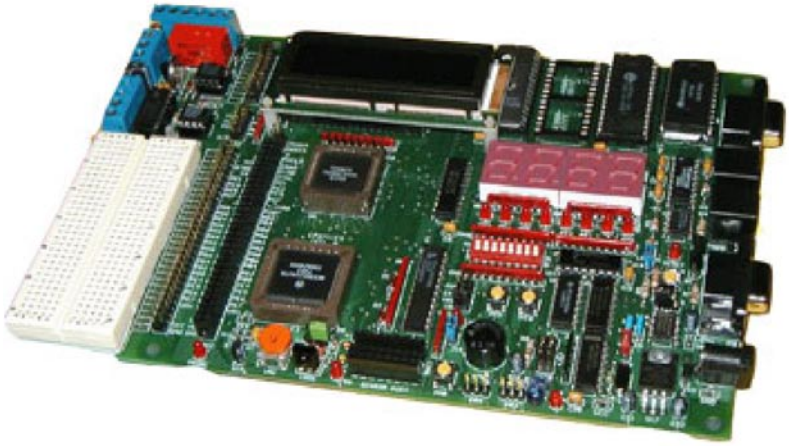

Figure 1: The Fox11 Trainer Board (Wytec Evaluation Boards, 2005)

Distance Microcontroller Based Laboratory

The distance microcontroller based laboratory results from obtaining the cost-effective Fox 11 Trainer Board and Moodle learning management system suitable for giving classes online to supplement face-to-face learning of the microcontroller class. Moodle is a free open source software package and can be easily modified to meet the requirements of offering microcontroller based laboratory at distance.

Method of Implementation

In order to evaluate the feasibility of implementing a microcontroller based laboratory distant course and the use of its equipment to get hands-on experience for distance students, the methodology of this project has been defined. This section explains the procedures of implementing the project.

Design of the system

The implementation of the project using Moodle software and Fox11 trainer board for hands-on laboratory for distance learning is developed in three phases:

1. Preparation of the web server for using the Moodle system:
   a. Specifying and setting up the required components for running PHP
   b. Creating the required components for running MySQL
2. Implementation of the system:
   a. Uploading Moodle software to the web server
   b. Running the installer script (install.php) on the web server
   c. Implementing the entire necessary configuration
   d. Connecting Moodle system to MySQL database to store the data
   e. Setup administration and user access
3. Testing: In this phase, the system is tested in four levels:
   a. Administrative
   b. Teacher
   c. Student
   d. Guest

Moodle system is very secure with all checked forms, validated data, and encrypted cookies. Also teachers can add an "enrollment key" to their courses to keep out non-students. When logged on as an administrator, he or she can do anything within Moodle and its interface which is shown in Figure 2.

Figure 2: Moodle Administrator Interface

There are two types of teacher accounts, one with an editing permission to the teacher that can populate a course with activities and provide learners with feedback such as grades, assignment comments and so on, and another without editing permission to provide the learner with feedback only. The teacher interface is shown in figure 3.

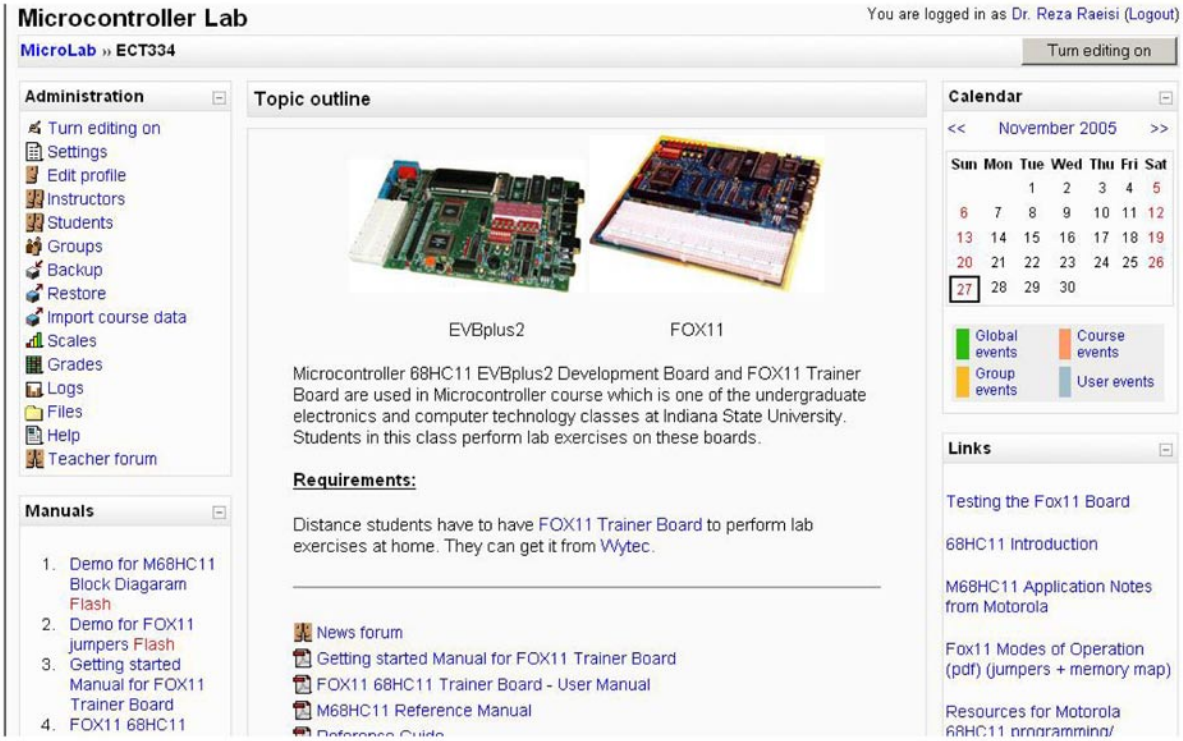

Figure 3: Moodle Teacher Interface

Course Materials

After the system has been tested, the Moodle system is supplied with microcontroller course materials. The course materials are populated in the following format:

a. Power point lectures for the Class
b. Manuals
c. Program examples
d. Links for further information
e. Flash file to demo jumpers and components of the microcontroller

The student access interface is shown in figure 4 below.

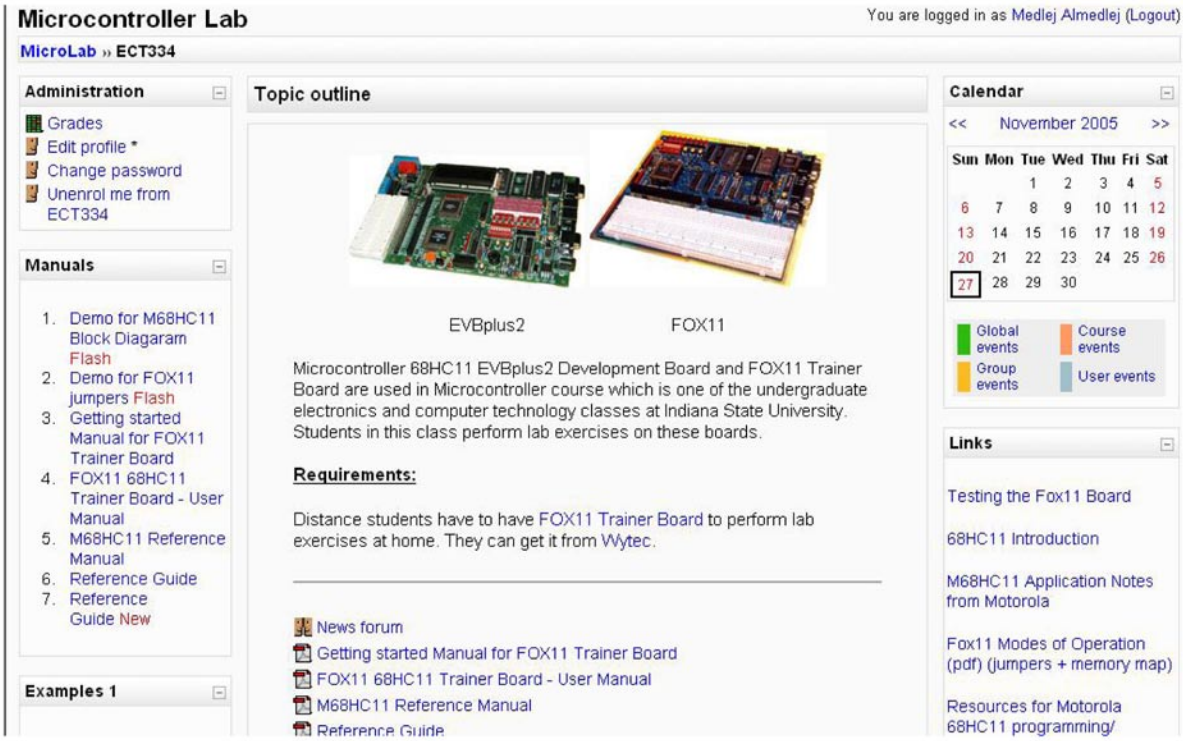

Figure 4: Moodle student access Interface

Summary and Conclusions

Moodle, an open source learning management system has been used to implement microcontroller laboratory with hands-on experience over the web in such a way that it offers convenient access to equipment without restricting the types of exercises that can be assigned for distance education. The effectiveness of this method is that it is cost-effective for a student as he can own the Fox-11 trainer board for less than $65.00 and for an instructor because Moodle is a free open source package.

The procedures of this project were divided into three parts. The first was the preparation of the web server to be compatible with Moodle. The second was the implementation of the system. The third one was to test the Moodle system. The system was tested in four levels: Administrator, Teacher, Student, and Guest. Administrator can do anything and go anywhere within Moodle. A teacher can populate a course with activities and provide the learner with feedback such as grades and assignment comments. Students have the capability to access only the course material, which means he/she can browse the course documents, perform microcontroller interfacing experiments, submit assignments, contact the professor and other peers. Lastly, there is a guest account in which the user can have a "read-only" access and is not allowed to participate in the course activities. Although, this does not seem to have much to offer to the user, it is really helpful, especially to students who plan to register for a certain course.

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OS and Application Management in a Dynamic Classroom Environment

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Abstract
It is a typical scene in a computer technology laboratory that students from different classes have conflicts with OS and settings. We discuss various solutions in this article and illustrate our integrated solution. Our approach not only makes the OS and application management easier and safer but also reduces the cost to set up the labs for computer technology students. The approach we take can be applied to all the public education schools, institutes and libraries where a dynamic environment is required.

Introduction
A typical scene in a computer technology lab is that different classes require their own operating system, applications and settings. For example, a server class expects to have Windows Server 2003 installed; an alternative server class requires Linux Server in place; and a computer repair class needs Windows XP, Windows 2000 and Windows 98 environment to practice troubleshooting skills for different Operating systems. To make things even more complicated, multiple sessions exist for some classes and each session demands its own settings to be saved such that students from different sessions can continue work on their projects that span multiple lab sessions.

In such a dynamic lab environment, how do you solve the operating system conflicts among different classes? How do you set up the lab in a well organized manner with limited budget? In this article, we present our solution which has proven to be successful in reality. In the rest of the paper, we first detail our lab environment and the problem descriptions. A number of possible solutions are then discussed and explanations are given as to why they are not satisfactory. Next, our solution is introduced followed by a comparison study of previous mentioned approaches. The paper concludes with our findings and recommendations to computer technology education, university, and public schools.

Problem Descriptions
The network setting of our computer technology lab is illustrated in Figure 1. Twenty identical PCs and two servers are connected to the Lab Ethernet. One of the servers is sitting on both Lab network and Campus network and serving as a Gateway for the lab network and the Network Address Translation (NAT) server between both networks. The other server is functioning as a file server for students to store their documents and files.

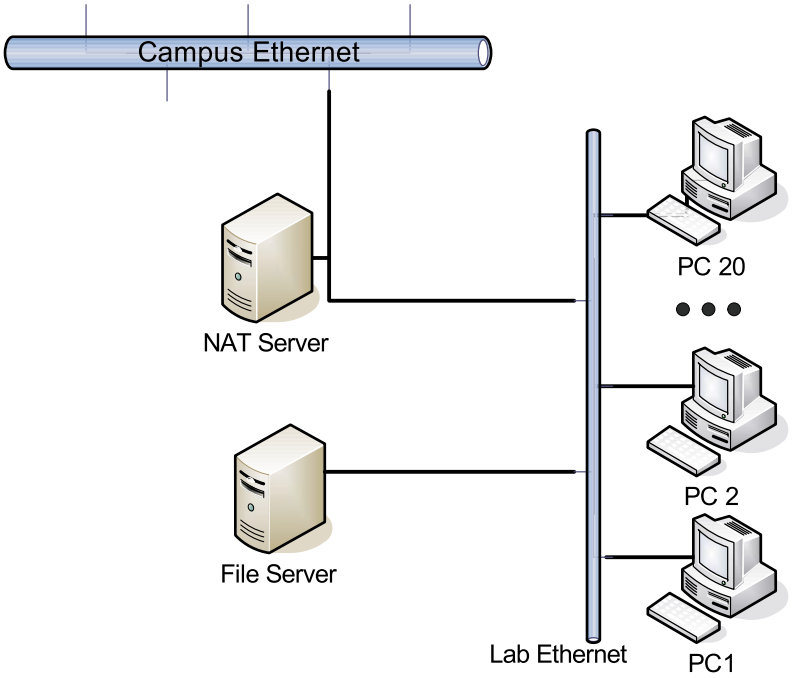

Figure 1: The setting of our Computer Technology Lab

For each PC, the following Operating systems need to be installed to run all the classes and labs for a given semester.

- Three copies of Windows Server 2003, one for each different class / session.
- One copy of Windows XP professional
- One copy of Windows 2000 Professional
- One copy of Windows 98
- One copy of Fedora Linux.

The goal of the solution should provide all the operating system and some common applications installed with satisfactory performance, easy manageability, and minimal budget.

Possible Solutions

Apparently, dedicating one PC for one class is the obvious solution. But that indicates you will have to purchase another six sets of twenty identical computers. It is pricy to purchase, maintain and it also demands much bigger lab space.

Another possible solution is multi-booting, i.e. installing more than one operating system on a computer. But to support multi-booting, each operating system requires at least one separate primary partition. And according to Jean Andrews (2005), the Mast Boot Record (MBR) of an IDE hard drive is hard coded to support at most four primary partitions, which entails that at most four operating systems can be put on a single PC without one interfering another.

If one hard drive is not sufficient, how about using removable hard drives, one for each OS? Money again is an issue. Purchasing over a hundred hard drives are still very costly and the management cost of removable hard drives is not trivial. Each hard drives should be labeled carefully and organized in a storage place when they are not used. In addition, hard drives are very fragile. If not handled properly, a removable hard drive fails, students would easily lost their work saved on that removable hard drive.

Alternatively, disk imaging techniques can be applied. Products like Drive image and Ghost can take a snapshot of the hard drive and back up an entire partition or hard drive as a single huge image file. With this technology, users can backup and restore their entire system, including applications, settings and documents easily. Two type of back ups are supported. One is back up locally to another partition, or the secondary hard drive. Another is to back up through a centralized server. Local backup is usually initiated by the users and requires booting from floppy disks, while network backup can be started and controlled from a management console. Another difference between two types of backups is the speed: local backup usually is a lot faster than network backup especially when the local area network is congested. The limitation of the drive imaging technology is that it does not fully support Linux operating system. So, drive imaging alone cannot solve the problem.

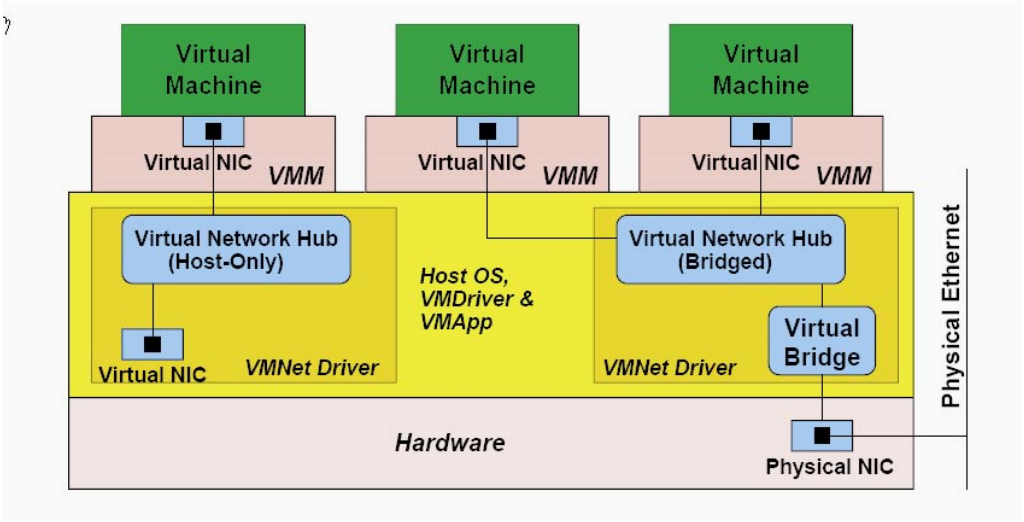

Figure 2: A typical Virtual Machine technology

Besides the approaches mentioned above, virtualization technology can also be applied in this scenario. The virtual machine solution enables you to run multiple un-modified guest operating systems on a host machine. VMware white paper (2006) describes a popular virtualization implementation. The architecture of such implementation is illustrated in Figure 2.

In a nutshell, a virtual machine is a software emulator of a real operating system. Each virtual machine will share the system resources of the host OS, such as CPU, RAM and hard drive. VMware solution also provides virtual networking interfaces to allow virtual machines communicate with host machine as well as other virtual machines. The major down side of the virtualization technology is the resource sharing, particularly RAM sharing. Assuming a PC has 512MB RAM installed. To run a virtual Windows Server 2003 on this machine, you need to allocate at least 256 MB RAM to the virtual machine. Both host OS and guest OS end up with only 256 MB RAM, which results in performance degrading in both host OS and guest OS. Another noticeable problem is that current virtualization techniques do not support some advanced technology, such as Active Directory, very well.

A solution integrates virtualization and drive imaging

From the discussions in previous section we can see both virtualization and drive imaging techniques have some desirable features to solve the OS management issue in a dynamic classroom environment in terms of cost. But each technique alone also suffers from a number of undesirable problems. In this section, we present an implementation that integrates both technologies. The objective is to maximize the system performance while maintaining centralized management features.

First, we define a common OS platform that enables users to access all the applications and interfaces to other operating systems. Windows XP pro is chosen due to its popularity and great software and hardware support.

On the common OS platform, both VMWare workstation and Norton Ghost client are installed. Because Ghost has certain conflicts with Linux OS, it leaves us no choices but using VMWare workstation as the interface to Fedora Linux. Operating systems like Windows 2000 and Windows 98 do not have advanced networking features and are normally not memory hungry. It is also desirable to run them as virtual machines.

For Operating Systems like Windows Server 2003, we have chosen to adopt Ghost to backup and restore entire system through centralized a management console because running server OS as an virtual system often results in very poor performance. Figure 3 describes our approach from end user's perspective.

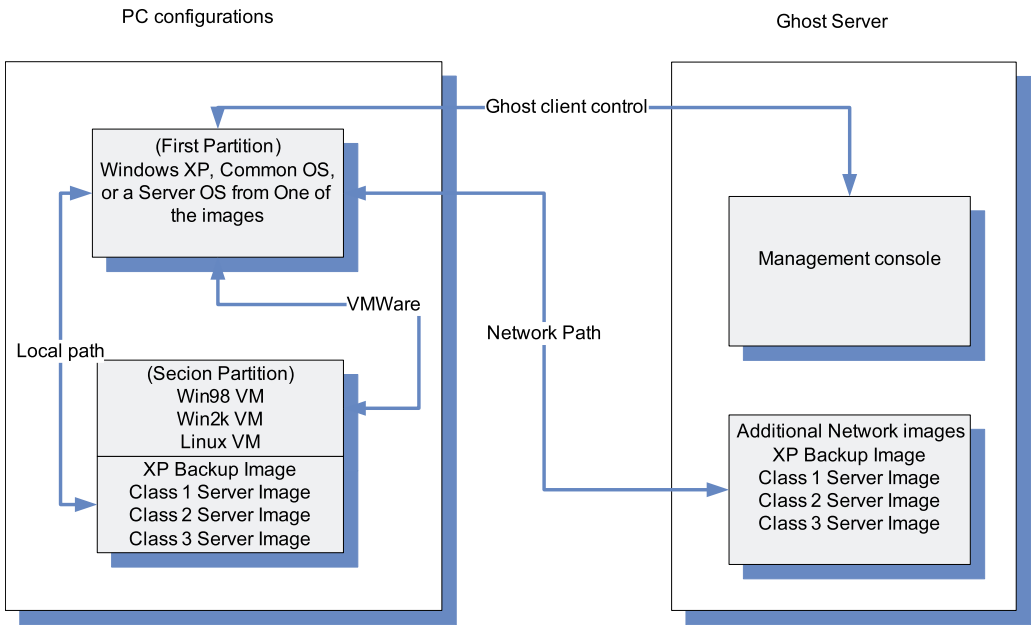

Figure 3: System setup from an end user point of view

At least two partitions need to be created on PCs. The first partition is marked as active and holds operating system, either common OS Windows XP or one of the server OS from images. The secondary partition can store various virtual machines and server images. To access a virtual machine, a user needs to launch VMWare workstation. For PCs have abundant RAM, multiple virtual machines can be loaded simultaneously, just like you open multiple internet explorers. To load a different OS on the first partition, users need to run ghost and re-image the desired OS images onto the first partition either from local secondary partition or from the back partitions saved on the server side. We provide both local path and network path to the users so that when one copy is damaged, they still have another copy to use. In reality, we have found some impatient user may pick the wrong source and targeting partition and therefore write the wrong OS or images to the targeting partition.

At the server side, a managed console allow administrators to multicast an image to selected PCs or to uni-cast an image to one particular machine. The image can be either a local image or a network image. The console also enables the administrators to dictate the rights and permissions that users may possess to perform image back up and restore.

A Comparison of various approaches

A comparison of possible solutions is summarized in Table 1. The proposed incorporation of VMWare and Ghost demonstrate many features that are suitable for a dynamic lab environment.

As to the cost of each approach, we assume that each PC cost $1000, one removable hard drive and hard drive docking bay cost about $100. The OS cost of VMWare workstation for academic users is $80 per user. But there are also free products available in this category, such as Microsoft Virtual Server 2005 and the open source Xen 3.0. And Norton Ghost 2003 is about $30 for one machine. So to support seven copies of operating system, Single PC single OS requires additional $6000 for each user and tremendous lab space. Removable hard drives incur additional $200 per user, while the integrated VM and Ghost need no more around $110 per user.

Table 1: A comparison of different approaches

	Single PC Single OS	Multi-boot	Removable hard drives	Virtual Machine alone	Ghost alone	VM and Ghost integrated
Max OSs supported	One per machine	4	4	Unlimited	Unlimited	unlimited
Require restart machine?	No	Yes	Yes	No	Yes	Depends
Support Linux?	Yes	Yes	Yes	Yes	No	Yes
Support advanced server features?	Yes	Yes	Yes	No	Yes	Yes
Time to switch between Oss	0	15 secs ~ 2 mins	15 secs ~ 2 mins	0	3 ~ 5 mins from local, 20 mins~45 mins from network	Depends
Cost	$$$$$	$	$$$	$$	$$	$$$
Manageability	Hard	Easy	Medium	Easy	Easy	Easy
Performance	Good	Good	Good	Degraded, depending on OS	Good	Depends

Other findings

One lesson we have learned is that VMWare process is running on the background even when you terminate the virtual machine. Figure 4 shows a snapshot of processes running on a XP with VMWare terminated. It has two implications:

- Needs to install antivirus software on virtual machine as well. We have found many virtual machines get infected by worms and viruses even when they are not running.
- A virtual machine configured as a DHCP (Dynamic Host Control Protocol) Server will hand out bad IP addresses even when it is shut down. The result is catastrophic: all the PCs configured as DHCP clients (the default behavior) cannot get online because of it.

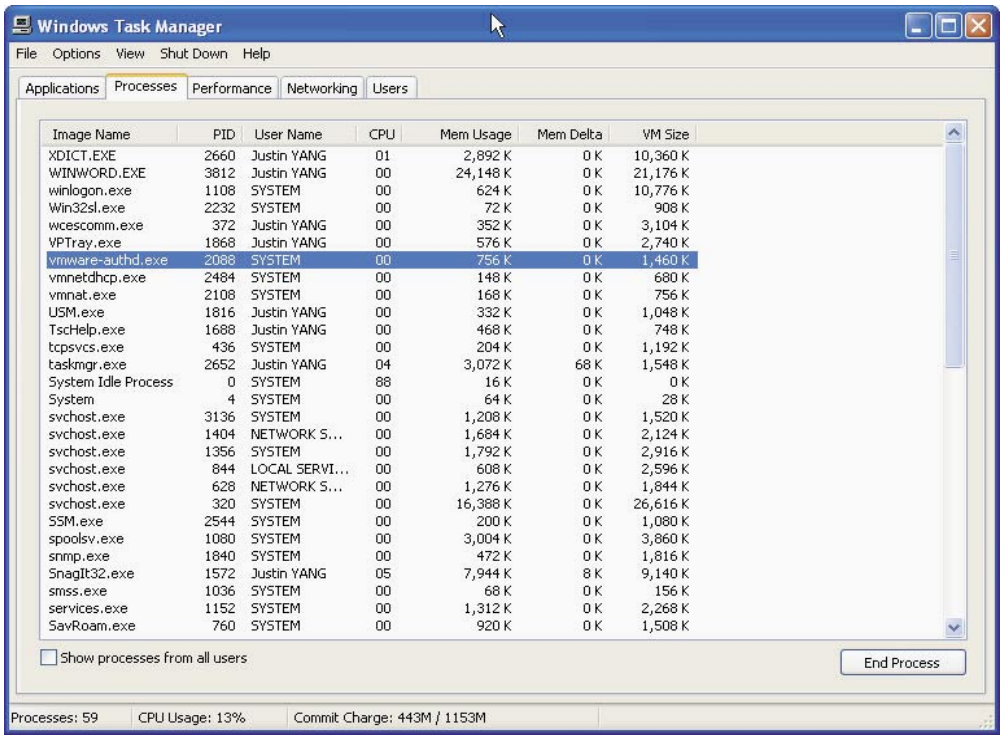

Figure 4: VMWare process running at the background even when VMWare application is terminated

Conclusions

In this article, a common OS conflicts issue in a dynamic classroom environment is introduced. A number of solutions are then discussed and an integrated solution is proposed and illustrated. We compared the different approaches and conclude that our approach is cost effective and meets the needs in the real world. We highly recommend this implementation to other universities and public schools or libraries.

In the future, we would like to move from the Virtual Workstation environment to the Virtual Server environment to further reduce the running cost.

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GRAPHICS

Student Profile and Technology Behavior in Web Design Coursework Taught Online in Higher Education

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Abstract
There are accepted and validated historical and pedagogical approaches to teaching graphic information technology face-to-face. Because significant graphic communications content is now delivered via the Internet, it is appropriate that Internet instruction methodologies be used to teach Internet technologies. In other words, use the technology to teach the technology.

The World Wide Web is deeply embedded in our contemporary society. Teaching Web design and development is an integral part of the Graphic Information Technology (GIT) curriculum at Arizona State University. It is the responsibility of GIT educators, who act as both Web curriculum designers and graphics instructors, to ensure that the online experience is effective and efficient. An important step in establishing appropriate course and curricular outcomes is understanding the target population and their online behavior. This study is a result of gathering data about student profiles and behavior in Web design coursework taught online at Arizona State University in the Department of Technology Management.

Introduction
Arizona State University is charged with the goal of securing an online head count enrollment of 100,000 in the next decade (ASU IT, 2006). Patricia Feldman, interim executive director of the School of Extended Education, has expressed this ambitious goal as having three components: (1) a strategic business plan, (2) a vigorous technical infrastructure, and (3) a design and development process to increase the availability of distance education curriculum (asuonline.edu, 2006).

ASU began its early distance learning commitment in 1935 with the advent of mail-order correspondence courses. Television courses began in the 1950s. By spring semester 2004 over 200 online courses were offered with an 89% completion rate — matching that of the face-to-face courses (McCann, 2006).

There are accepted and validated historical and pedagogical approaches to teaching face-to-face. In the last decade World Wide Web technologies have opened up opportunities for online learning in higher education. Significant graphic communications content is now delivered via the Internet and it is appropriate that virtual teaching methodologies be used to teach Internet technologies.

The 2.8 million higher education students enrolled in online courses in 2000-2001 represents a doubling in the three years since 1997-1998 (McCann, 2006). With 49% of all public institutions offering an online degree, and 97% offering at least one online course, distance learning is becoming one of the fasted growing higher education trends (McCann, 2006). Because research is not as robust in pedagogical approaches to teaching online as has been established in face-to-face instruction, and because Internet technologies are constantly updated and introduced, this study was initiated.

In this study the authors gathered opinion agreement data on the online behaviors and profiles of students who have completed university Web design courses on the Internet. Open-ended questions on the benefits and limitations of taking online courses were included in the questionnaire. Along with demographic questions, other questions were asked about the student usage of e-mail, online chatting, blogging, mailing list server, and browser technology. In order to better understand the results of the survey, an overview of each of the Web technologies is presented.

E-mail Technology

There are several e-mail technologies: (1) Web, (2) POP, and (3) IMAP. Web-based e-mail can be used with any computer with Internet access and a browser. It requires no configuration. It is functional, feature-rich and mobile (Entergroup, 2006).

E-mail management software such as Eudora or Outlook are used with Post Office Protocol (POP) mail. The mail is downloaded to the user's hard drive, after the computer is connected to a shared mail server. It has static usability with a single computer (Entergroup, 2006).

Internet Message Access Protocol (IMAP) is more complex than Web and more complex to implement than POP. It has a combination of Web-based and POP mail features. IMAP is a client/server protocol that is used primarily with business servers. Messages remain on the server and the need for computer-to-computer message transfers is eliminated. IMAP synchronizes multiple computers. It has online performance optimization and is mobile (Entergroup, 2006).

Chat Technology

Chatting on the Internet can be done through text chat, Webcasts, moderated chats, video/voice chat, bulletin boards, and instant messaging. Moderated Webcasts are just beginning to increase in popularity (Digi-net Corporation, 2006). Chat protocols were posted for all the ASU online students in this study *(Refer to Appendix B)*.

Blogging Technology

Blogging is one of the newer online communication technologies. It is a way for people to network with information and to socially network. An online site is set up in which the general public can express their opinion or add to the information. The top three blogs are: (1) Digital Camera Review – Digital Photography Blog, which is a discussion board containing digital camera reviews, news and tips (Blogtopsites, 2006); (2) Elliot Back: Technology & Life, which is the world according to a computer scientist; (3) Forever Geek, which is a report on the most updated news for "geeks." Between these three blogs, they average about 12 million hits. The top 25 blogs are all based on topics of technology (Blogtopsites, 2006).

Mailing List Server Technology

A mailing list server is often referred to as "LISTSERV," which is a specific L-Soft International commercial product (Look.net, 2006; Webopedia, 2006). This is the same as referring to "Kleenex" for all facial tissues.

A mailing list server is an automatic server with a mailing list that broadcasts communication for a specialized membership via e-mail (Webopedia, 2006). It is different from a forum or a newsgroup in that the transmission of information occurs through the use of e-mail. The technology was developed in 1986 by Eric Thomas for BITNET. Another example of a mailing list server that has increased in popularity is Majordomo, which is freeware.

Browser Technology

Browser technology has become more competitive as usability, security, and standards are addressed. In the last decade browsers have been narrowed down to several players: Internet Explorer, Netscape Navigator, Safari, Opera, FireFox, and Mozilla (Dumbill, 2006; Treloar, 1999; IDEAlliance, 2005).

Methodology

An online survey was taken in three online Web design and development courses at Arizona State University in the fall semester of 2005. The survey was designed to form a profile of the student and their online behaviors. The survey consisted of 17 multiple-choice and open-ended questions and was itself delivered online. The data from these three courses collectively describe the profiles and behaviors of the distance learning experience so that future online coursework can be continuously improved. The 67 students who participated in the survey took one of the following courses: (1) GIT 394 Introduction to the Web, which is offered to non-majors; (2) GIT 337 Digital Design (HTML), which is a requirement for majors; or (3) GIT 414 Internet Development, which is an elective for GIT majors.

The survey was designed to help learn more about the profile and online behavior of the students, so that improvements can be made in online course delivery. The survey was voluntary and anonymous with no identifying information collected with the survey results. The survey consisted of 17 questions delivered online at the conclusion of the course. Fifteen questions were multiple choice and two questions were open-ended. Forty-three out of sixty-seven (64%) students enrolled in the three courses participated.

It is important to understand that online students were initially provided with resources to help them gain basic Internet knowledge required for online course success. This was part of the learning experience. They were provided online and written documentation on the essential technologies necessary to accomplish the virtual format of instruction in accessing e-mail, World Wide Web, chat sessions, course content, and online discussion boards. Additionally, instruction on assignment delivery was posted, along with IT contacts and website links for troubleshooting any technical difficulties. To assure student competency, online discussion boards were set up as class weekly participation modules, thereby maximizing their capability to complete the class successfully in the virtual environment. GIT 377 offered optional Web design tutoring.

Delimitations of the Survey

The survey was set up with forced completion. It could be saved and taken at a later date, but could not be taken more than one time. Emphasis was not placed on value added (how much the content understanding improved from the beginning of the course to the end), or the outcomes (the state of affairs after course completion). In the survey, there was no consensus as to the effectiveness of the Internet technologies — only their utilization.

Results and Analysis

The survey was delivered online using the Blackboard course management system. Participation was voluntary. This survey was independent of, and fundamentally different from, the standard distance education evaluation of teaching and course effectiveness used in all online courses.

Three courses were surveyed: GIT 337 (Web Content Design, N=13), GIT 394 (Website Development, N=40), and GIT 414 (Advanced Internet Programming, N=14). Sixty-four% of the population responded to the survey (43/67). Fifty-eight% of students in the two lower division courses responded; the response rate for students in the one upper division course was 86%.

Profile

Results indicate the profile of the surveyed population is nearly evenly split between males and females (56% male, 54% female); undergraduates made up a majority of respondents (82% undergraduate, 18% graduate); more respondents were not graphics majors (26% majors, 71% non-majors, 3% unsure); students had some experience with online instruction (first course 36%, two to four courses 26%, five or more courses 38%).

Web Technology Behavior

Respondents showed a preference for desktop computers (52%) over laptops (30%); 18% used both desktop and laptop computers. Operating system preference was decidedly Windows-based (85% Windows, 10% MacOS, 5% combination). Browser preference failed to show exclusive use. Respondents in all three courses used Internet Explorer, though not exclusively. Netscape Navigator was also used by 96% of the students; it was much more likely for upper division students (57%) to also use FireFox, Safari, or another browser that it was for lower division students (0%) to entertain a browser other than Navigator or Explorer.

The data show a majority of online students access online courses using broadband (73% cable or DSL) or wireless connection (21%). Dial-up modem connections were used by 6% of the respondents. The number of hours devoted to the online course increased with the course's level. Students in lower division courses devoted five or fewer hours (49%) or six to ten hours (43%); students in the upper division (GIT 414) course were more than twice as likely to devote more than twenty hours (8.3%) than lower division (3.7%) students.

Surveyed students did not make considerable use of two popular Internet-based communication technologies. Sixty-four percent of the respondents never or only occasionally used instant messaging; more than half (64%) have never used a Web blog. Additionally, 60% have never used a list serve.

Open-Ended Responses

More than half (52%) of the population responded to the open-ended questions.

1. A positive response to convenience. Students generally were positive that the online course met needs for flexibility. However, there were comments which intimated that the more constrictive the online course (specific turn-times, required discussion groups, scheduled tests, etc.) the less the appeal.

2. Many students have experienced scheduling and transportation conflicts that online courses appear to alleviate.
3. There is a feeling that there is not enough "teaching," as defined in student terms, in an online course. Giving reading assignments, pointing students to Web sites that have resources is not generally defined as "teaching."
4. There is a feeling among some students that an online course should be self-paced.
5. There is a perception that less learning occurs in an online course than in a face-to-face course.
6. The perception of quality in an online course is related to the amount and clarity of communication and clear time tables for assignment due dates.
7. Because of online anonymity, there is a feeling that online courses provide fewer restraints based on gender, race, or age.
8. Students admit that being a self-learner is critical in predicting online success.
9. A lack of synchronous communication with the teacher and other students appears to be a factor that limits online success. Students would appreciate the opportunity to personally interact with the instructor once or twice during the semester.
10. The type and completeness of feedback on assignments and examinations contributes to perceptions of online quality.
11. Students did not feel that group projects or discussions were particularly effective.
12. Alternative methods for providing documentation (lectures, notes, demonstrations) should be provided. Thirty-two percent of students still print much of the course documents.

Conclusions

Students surveyed in this study were enrolled in courses that provide fundamental skills and knowledge in Internet technologies; they might be expected to embrace those technologies to a greater degree than might the university student population in general. Indeed, more than 60% of the respondents have taken more than two online courses; nearly 40% have taken five or more online courses. There appears to be a developing cadre of students who are technologically and intellectually prepared to succeed as online students in graphic information technology.

Only six percent continue to use a dial up connection. It appears that the availability of appropriate technology for this group is not a problem and has implications for the type of media that can be entertained as part of an online course. Twice as many students read materials online as those who print online materials. Anecdotal evidence supports that this as atypical to the general student population. However, online students generally bear the entire cost of printing and this may place a serious damper on printing syllabi, assignments, and labs. The implications are that documents that in the past have been static because they were designed to be printed can now be interactive.

There are Internet technologies the surveyed population does not use. Indeed, the negative comments on course discussion groups may be related to not making use of chat, blogs, or list servers. Because technology is not an issue, these communications tools should be carefully monitored for online applicability.

Universally, students believe that communication is critical to the success of an online course. Results indicate that virtual students expressed more frustration from the inability to talk directly to the professor as in a face-to-face setting. A previous study from California State University - Northridge indicated the same finding (Schutte, 1997). In the CSU comparison study, evidence was presented to show that online students received higher grades than face-to-face students did. Jerald G. Schutte deduced that students compensated through increasing their interaction with each other. The highest performing students reported to have the highest peer collaboration. It appears that students may overcome this feeling of loss in not being able to communicate directly with the teacher by extensive peer collaboration.

Convenience remains a major strength of online delivery. Therefore, any course element that reduces convenience should be carefully considered before implementation. This would include online tests that must be taken at a specific time, synchronous communications such as scheduled lectures, or regularly timed discussions. However, there is an element of expected "self-paced" instruction in students' perceptions as to what constitutes an online course.

Students bring face-to-face perceptions to the online experience of what constitutes "teaching." That is, if an online instructor is not actively engaged in delivering instruction, communicating with students, and evaluating performance (all expectations of traditional face-to-face courses), there may be a perception that the online instructor isn't actually teaching. Of course, these are the same criticisms of traditional instruction: teachers don't really teach.

Future Study

The pedagogy of online graphics instruction is currently being defined. This investigation has raised several questions worthy of future study.

1. Further studies should be done to determine if online students compensate for a lack of direct interaction with the instructor by increasing interaction among peers, as evidenced in Schutte's 1996 study.
2. Is there a relationship between the level of self-learning and perceptions as to what constitutes online teaching.
3. Further study should be done to determine the relationship between the level and quality of peer interaction, and a positive perception of online teaching.
4. How do expectations of self-paced instruction affect success in online courses?
5. Determine whether or not a unique and quantifiable pedagogy exists for online instruction and if one does exist, the extent that face-to-face pedagogy enhances or inhibits online success.

Summary

There are compelling reasons to consider that Web design and development be taught online. First, technological overhead has been reduced to the point that most potential students are able to fully engage the online experience. However, because online offerings have developed along side traditional face-to-face instruction, online has not developed a unique, identifiable, and accepted pedagogy. Teachers and instructional designers bring pedagogical biases to their courses; students bring biases to their learning.

Using the technology to teach the technology may be the most compelling reason for online instruction in graphics. There are some activities, however, that may not lend themselves to distance technologies. This is similar to acknowledging that certain educational activities do not lend themselves to the classroom—hands on laboratories, field trips, internships, shadowing, and work study. Students will adapt to different models of learning, as teachers adapt to different models of teaching.

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Appendix A: Survey of Online Student

Instructions:

This survey is designed to help us learn more about the nature of the students taking our online courses so that we can better accommodate them in the future.

This is an anonymous survey, no identifying information is transmitted with the survey results. Please answer all of the questions as accurately as possible.

Multiple Attempts:

Not allowed. This Survey can only be taken once.

Forced Completion:

This Survey can be saved and resumed later.

Question 1: What type of computer is your primary computer? *Choose one from the list.*

A. Desktop Computer
B. Laptop Computer
C. Both Desktop and Laptop computers

Question 2: What type of computer operating system did you use most often when working on this class?

A. Windows based computer
B. Mac OS based Computer
C. I use a combination of Windows and Mac OS computers
D. Other

Question 3: Please check any of the places that you have worked on this course using a computer?
Please check all that apply

A. Home/dorm
B. Library or other public computer facility
C. School Computer Lab
D. Public facility such as a Starbucks or other wireless hotspot

Question 4: Which of the following browsers are installed on the computer(s) that you use for this class?
check all that apply

A. Netscape Navigator
B. Microsoft Internet Explorer (IE)
C. FireFox
D. Safari
E. Other

Question 5: Which of the following browsers do you use most often for this class? *choose only one from the list*

A. Netscape Navigator
B. Microsoft Internet Explorer (IE)
C. FireFox
D. Safari
E. Other

Question 6: What type of internet connection do you use most often when working on this class?

A. Dial-up (modem)
B. Highspeed connection such as cable or DSL
C. Wireless
D. Don't know

Question 7: How many hours do you generally spend per week on this course?

A. 5 or less hours
B. 6 to 10 hours
C. 11 to 20 hours
D. more than 20 hours

Question 8: Which choice best fits how you read course related documents?

A. I generally print them then read them
B. I generally read them on the screen

Question 9: Including this course, how many completely online courses have you taken at the college or university level.

A. 1 course
B. 2 to 4 courses
C. 5 or more

Question 10: How often do you use an online chat program such as AIM or iChat to communicate with others?

A. Never
B. Occasionally
C. Frequently

Question 11: Do you participate in any Web Blogs?

A. Never
B. Occasionally
C. Frequently

Question 12: Do you participate in any List Serves?

A. Yes
B. No
C. Not sure

Question 13: Are you a GIT Major?

A. Yes
B. No
C. Unsure

Question 14: What is your class rank?

A. Student
B. Graduate Student
C. Unsure

Question 15: Gender:

A. Male
B. Female

Question 16: Please take some time to list the things that you liked best about ANY of your online courses.

Question 17: Please take some time to list some of the things you disliked about ANY of your online courses.

Appendix B: Chat Room Protocol

Chat Room Protocols

Many of you may participate in online chatting such as AIM. This is typically a fairly unorganized form of communication where anyone can interject at any time. This does not work well for chats designed to facilitate team work. I have created this list of suggested chat room protocols to help maximize the communication process without significantly affecting your ability to communicate freely.

Prepare for your chat ahead of time:

- Use the Group discussion board to communicate with group members. Do not use email as there is not common record of the communication.
- Choose a team member to be the Group Moderator. The instructor may choose to assign graduate students the task of being Group Moderators
- Select a time that is convenient for the chat. A list of possible chat times are posted in the module folder. I recommend that each team member list the times that work for them in the discussion board and the team moderator pick the best one. If you can not all agree on a time contact the instructor by email immediately. Participate of all group members is mandatory.

Log in early:

- Log into the Group discussion board 5 to 10 minutes before the chat is to start. (Groups menu --> Group Number folder --> Collaboration)
- Take time to introduce yourself to each other that way you have that out of the way when you begin to record the chat.

Chat Protocols:

- Only one person at a time can have the floor. Online class related chats should be conducted similarly to a classroom discussion. One person should speak at a time. We will refer to this as having the "**floor**."
- The Chat Moderator should be responsible for controlling the "flow" of conversation.
- The Chat Moderator should begin the conversation by introducing the topic or posing a question. Other group members should respond the to question one at a time.
- The Chat Moderator is responsible for starting and stopping the recording. The Chat monitor should also be responsible for naming the Chat appropriately so the instructor can find it.

Chat Symbols:

Only one person at a time can have the floor. Please use the following symbols to help facilitate smooth communication

- % member name - should be used to yield the floor to someone else.
- **&** - Enter a single ampersand (&) if you want to request the floor from someone else. Then wait for the floor to be yielded to you. If you want to direct your question comment to someone specific. Type the & followed by the person's name.
- **#** - Use the pound sign (#) at the end of your statement to indicate that you are done. This allows you to take time to think and type. It also allows you to make a statement that takes more than one entry screen.
- **-->** - use this symbol if you must step away from the screen.
- **<--** - use this symbol when you return.

Other Guidelines:

- If you loose connection with the server. Do your best to reconnect as quickly as possible. Once you reconnect do not interrupt by integrating comments about what happened just rejoin "**quietly**."
- If the moderator looses his/her connection have a back up person who will take over until the moderator is able to return.
- Avoid idle chit chat. You are welcome to chat with other class member on your own.
- All group members are expected to participate actively in the chat. Don't waste chat time with comments like - Ditto, I agree. Active participation requires well thought out comments and questions. **Each group member is graded separately on their participation.**

INDUSTRY

Time Studies and Efficiency Planning Using Lean Manufacturing

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Abstract
Through this paper the audience will understand how to perform time studies by first writing, verifying and executing Standard Operating Procedures (SOP). Once the process has been documented, workers can then perform their time study using either stopwatches or videotape. The data collected helps create equivalencies that can be used for planning, purchasing, pricing, and manufacturing. It is also used to calculate the value-added time (VAT) of the process. The VAT helps determine the percentage of waste in the process. Lean Manufacturing strives to eliminate waste. The first tool to be used in eliminating waste is Value Stream Mapping (VSM). After conducting VSM, companies can then focus their continuous improvement initiative to attack the waste while striving toward achieving current business objectives such as reducing Internal Cycle Time, reducing Work-in-Process, or increasing Visual Flow.

Introduction
Time studies, although a century old concept, are reemerging as valuable tools in industry of the 21st century. Properly conducted time studies, with a focus on Standard Operating Procedures, can yield valuable data that can be used to create equivalency models critical toward daily decision making in the areas of planning, purchasing, sales, and production.

The time study data can be used one step further in determining Value Added Time Percentage. This calculation is an indicator of the amount of waste companies have in their processes. Once the waste level is determined, powerful lean manufacturing tools can be used to reduce and/or eliminate that waste. The most instrumental tool for waste elimination is the Value Stream Map. This tool pictorially documents the "door-to-door" flow of materials and information and exposes many of the weak areas.

These weaknesses can be strengthened by aligning continuous improvement activities with the company's overall business objectives. While every company has different requirements and objectives, most will use these equivalency models in conjunction with Value Stream Mapping results to reduce internal cycle time and work-in-progress while striving to make the process more visual and self-sustaining.

Time Studies
According to Liker (2004) Frederick Taylor, the "father of scientific management," was one of the pioneers in conducting time studies (p. 140). Taylor used stopwatch timing to break down the elements of tasks (Wang, McNeel, Baumgras, 2003, p. 47). Although highly controversial at the time, and widely dismissed today, time studies can still play a critical role in process improvement (Ferguson, 1997, p. 22). Taylor would use the findings of the time studies against the workers by raising productivity requirements and setting unrealistic objectives (Liker, 2004, p. 140). However, when administered properly and with the correct objectives, time studies can be informative and instrumental in making improvements to the process which will ultimately enhance the employee's quality of life on the job (Michalski, 1998, p. 47). The accuracy of the data collected from the time study can be ensured by analyzing Standard Operating Procedures.

Standard Operating Procedure (SOP)

Without standardization, time study data will not be useful (Thomas, 2006, p. 36). Standard Operating Procedures (SOPs) are instrumental to the standardization of the process (Liker, 2004, p. 143). SOPs ensure that processes can be repeated by the same worker and reproduced by another worker (Schmidt, Kiemele, Berdine, 1999, p. 109). A good time study conductor will take measures prior to beginning time studies and follow three critical steps: (a) verify SOP existence, (b) verify SOP accuracy, and (c) verify SOP execution (Schmidt, Kiemele, Berdine, 1999, p. 140). (See Figure 1)

The first step is to verify that SOPs exist for a particular process. Without SOPs in place, there is no way to ensure that workers are knowledgeable of the steps they are required to perform in the process to produce a high quality, accurate part. If the SOP does not exist, it must be created in collaboration with the operators. If the SOP does exists, it is important to determine if the documented approach is indeed the "best practice" for that task performance. Discussions with the workers performing the task will highlight weaknesses in the documented SOP. If necessary, it is important to make changes to the existing SOP. Proper training of the changes must be conducted to ensure that all operators are aware of the changes. Once the verification and accuracy processes have taken place, it is important to observe whether or not the process adheres to the SOP. Many companies will have robust process documentation, but

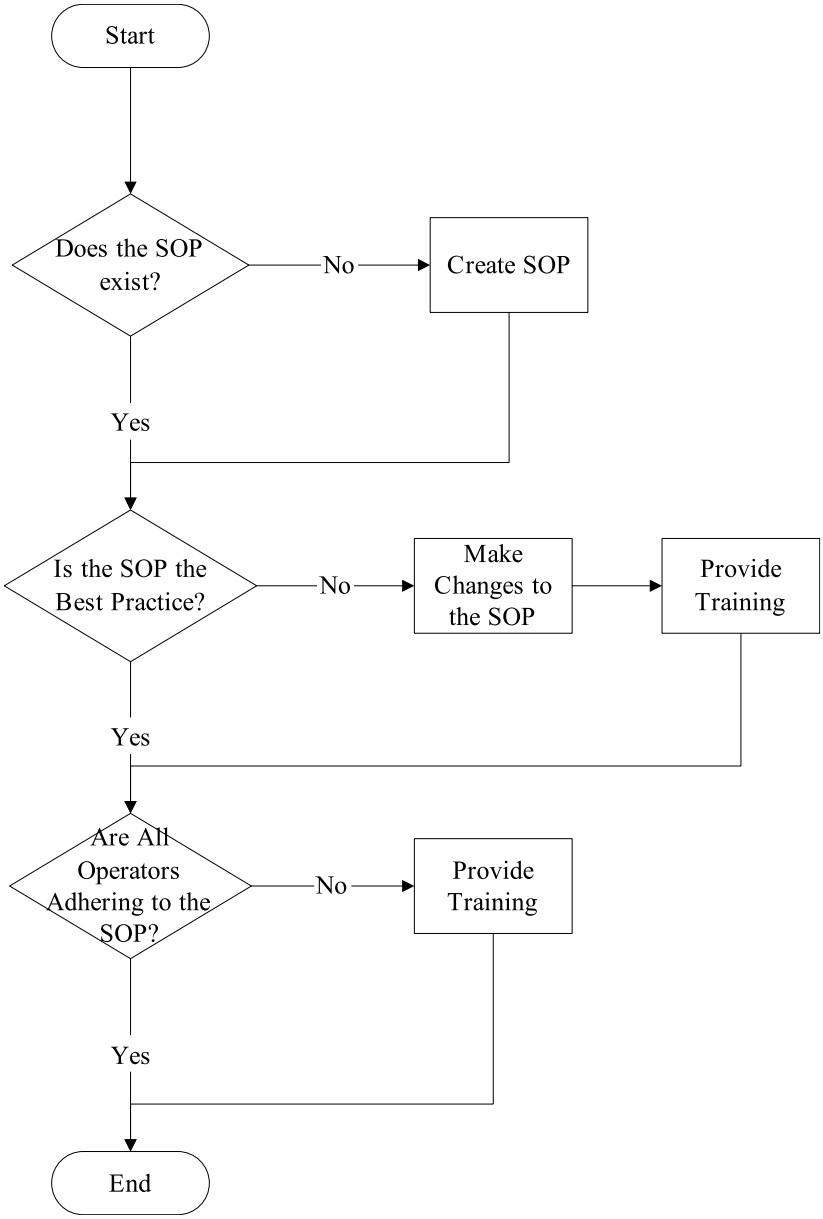

Figure 1. Standard Operating Procedure Process Flow

due to careless management practices or high turnover, SOPs may not be executed according to company policy (Liker, 2004, pp. 147-148). Additional training may be required prior to conducting time studies, but these precursor steps are critical to the accuracy of the collected time study data. All operators must produce repeatable and reproducible parts (Liker, 2004, p. 38).

Performing Time Studies

Once the SOPs are in place, time studies may be conducted to gather data for analysis. The objective of the time study must be clearly stated to everyone involved in order to obtain accurate data. Materials must be gathered and time collectors trained. (See Figure 2)

The primary objective when collecting data from a time study is to differentiate individual process rates for the three inputs of the global process: (a) process steps, (b) material requirements, and (c) process complexity. Process steps must be broken into individual tasks or combination of tasks. A clearly defined beginning and end point of the process must be determined. It is also important to distinguish between different materials that are used in the process because material input can have a major effect on process time. Finally, task complexities are highlighted and the data compiled are used to establish product equivalencies.

There are two main medium to collect the data: stopwatches and videotape (Rother, Shook, 1999, p.14). If stopwatches are being used operators may get nervous or work differently. This may cause inaccuracies in the time study data. Nevertheless, if the workers understand the objectives of the time study and are comfortable with the process and conductor, they can eventually work at their natural rate. The better way to collect the data, however, is by using videotape. Video-cameras can be placed in inconspicuous locations, which may result in greater data accuracy. Furthermore, the video can be reviewed multiple times by multiple people. It can be used for training purposes as well as for determining future best practices (Wang, McNeel, Baumgras, 2003, p. 47).

In all, the best data will come when the operators themselves collect it (Thomas, 2006, p. 38). That process would ensure the operators' buy-in to the process and potential outcome of the study. If the operators are unavailable, the next best conductor would be the process engineers. Because of their familiarity with the process and the people performing the process, the process engineers, too, can have a significant impact on the outcome (Hanson, 2005, p. 14). At all costs, management should not conduct the time studies unless there is a very fluid, trustworthy relationship between management and operators.

Equivalencies

Time studies allow affected parties to become more knowledgeable about their process. If a baseline product is produced, the time study data can be used to determine equivalencies of other products against that baseline. Every product, process, and complexity can be given an equivalency factor that can then be used for better decision making.

Calculating and Using Equivalencies

Once the baseline product is determined, that product is given a ratio of 1:1. From that point forward, all other products will have a ratio in relationship to that product.

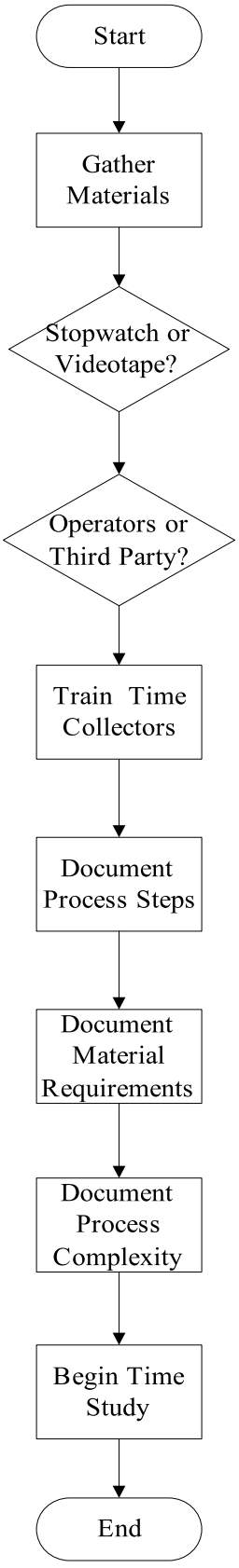

Figure 2. Time Study Requirements Process Flow

Example: It takes the baseline product ten (10) minutes to be processed at a particular station (1:1). Another product that runs through the same line is at a slower rate of eighteen (18) minutes. Therefore, the product ratio is 1.8:1.

As the equivalencies of all product types and families are created, a model can be established to be used in decision making. Some decisions affected by the equivalency model include the following: production planning, purchasing, sales cost, and product engineering.

Value-Added Time Percentage (VAT%)

The time study data along with the rates that have been established can be used to determine Value-Added Time Percentage (VAT%). Three critical pieces of information are needed in order to determine the VAT%: Value-Added Time (VAT), batch size, and batch throughout rate. **VAT** is the "time of those work elements that actually transform the product in a way that the customer is willing to pay for" (Rother, Shook, 1999, p. 21). In other words, it shows how quickly and efficiently one piece can move from the exact beginning to the exact end of the process. **Batch size** is the volume of work that typically passes through the process together before more as a unit to the next station. And finally, **batch throughput rate** is the time needed for that entire lot to travel, as a group, from the beginning of one process to the beginning of the next process (including wait time between process steps) (Womack, Jones, 1996, p. 179). Although the batch size number is not included in the calculation, it is important to know that batch size data prior to collecting the throughput rate of the batch.

Once these three pieces of data are collected, that VAT% can be calculated:

VAT% = VAT/Throughput

In other words, the equation indicates how quickly one piece flows through that specific process in relationship to the batch. The ideal outcome would be 100% meaning that the batch size was a single piece and that there was no wait time or queue time between the current process and its up and down stream processes. Anything less than 100% indicates that there is waste in the process that should be eliminated.

Example:

VAT (One piece) = 42

Throughput (Batch) = 11520

VAT% = 42/11520 = 0.3% VAT

World leaders in industry obtain a 30% VAT%. Due to mechanical and information limitations it is not possible to reach 100% VAT%. Average American companies hover around 12.5% VAT% (Wilkerson, 2002).

Waste

Waste exists in all work and in all industries. The key is to know how to identify the wastes and ultimately eliminate them, moving further to the right on the VAT% continuum. Lean manufacturing has identified seven different wastes: over-production, wait time, transportation, processing, inventory, motion, and defects. Each waste can be defined, uncovered and removed.

The seven wastes defined are the following:

- Over-production is producing more than needed at a faster rate or before it was required.
- Wait time is any moment where a worker and machine are idle.
- Transportation is the unnecessary movement of material.
- Processing is repeating an action that ultimately does not add value to the product.
- Inventory is excess supplies.
- Motion is the unnecessary movement of people.
- Defect is reworking or repairing a product in addition to scrap.

Oftentimes, an eighth waste is included. It is underutilizing human resources resulting from the lack of employee input (Liker, 2004, pp. 28-29). All of these wastes can be significantly reduced and/or eliminated by using lean manufacturing techniques.

Lean Manufacturing

Lean manufacturing focuses on the elimination of waste from the customer's perspective (Solomon, 2005, p. 31). There are many different tools that fall under the lean manufacturing umbrella such as: Total Productive Maintenance (TPM), Single Minute Exchange of Dies (SMED), Poka Yoke, Cellular Manufacturing, 5S, Visual Management, Takt time, Kanban, and Kaizen (Dailey, 2003, pp. 2 - 4). However, the best tool to highlight waste is the Value Stream Map.

Value Stream Map (VSM)

A Value Stream Map (VSM) is a pencil and paper tool that is used to highlight all "door-to-door" activities at a high level (Rother, Shook, 1999, p. 14). (See Illustration 1) It illustrates not only material flow, but information flow as well (Dailey, 2003, p. 18). It spans a broad level from raw material to delivery of finished goods and is critical helping illustrate upcoming kaizen (process improvement) events (Rother, Shook, 1999, p. 58). VSMs document value added and non-value added activities. The repeated use of a set of standard icons ensures homogeneity and provides a common language for everyone across the entire organization (Rother, Shook, 1999, p. 4).

The data collected from the time study is used to populate the VSM. Since the VSM looks across the span of the business, the time study data helps indicate areas of uneven production and major bottlenecks (Rother, Shook, 1999, p. 9). As the Future State Map (See Illustration 2) is created and processes are refined or combined, it may become necessary to conduct more time studies in the manner indicated above.

Illustration 1. Current State Value Stream Map

Illustration 2. Future State Value Stream Map

The first round of VSM will evoke both positive and negative reactions. The negative reactions occur because the VSM exposes the weaknesses of the processes. These typically include tunnel vision, silo mentality, and cherry picking of expedited orders, which are all sources of waste. On the other hand, it facilitates discussions about product and information flow and will result in the creation of an implementation plan. That implementation plan should go hand-in-hand with the company's overall business objectives (Rother, Shook, 1999, p. 4).

Business Objectives

Every business has its own objectives but when embracing lean manufacturing, the majority focus on reducing internal cycle time, reducing Work-In-Process (WIP), and increasing visual flow. Other business objectives include reducing scrap, improving quality, and increasing customer satisfaction, all without jeopardizing safety standards.

Internal cycle time can be reduced in this process by using the equivalency model created from the time study. These equivalencies, in conjunction with the VSM, can aid in level loading production, decreasing batch size, increasing release frequency, and allowing for a means to manage a variable constraint (Dailey, 2003, p. 32). Lean manufacturing in conjunction with the VSM will focus on the queues not the process or the people (which differs from Taylor's action plan).

WIP reduction begins with setting attainable goals for the employees and allowing the work to be pulled, not pushed, through the facility (Dailey, 2003, p. 34). When the WIP is pulled, it eliminates pile-ups and facilitates WIP management.

Finally, the creation of visual flow empowers all employees to know exactly what to do, when to do it, and at what rate. It eliminates "cherry picking" and instills a First-In-First-Out (FIFO) mentality. Additional lean tools such as Kanban and Visual Management are extremely appropriate to accomplish this objective (Dailey, 2003, p. 25). This empowerment of the employees leads to a happier workforce that correlates to increased productivity. Those productivity measures are known in "real time" and are obvious to all those involved in working on the product.

Conclusion

The misconception when dealing with time studies and lean manufacturing is that it is applicable only in high volume, "widget-building," low changeover environments. This, however, is not the case. The basic steps highlighted above in regards to time studies, equivalency modeling, lean manufacturing and waste reduction using value stream mapping can be conducted in any type of business no matter how large or small, independent of the product or service. The key to success depends on top-level management buy-in and drive. Lean manufacturing can be applied in varying degrees, but one underlying truth prevails: continuous improvement is a necessity in today's global business climate. The tools and techniques outlined here are just a few vital steps that must be taken in order to be actively competitive for years to come.

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Appendix

Definitions of Key Terms

5S – a methodology for organizing, cleaning, developing, and sustaining a productive work environment
Batch size Reduction – a manufacturing approach that emphasizes the reduction in process batch sizes by eliminating the system constraints that force large batch sizes
Cellular Manufacturing – a manufacturing approach in which equipment and workstations are arranged to facilitate small-lot, continuous-flow production
Kaizen – Japanese for "Continuous Improvement" – a management philosophy emphasizing employee participation, in which every process is continuously evaluated and re-evaluated for the elimination of waste
Kanban – Pull Scheduling combined with traveling instructions conveyed by simple visual devices
Poka Yoke – Japanese for "error proof" – A quality improvement strategy emphasizing preventing defects through the selection of low defect rate design options
SMED – an acronym (Single Minute Exchange of Dies) – also the name for a group of quick-changeover strategies
Standardized Work – the process of documenting and standardizing tasks throughout the value stream
Takt Time – the production tempo (Takt is German for "beat") – time per unit Takt time = Time Available (within a work center)/Demand
TPM – an acronym (Total Productive Maintenance) – strategies for creating employee ownership and autonomous maintenance of production equipment
Value Stream – all actions (both value added and non-value added) required to bring a specific product or service from raw material to the possession of the customer (includes information flows)
Value Stream Mapping – the process of identifying and charting the flows of: information, processes and physical goods across the entire supply chain from the raw material supplier to the possession of the customer
Visual Management – the strategy of providing visual information on daily activities available for everyone in the workplace
Waste – non-value added activities or information flows (cost without compensating benefit)
(Dailey, 2003, pp. 2 – 4)

MANAGEMENT

Developing a Graduate Certificate Program in Lean Concepts for Industry and Technology Managers

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Abstract
An online Graduate Lean Certificate Program in higher education meets an industrially identified need in the areas of Lean Techniques, Quality Systems, Production and Operations Management, Advanced Strategic Quality and Standards, and Lean Implementation. Through training in Lean Concepts and Thinking, prospective graduate students are exposed to five three-hour graduate-level courses earning them a Lean Certificate from a major university and preparation to take either the Lean certification examination from the Society of Manufacturing Engineers (SME) and/or the Manager of Quality / Organizational Excellence certification examination from the American Society for Quality (ASQ). Furthermore, students wishing to pursue a graduate degree may matriculate the same five courses into an established graduate degree program.

Introduction
Several large corporations, such as Whirlpool, Xantrex Technology, Gorton, agree that Lean processes help in lowering inventories, reducing waste, minimizing lead-time and facilitating improvement in the quality of products. Lean manufacturing principles eliminating waste by focusing production on specific customer needs (Kroll, 2004). The main topics of Lean concepts include defining value added, mapping the value stream, creating a pull system, analyzing failure modes, and Lean tools and techniques (Five S's, Kanbans, Total Productive Maintenance, Kaizen, and Lean Metrics).

Currently, most industrial personnel are trained in Lean concepts through in-house training programs, out-of-house Lean consultants, or college courses that only touch upon Lean principles. With the certificate program being developed, students would be exposed to five Lean manufacturing courses in an online format. Through the development of an accredited Lean Systems certificate, graduates will be better equipped to find and implement cost savings for their respective companies.

There has been a remarkable growth in the numbers and kinds of certificate programs resulting in enormous growth in higher education (Patterson, 2001). Certificate programs play an important role for the graduate student in permitting a "modular" path to graduate study that may seem less intimidating to the entering student. According to Science and Engineering Indicators 2006, certificate programs from colleges, universities, and various forms of industrial learning centers play a small but growing role in Science and Engineering (S&E) higher education. Certificate programs have become a popular means for students to gain particular skills, for universities to be flexible in a changing environment, and for industry to upgrade the skills of its workers in emerging and rapidly changing fields. In 2002, about 22,300 S&E certificates were awarded in U.S. colleges and universities, up from about 4,100 in 1983 (National Science Foundation, 2006).

Significance, Purpose of the Study

As industry and business confront the current economic crisis, and the financial challenges, technologists and managers need a practical strategic method to guide cost reduction while increasing productivity of organizations. Lean concepts are a top strategy for industrial managers that have been around for a long period of time and incorporate many methods of waste removal and quality improvement. The purpose of this study is to review the Lean certificate programs in today's market and to develop a graduate curriculum of Lean Thinking in Manufacturing Management. This study organizes and synthesizes the current body of research related to Lean methodologies, with a survey of selected individuals in a variety of management levels in organizations. The results of this study will guide the development of goals and outcomes for a certificate program in Lean systems and provide systematic tools applicable in a variety of managerial settings.

Defining Certificate Program and Lean Concepts

Graduate Certificate Program

A graduate certificate program (GCP) is not defined as a degree by Central Missouri State University's Graduate School. It is a linked series of credit bearing graduate-level academic courses that are designed to enhance the particular skills and knowledge of graduate students. The program is designed by an academic department and taken for credits by Extended Campus students and/or current degree program students. Furthermore, a graduate lean certificate program in the School of Technology at CMSU can be served as a stand-alone graduate certificate program for non-degree graduate students and as a graduate certificate program integrated with a graduate degree program.

Lean Systems/Concepts

A Lean system emphasizes the prevention of waste: any extra time, labor, or material spent producing a product or service that doesn't add value to it. The goals include: 1) improve quality, 2) eliminate waste, 3) reduce lead time, and 4) reduce total costs (MacInnes, 2002). Tools and techniques of the Lean System include value stream mapping, visual management, error proofing, quick changeover, standard operations, the Kanban System, Lean Metrics and Total Productive Maintenance. The characteristics of Lean Systems are pull methods of work flow, consistent quality at the source, small lot sizes, uniform workstation loads, standardized components and work methods, close supplier ties, flexible workforce, line flows, automation, 5S practices (sort, straighten, shine, standardize, and sustain), and preventive maintenance (Krajewski, Ritzman, and Malhotra, 2005).

Methodology

The study collected data into two avenues. First was to review current literature on market-accepted Lean Certificate Programs and the statistical number of certificate program in the higher education. Secondly, survey the panel of experts in manufacturing and industry regarding the topics of Lean systems/concepts.

Literature Review

There are a number of Lean Certificate Programs that are offered throughout the universities, colleges, and other private for profit and non-profit institutions. The study selected the top ten Google search Lean Certificate Programs in the United States. Furthermore, the study gathered data from the National Science Foundation (NSF) regarding the number of students who completed higher education certificate programs in Science and Engineering. Statistical numbers obtained helped in analysis of certificate program growth in the United States at the higher education level.

Survey Data

The study collected data from the panel of experts in manufacturing and industry. Experts consisted of Advisory Board Members for the School of Technology (SOT) at Central Missouri State University. Through an Advisory Board meeting with SOT professors and staff on March 2, 2006, educators learned what industrial people expected from the graduate level Lean certification.

Advisory Board Members were presented a questionnaire based on Lean Certification – Body of Knowledge Rubric Version 1.0 from Society of Manufacturing Engineers (SME) – that offers three levels of Lean Certificates: Lean Bronze, Lean Silver, and Lean Gold. There were 15 production managers, engineers, Lean practitioners, and quality supervisors in the manufacturing and industry areas responding to this questionnaire. Data from the 15 respondents were entered into an Excel Spreadsheet for mathematic computation and summarization.

Findings

From the literature review and survey data, the study established a guideline for curriculum development of a Lean Graduate Certificate Program. The findings were organized into two sections: 1) Characteristics of Lean Certificate Programs and 2) Topics for Lean Systems Curriculum.

Characteristics of Lean Certificate Program

Most Lean Certificate Programs were designed to provide technical knowledge in Lean Systems to students and to assist manufacturers with the challenge of implementing and maintaining production and service improvement. This study summarized the main characteristics of eight selected Lean Certificate Programs in the United States. The following details the institutes and the name of programs.

1) Rhode Island Manufacturer's Extension Services is a partner with CCRI (CCRI/RIMES) – Lean Graduate Certificate Program
2) Institute for Public Service at University of Tennessee (IPS) - Lean Certificate Program
3) Canadian Manufacturing & Exporters (CME) – Foundations of Lean Certificate Program
4) Nebraska Business Development Center at University of Omaha, Nebraska (MBDC/MEP) - Lean Enterprise Certification
5) Institute of Industrial Engineers (IIE) – Online Lean Certificate Program in Supply Chain Management
6) The California State University, East Bay - Lean Mastery Certificate
7) The Ohio State University, Fisher College of Business – Lean Manager Certificate Program (LMAC)
8) Northwest Wisconsin Manufacturing Outreach Center at Stout University of Wisconsin is a partner with Wisconsin Technical College System – Lean Certificate Program.

These eight institutes providing Lean Certificate Programs can be summarized and analyzed into four characteristics: delivery method, costs of study, course offered, and credit counted. Appendix A presents characteristics of Lean Certificate Program in the eight institutes identified.

Delivery Methods

Delivery methods of Lean Certificate programs consist of a workshop, online delivery, and classroom learning. Workshops are composed of five-workshop sessions, 56-hour workshops, or a seven-day workshop at a company. Online delivery can be conducted through nine modules over 12 weeks or one graduate course (6 credits) in a semester. Classroom instruction can be accomplished through a single weeklong session (Monday through Friday) or five days each week for four weeks.

Costs of Study

Most institutes have costs ranging from $1,000 to $1,700. For a comprehensive 20-day program, costs accumulated to $15,000.

Courses Offered

Several institutes reviewed emphasized Lean principles, elements, tools and techniques (e.g. Value Stream Mapping, 5S, Kanban, TPM, and so on). Some institutes required company Lean project implementation. One institute required students to take assessment testing in Math and English, prior to involvement in Lean training courses.

Credits toward the degree

Some institutes provided credits applicable towards a graduate degree or to Continued Education Units. Reference Appendix A for more information.

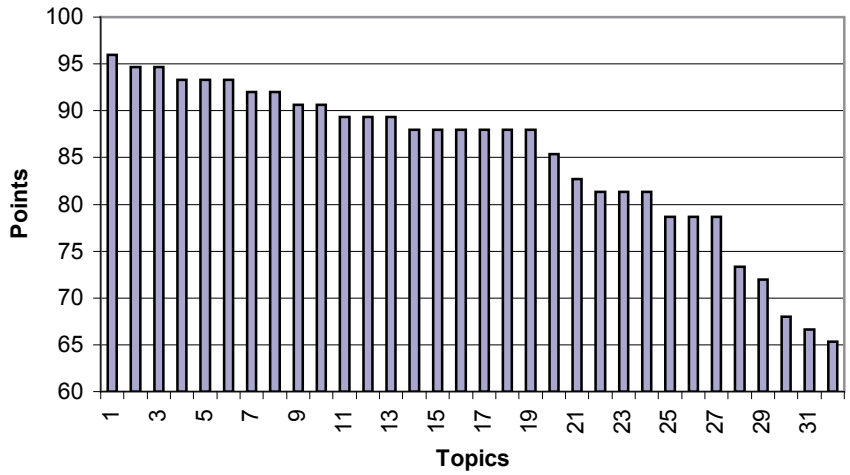
Topics for Lean Systems Curriculum.

The Advisory Board survey results present Lean concept areas of knowledge, making it possible to differentiate topics of highest importance in order to refine coverage areas needed in a Lean Certificate Program. Table 1 ranked areas of knowledge in Lean concepts from high to low in 32 areas of knowledge. Survey respondents agreed that delivery and customer service (ranking 96 points) is the most important area included in Lean curriculum. Figure 1 is a bar chart dividing these 32 areas into 3 groups of A, B, and C.

Table 1. Area of knowledge in Lean concepts, ranking high-low.

No.	Topics	Pts	No.	Topics	Pts
1	Delivery and customer service	96	17	Quick changeover and single minute	88
2	Employee training and development	95	18	Workstation design and flow racks	88
3	Cost and productivity Improvement	95	19	Suppliers relationship development	88
4	Waste identification and elimination	93	20	Long and short-term planning	85
5	Mistake/Error proofing	93	21	Pull systems, material control and Kanban	83
6	Quality & quality improvement	93	22	lean corporate culture	81
7	5S and workplace management	92	23	Principles of empowerment	81
8	Customer satisfaction/feedback	92	24	Just-in-time (JIT) operations	81
9	Quality Tools, e.g. PDCA, …	91	25	Standard work methods	79
10	Problem solving	91	26	Total productive maintenance (TPM)	79
11	Value stream mapping	89	27	LEAN office	79
12	Leading a Kaizen (cont. improvement)	89	28	Market share	73
13	Value stream profitability	89	29	Suggestion/feedback/appraisal systems	72
14	Business vision, mission, strategies	88	30	Employee turnover and compensation	68
15	Principles of lean leadership	88	31	Visual management	67
16	Teamwork	88	32	Respect for humanity and social res.	65

Figure 1. Areas of Lean Knowledge in Groups A, B, and C



Topics one through ten are above 90 points; these are categorized into Group A. The respondents agreed that topics 1 through 10 are highly important for a Lean Certificate Program. Group B contains topics 11 through 21, at 80-90 points. Group C contains topics 22 through 32 and are all at less than 80 points. This means that topics in Group B are more important to Lean Certificate Program than topics in Group C.

Establishing Lean Graduate Certificate Program

Benefits on Lean Certification Program

Lean Certification Programs can help students to acquire a new, or better, job and become more professional and productive in their chosen field. The curriculum is designed to tie Lean principles and concepts with successful Lean implementation. Through certificate training, participants will be able to utilize Lean principles to discover wasteful activities and optimize value-added activities in manufacturing and services.

Lean Graduate Certificate Program

After reviewing the body of knowledge from SME, the curriculum from other Lean certificate programs, and survey results from the Advisory Board, the researchers proposed the curriculum for Lean Graduate Certificate program including program description, program objectives, program requirement and core courses.

Program Description

The proposed certificate program is designed for industrial professionals seeking insight to Lean System techniques and for preparation for Lean Certification by the Society of Manufacturing Engineers (SME), and/or through the Manager of Quality/ Organizational Excellence Certification from the American Society for Quality (ASQ). While this certificate program is not for a degree, courses completed may be included in a program of study leading to a Master of Sciences degree.

Program Objectives

Students will gain the most recent skills and knowledge in Lean systems, Six Sigma, quality tools, and quality management principles while preparing for certification exams.

Specific objectives include:

- Applying Lean concepts in various industrial settings to eliminate waste and maximize quality.
- Utilization of statistical tools and quality techniques to problem solve a given industrial scenario.
- Developing a continuous improvement plan using quality standards criteria established by the International Standards Organization series and Malcolm Baldrige Awards program.
- Preparation for Lean certification by the Society of Manufacturing Engineers (SME) and/or the Manager of Quality/ Organizational Excellence Certification from the American Society for Quality (ASQ).

Program Requirements

Students in this certificate program will complete fifteen semester hours of graduate credit or five three-hour courses and maintain a minimum grade point average of 3.0. Of these five courses, two are already developed and being taught in the Master of Science in Industrial Management program since 2001. The certificate can be completed in one calendar year. The School of Technology graduate coordinator will advise students and confirm completion of certificate requirements. The five courses include IndM 5222 – Lean Techniques, MMgt 4580 – Quality Systems, IndM 5212 – Production and Operations Management, IndM 6580 – Advanced Strategic Quality and Standards, and IndM 5232 – Seminar in Lean Implementation. Reference Appendix B for additional course descriptions.

Summary and Conclusions

Lean is here to stay. If companies are to remain profitable, higher education must be quick to address the technological needs of our national workforce. Through the investment in a Lean training certificate, work associates and companies will acquire a method for systematic identification and reduction of waste; ultimately resulting in higher profits and an optimally employed workforce.

There is also information indicating that older students will find certificate programs more attractive and accessible than traditional graduate programs. In addition, once an older student completes the certificate program, he or she would be more inclined to take on the fulfillment of a graduate degree. It seems clear that certificate programs fulfill an important need, whether it is to provide needed opportunities in one's professional development, or to provide the path towards a desired graduate degree (Patterson, 2001). Through a Lean Certificate Program and ultimate completion of a graduate education, students will be enabled to meet their professional goals.

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Appendix A

Institutes	Delivery Method	Courses	Costs	Note
CCIR/RIMES	Five-workshop series: - five one-day workshop - take individual workshops	1) Assessment testing: Math and English 2) Lean training 3) Req. courses; Math, English, and Business	Each workshop vary: $175, $200, or $250 between: $1,000-$1,200	15 credits apply towards Associates' degree
IPS U. of Tennessee	Mon-Fri, 5days Hands-on learning and classroom instruction	Practical Lean manufacturing tools	$1,325	Units: 4.0 CEUs
CME	1 full day for each course, classroom	4 courses in Lean tools and techniques	Each course vary Non-member: $450	
NBDC	6 Workshops: 56 hrs 1-2 days for each workshop	Workshop in Lean tools and techniques	$1,700 each workshop	Units: 5.6 CEUs (continuing education unit)
IIE Online	9 modules with 12 weeks	Lean tools and techniques Supply chain management	Non-member: $1,345	Units: 2.1 CEUs
CSU Online	1 course online self-paced, 1 semester	Lean theory, Lean elements and rules, value stream mapping, TPM and DFMA	$1,495	
LMAC - Ohio	four non-consecutive weeks, 5 days a week	Lean concepts, tools, and implementation	$15,000	Certified: - 4-week training - 2 hrs exam - project implementation
NWMOC	7 full-days on-site company	Lean concepts, tools, and implementation		4 Associate degree credits from WI Technical College

Appendix B

- **IndM 5222 - Lean Techniques.** A survey of theory, goals, and applications of Lean principles and strategies in industrial organizations. Applying Lean concepts to business strategy, product design, and tools for finding and eliminating waste and for continuous improvement. Mapping the value stream, error proofing, failure analysis, and the Lean metrics are covered.
- **MMgt 4580 Quality Systems**. The principles and practices of Total Quality and Six Sigma, and the decision making tools and techniques utilized by professional in today's successful industries. Emphasis on Statistical Process Control (SPC) to reduce variation.
- **IndM 5212 Production and Operations Management**. Production/operations concepts with emphasis upon systems, systems design and analysis, strategies, productivity, planning, forecasting, deterministic and stochastic inventory control, MRP scheduling, and project planning.
- **IndM 6580 Advanced Strategic Quality and Standards.** An investigation of advanced quality techniques for production/quality managers, global standards criteria (ISO series and Malcolm Baldrige Award), and standard certification training for quality managers and professionals.
- **IndM 5232 Seminar in Lean Implementation**. Individual research directly related to Lean implementation in an industrial enterprise. Preparation for the Lean Certification and Manager of Quality Certification exams.

MANUFACTURING

Meeting the Challenges of Globalization with an Agile Technology Curriculum

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Introduction

Educational programs in the areas of Industrial and Manufacturing Technology are increasingly under pressure due to a rapidly changing manufacturing environment and globalization. As traditional manufacturing careers leave the United States, there is a strong public perception that industrial and manufacturing education is a dead-end. Nothing could be further from the truth as plentiful opportunities exist for skilled professionals in both traditional and emerging industries. To prepare for these opportunities, a more agile academic approach is needed that combines new and traditional programs in technology, while expanding internet and interactive television presentation for nontraditional students. This paper outlines such an approach as it is currently being implemented at Missouri State University.

Background

As numerous manufacturing jobs leave America and Europe for cheaper labor markets in China and various other developing countries, there is a constant drumbeat proclaiming manufacturing and industrial career opportunities are a thing of the past in the United States. It is true that fewer people are working in manufacturing in this country, however this sector still accounts for about 22 to 25 percent of the gross domestic product as it has for the last 50 years (Shinn, 2004). Those who do remain in manufacturing provide a significant amount of added value. It is important to plan for these rapid changes in manufacturing labor markets by becoming more technologically sophisticated and introducing new technology to manufacturing in a timely manner (Shinn, 2004).

New technology always brings challenges. New jobs that will require additional education are being created as technology rapidly changes. As this happens it is predicted that labor markets will shrink as educators see increased competition among their respective disciplines (O'Meara and Carmichael, 2004). The rate of change in technical knowledge is significant and will require continuing education for those already on the job and redesigned curricula for students entering technology programs at the college level. In a recent Society of Manufacturing Engineers (SME) survey 82% of respondents indicated that Lean Manufacturing is a needed continuing education topic. 82% of respondents also indicated that training in new technologies is a needed area of continuing education (SME, 2005).

In the U.S. the traditional manufacturing professional (manufacturing technologists or manufacturing engineer) is being asked to perform different skills and functions than in the past. Lean tools and a team approach, including Six Sigma, 5S, Lean Manufacturing, and Kaizen, require the manufacturing professional to be more of a team leader and supervisor than

ever before. Traditional functions such as troubleshooting production and researching new methods and processes are still highly valued. In addition, facilitating new process changes, preparing business and capital plans, and interacting with a variety of support functions such as purchasing, quality control, and education are often required. With this increasing variety of roles and tasks the modern manufacturing professional is expected to wear a number of hats and demonstrate competence in a number of hard and soft skills (SME, 2005).

In addition to an expanded number of roles, the types of industries requiring support are also changing. The manufacturing professional is becoming an expert in process improvement in general. Six Sigma, Supply Chain Management, quality control, and team concepts, to name a few, are all tools that can be applied to a variety of non-manufacturing concerns. This opens up opportunities in a number of growing industries that traditionally have not emphasized skills common to most manufacturing professionals. There are many common functions between manufacturing and service industries including the development of new products, troubleshooting, marketing, process improvement, etc. As globalization exerts pressure on service industries to streamline or upgrade, common manufacturing tools are increasingly being utilized (Shinn, 2004).

In addition to the well developed manufacturing and service industries, entirely new high tech industries are emerging and rapidly developing. Breakthroughs in material science, electronics, and health care are increasingly the result of either microtechnologies or nanotechnologies (Kalpakjian and Schmid, 2006). This area typifies the trend toward the convergence of technologies that is predicted to be dominant in the future economy. A number of industries continue to develop around the convergence of disciplines such as computing, engineering, physics, biology, chemistry, and material science. Microsensors that can be introduced into the bloodstream, robotics utilizing neural networks and intelligent software, and carbon nanotubes that greatly improve material performance are a few examples of applications being developed from the convergence of technologies (McCann, 2006).

These high tech applications require similar process development and improvement, quality control, team concepts, and business expertise as do the traditional developed industries. Individuals with a multifaceted education that includes technological knowledge combined with strong business skills are currently in great demand in industry (Djassemi, 2005). As these new high tech industries develop and strive to be more efficient and profitable, the well rounded technical/ business professional will be highly sought.

The substantial exodus of traditional manufacturing from the U.S. and the emergence of new high tech industries signal change and adjustment for the manufacturing professional, but not necessarily demise. The remaining manufacturing industries along with service and new technology industries will provide numerous opportunities. Technology education must adjust to prepare for these new opportunities. Programs that better prepare traditional college students and offer continuing education and completion degrees for non traditional students can meet this challenge. A more flexible, versatile education that can focus on new trends and interests while providing well rounded technical and business exposure is needed (Sinn, 2004).

Developing an Agile Curriculum

Missouri State University is currently revising its Industrial Management program to meet the challenges of the new economy. As with many similar programs across the country, Missouri State's technology programs face low enrollments as poor publicity concerning manufacturing opportunities takes its toll. Facing this reality, the Industrial Management program was totally overhauled to take advantage of significant existing opportunities and identified student demand.

The Industrial Management Department at Missouri State University has a well established Industrial Technology program that has been successful in the past. This program is primarily focused on a blend of technical and managerial content relating to the manufacturing production environment. Students graduating with the Industrial Management degree are in high demand with manufacturing firms and receive among the highest starting salaries on campus. However, the narrow focus on manufacturing has limited enrollment as many prospective students are concerned about a future in this area.

The challenge for the department was to expand the number of specialization areas and means of delivery to establish career opportunities in the service and developing industries, and to accomplish this without adding new course offerings or additional faculty. This proved to be a difficult challenge, but was accomplished through changes in course content, expanding means of delivery including interactive television and the internet, and cooperating with other departments and resources on campus to increase the number of option areas and exposure to new technologies.

Expanding Choices Around the Core Curriculum

The traditional Industrial Technology degree at Missouri State is the Bachelor of Science in Industrial Management. The core curriculum for this degree is similar to other traditional Industrial Technology programs and contains basic mathematics and physics, natural sciences, and a variety of technical and managerial offerings relating to the production

environment. The first step in developing a more versatile curriculum was to establish option areas, some relating to manufacturing and others relating to processing and service industries. Each option area consists of four focus courses that replace the elective block. Some option courses already existed within the Industrial Management Department and others were out of department. In the case of out of department offerings, discussions were held and agreements were made with the various other departments that contributed option courses. The resulting degree consists of the traditional Industrial Technology core with five option areas that allow for specialization relevant to a variety of industries. The five new option areas are:

- Distribution
- Quality Control
- Food Processing
- Computer-Aided-Design
- Production

The course requirements for the distribution option are shown below in Table 1 as an example of the multidisciplinary nature of these specialization areas.

Distribution Option		
Required Courses	Credit Hours	Prerequisites
Industrial Management 459 – Distribution Systems	3	53 hours completed
Marketing 430 – Logistics and Distribution	3	Marketing 350, Management 440
Marketing 440 – Logistics Models	3	Marketing 430
Marketing 450 – Supply Chain Management	3	Marketing 440

Table 1. Required Courses for the Distribution Option

Opportunities for Non-Traditional Students

A second strategy in redesigning the program was to improve choices for mostly non-traditional students. The Bachelor of Applied Science in Technology Management was developed for graduates of Associate of Science or Associate of Applied Science programs. Many prospective students for this program are already employed and are interested in obtaining a Bachelor's degree while working full time. These students come from a variety of backgrounds and need maximum flexibility in a curriculum that will meet their specific needs. The Bachelor of Applied Science degree accepts all credits from the two year degrees mentioned above. To complete the Bachelor's degree Missouri State's general education requirements must be met, along with twelve hours of upper division Industrial Management coursework including technology management and project management. Twenty-five additional advisor approved upper division credits must be taken campus wide. This gives students total flexibility in selecting an area of interest that meets their career needs.

To ensure the success of this program, a variety of delivery methods are utilized. Live courses for this program are always offered for students who can participate on campus. Several upper division courses in the Department of Industrial Management are also available through internet delivery. Some courses are available through interactive television at remote locations in the state. It is possible to complete the entire Bachelor of Applied Science program off campus with internet and/or interactive television offerings.

Emerging Technologies Management

A third major component of the redesigned curriculum is the creation of a new Bachelor of Science degree: Emerging Technologies Management. The creation of this degree was prompted by the strong trend toward converging technologies that exists now and is expected to accelerate in the future. As with the Industrial Management degree, this degree is centered around the core Industrial Technology curriculum. Processing and integration courses in the core have been revised to include topics in emerging technologies. Students in this major are required to take calculus for a stronger mathematics background. Additional design courses that are electives in the other degrees are also required.

The defining feature of this program is a strong interdisciplinary involvement with the Missouri State University Center for Applied Science and Engineering (CASE). CASE is heavily involved with converging technologies research. Experts in nanotechnology and biotechnology are currently involved with major projects for the center. An agreement has been signed between the Industrial Management Department and CASE concerning the Emerging Technologies Management Degree. CASE personnel will be made available to teach two upper level special topics courses in the Industrial Management Department. These courses will reflect current research in CASE relating to emerging technologies. The Industrial Management Department and CASE have also agreed to share equipment and facilities where possible.

Graduates of the Emerging technologies program will have a strong background in Industrial Technology and will also be well informed on current trends and issues in the Emerging Technology Industries. These students will be well prepared to address issues of efficiency, quality, planning, and management in new technology industries as they develop.

Summary: An Agile Curriculum

The new programs and options in the Industrial Management Department at Missouri State University are "Agile" in that they are flexible and easily adaptable to changes in the economy and industry. The Industrial Management degree offers five options that are relative to both manufacturing and service industries. The options offer a wide range of choices for specialization that address a number of interests and opportunities. These options can be easily modified and adapted to changes as they occur in industry. The Bachelor of Applied Science provides maximum flexibility in course selection and delivery methods. This is critical for non-traditional students who are often fully employed. The Emerging Technologies Management program is very adaptable to new technologies as they develop. The special topics courses in this program can reflect current topics and trends without changing the course name or catalog description.

The programs of the new Industrial Management model are all centered around the basic Industrial Technology core. This allows thirty-seven hours of Industrial Management coursework to be taught across all three programs. This is critical for faculty efficiency given relatively small enrollments in individual programs. Many of the specialization courses are taught outside the department. This is critical in allowing new areas of specialization without creating new courses within the department.

Conclusions

The revised Industrial Management Degree with the five options has been offered since the fall of 2005. Enrollments in freshman level courses for this degree have seen a moderate increase in the program's first year. It is possible that the five option areas are attracting students from a wider area of interest. The Bachelor of Applied Science Degree has been in existence since the late 1990's. Total enrollment in this program is approximately 35, but little recruitment has been done. Recent contacts with community colleges in the region have been very positive and have generated a great deal of interest. It is expected that enrollments in this program will rapidly increase with additional recruitment and articulation agreements. The Emerging Technologies Management program is in the final stages of development and will be first offered in the fall of 2006.

The interdisciplinary component of the new programs has already been a success. The agreement with CASE has been well received on campus and has been applauded by upper-level administration. The sharing of equipment, facilities, and personnel opens up new opportunities for teaching and research within the department.

Overall, the substantial program changes within the department of Industrial Management have been achieved without adding faculty or creating new courses. These adjustments allow the department to adapt to changes in technology and industry, thus strengthening its contribution in the new global economy.

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RESEARCH

Research of an Industrial Microwave Manufacturing Process for Mass Production of Carbon-Fiber Composites

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Abstract
Beginning in 2005, U.S. Environmental Protection Agency fuel economy regulations have been increased to 27.5 mpg for passenger vehicles and 21 mpg for light duty trucks. Using lighter weight materials can reduce fuel consumption and improve the mileage per gallon of automobiles. One approach being followed by OEM automakers is the adapting of new materials such as carbon fiber composites for structural and appearance components (Aronson, 1999). Carbon Fiber composite material provides a high strength alternative to steel while cutting 65% of the weight (Akasie, 1999). One problem with the conventional processing of Carbon Fiber composites is that it requires lengthy cycle time. A second problem is the high cost of manually processing Carbon Fiber components. According to Feher and Thumm (2004) the manufacturing process of carbon fiber plastic composite has the highest potential for shorter cycle time and cost reduction. Research of the microwave as a manufacturing process of carbon fiber composites can fit into the category of potentially reducing cycle time and reduce cost making it a viable mass production process.

Introduction
Carbon Fiber Composites
Beginning in 2005, U.S. Environmental Protection Agency (EPA) fuel economy regulations have been increased to 27.5 mpg for passenger vehicles and 21 mpg for light duty trucks. "Of critical importance will be the extent to which more than 200 million light vehicles on U.S. highways, which consume 11 percent of total world oil production, become more fuel efficient as vehicle buyers choose the lower fuel costs of lighter or hybrid vehicles" (Greenspan, 2005). Although spurned for many years, one approach being followed by OEM automakers is the adapting of new materials such as carbon fiber composites for structural and appearance components (Aronson, 1999).

Statement of Problem
Two problems exist with carbon fiber composites making it unsuitable for mass production. First, the majority of carbon fiber composite components are produced in a manual autoclave process for small volume production requiring lengthy production time (2 – 8 hours) compared to processing components of conventional material such as steel and aluminum (Akasie, 1999). A second problem is the associated cost of manually processing carbon fiber components with carbon fiber. New processing methods must be achieved to mass produce carbon fiber composite material to reduce processing time and cost. One approach is to microwave the carbon fiber to crystallize it rather than heating it in a conventional autoclave process. The purpose of the research is to study the processes for producing carbon fiber composites and assess the microwave as a viable manufacturing process of carbon fiber composites for mass production.

Review Of Literature
Mass Production
The book titled *World class manufacturing: the next decade* by Schonberger (1996) describes the transition of U.S. manufacturing from the Japan's Decade (1970's) and America's Decade (1985 – 1995) into the current Global Decade. Schonberger describes the image of mass production as one of being high volumes, uniform output, low unit costs, and few surprises. To support this image of manufacturing the author reviews sixteen principles of which three apply to the industrial microwave processing of carbon fiber composites: 1) cut to the few best components, 2) cut flow time and distance, and 3) seek simple flexible, movable, low-cost, readily available equipment and facilities (Schonberger).

The industrial microwave processing of carbon fiber composite components are applicable to Schonberger's principles of mass production. First, using the microwave presents an opportunity to move from mass produced steel components to customized end products by communization of components – reducing the number of stamped steel components to one single component cured in the microwave.

Next, by dedicating a manufacturing cell to produce the same components in volumes that match the demand of the end product eliminates inventory, WIP storage, and job setups. This also relates to the concept of synchronous manufacturing (Schonberger, 1996).

Third, borrowing from the socio-technical systems of the 1960's is the preferred U-shape assembly line (Schonberger, 1996). Using the U-shape, a longer station cycle time is created which eliminates the non-valued added motion of passing parts from one operator to another. By increasing station cycle time and the number of tasks performed at each station, the number of stations is reduced and through-put is increased.

Fabrication of Carbon Fiber Composites

Conventional fabrication of carbon fiber composites is a slow, labor intensive process as described by Valenti (1992). The conventional process for curing carbon fiber composites utilizes an autoclave. Autoclave composite manufacturing begins by heating a resin until it is a liquid. The liquid resin impregnates a fabric form called a "prepreg" - pre-impregnated with resin.

A specific number of prepregs are then stacked, or laid-up, to the required thickness. The laid-up prepregs are placed into a plastic membrane which is put into the autoclave for curing. Air is evacuated from the plastic membrane forcing the composite material against the tooling to give the part its final form.

Valenti (1992) points out that a more innovative approach is the resin transfer molding (RTM) process. In RTM processing, a single three-dimensional fabric preform is woven in the shape of the finished part and placed in a mold. A vacuum is induced prior to injecting the resin into the mold to draw the resin through all of the spaces and voids of the preform. The final part can then be cured in the mold itself, or it can be transferred into an autoclave for final curing.

The aerospace industry has been the leader in utilizing the RTM process for mass producing carbon fiber components as described by Ashley (1997). An advanced-RTM process starts by weaving carbon fiber fabric, laser cutting it into a preform shape then transferred into a tackifier (binder) machine. After binding, a pick-and-place robot stacks each ply into the correct location, according to a CATIA three-dimensional CAD design. This same station uses an ultrasonic knife to cut the plies into the correct pattern.

Ashley (1997) further states that the consolidated preforms are then combined with dimensionally matched tooling and placed into a mold frame. The traditional curing process is the autoclave system. As the entire assembly is heated the resin is injected, then cured under high pressure. After a cool-down cycle the part is de-molded, cleaned, trimmed and then inspected using an ultrasonic process. The preparation, lay-up and de-molding is a highly manual process. Figure 1 shows the manual labor of the autoclave process compared to the vacuum assisted process (VAP) also known as the intrusion process (Feher & Filsinger, 2005, p. 55). Using VAP can reduce the manual labor process, however, what about the actual curing process?

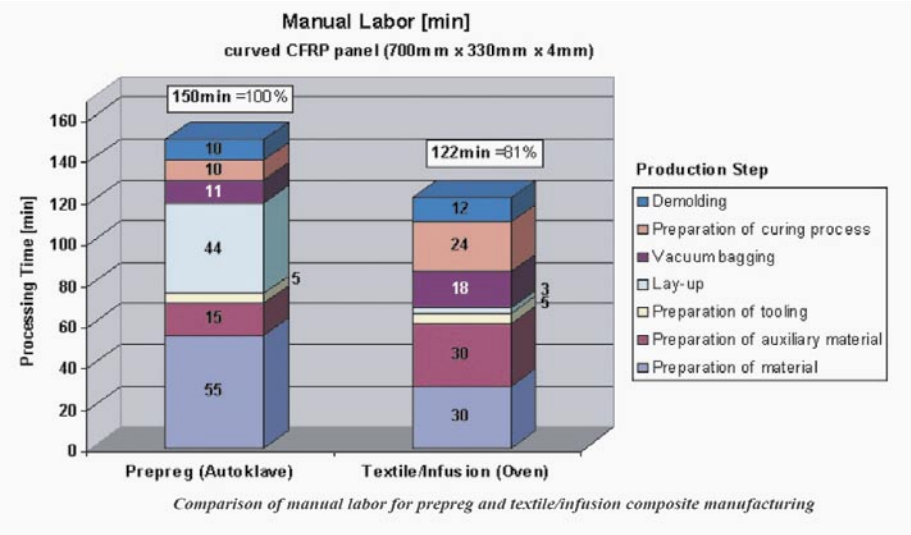


Figure 1.

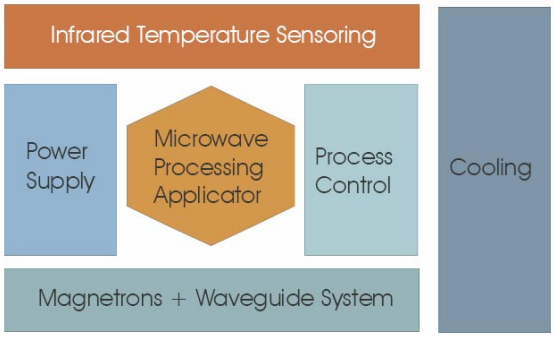
The manufacturing process of carbon-fiber composites has the highest potential for reduction of cycle time and cost. As stated by Feher and Thumm (2004), "The highest potential for cost reduction is to be found on the manufacturing process which implies substantial long-time and high-energy consumption, as well as a low degree of automation" (p. 73). Potential benefits of using the microwave technology for fabrication of carbon-fiber-reinforced-plastics (CFRP) can include "high heating rates – reduction of processing time; savings on energy consumption; 'clean' heating technology;[and] high degree on automation" (Feher & Thumm, 2004, p. 73).

Similar to an autoclave system, carbon fiber preform woven material is placed in a vacuum bag and mold. The preform mold assembly is placed into the chamber of autoclave and the temperature is raised prior to injection of the resin. Unlike the super-heated steam system of a traditional autoclave, heating the preform weave assembly and resin is accomplished by the distribution of magnetic-fields from microwave energy using a finite-difference-time-domain (FDTD) algorithm code. The FDTD used in the Feher and Thumm (2004) research utilizes an explicit 3-D FDTD code, "DELFI" (p. 76), for solving the full time dependent Maxwell equation. Based on the literature review, the research addresses the following question: What are the processes to produce carbon fiber composites? The next question to be asked is can a novel microwave method of processing carbon fiber composites be faster than conventional methods?

Research Results

2002 – 2005 Research

The initial research completed by Feher and Thumm in 2004 is based on application of an industrial microwave labeled "HEPHAISTOS (High Electromagnetic Power Heating Autoclavless Injected Structure Oven System)" (Feher, Thumm & Drechsler, 2005, p. 54) developed in partnership by the Institute of Pulsed Power and Microwave Technology at the Forschungszentrum Karlsruhe, Germany and the Votsch Company. The name of Hephaistos is from the builder and craftsmen for the Greek gods. The set-up of the HEPHAISTOS CA system is shown in Figure 2 (Feher et al, p 55).



Schematic Set-up of HEPHAISTOS-Systems

Figure 2 - HEPHAISTOS

HEPHAISTOS CA is a 2.45 GHz, 12 kW microwave using a cylindrical applicator with a hexagonal insert and slotted waveguide system (Feher & Thumm, 2004).

A critical issue with an industrial microwave manufacturing process of carbon fiber composites is the homogeneity of the field of distribution of heat in the applicator. Figure 3 shows three pictures of applicators: a) cylindrical, 2) globe, and 3) hexagonal (Feher, Drechsler & Filsinger, 2004).

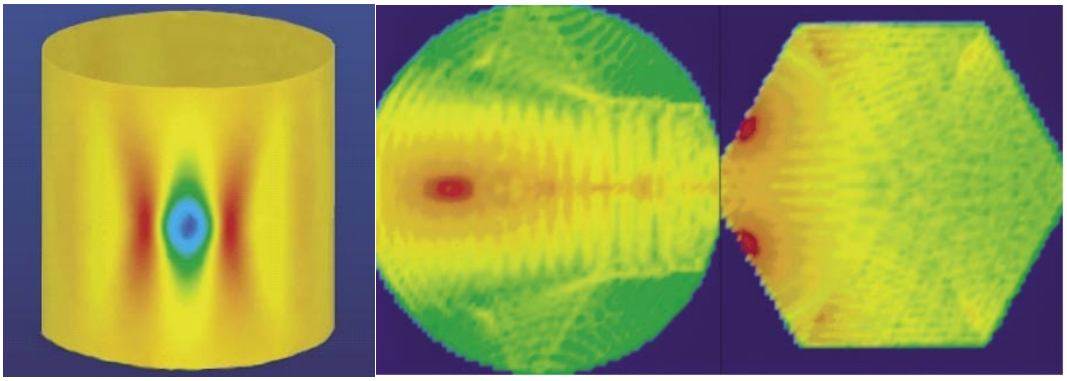


Figure 3a – Cylindrical Applicator *Figure 3b – Globe Applicator* *Figure 3c – Hexagonal Applicator*

Using an ultrasonic color scan of the applicator shapes during transmission, the cylindrical shape (see figure 3a) shows a cold spot in the center, flanked by a ring of intense heat. The globe (see figure 3b) shows a droplet shape of intense heat at one side of the round shaped applicator. According to Feher and Thumm (2004), the hexagonal shape has two configurations: 1) direct reflecting and 2) beam splitting shown in Figure 3c. Direct reflecting is the focus of the field of distribution of heat on one fascia of the hexagon. The beam splitting has the focus of the field of distribution of heat at one node of the hexagon shape with reflection from the two contiguous sides as shown in Figure 3c. The scan of the hexagonal shape shows a large homogeneous field of distribution of heat in the applicator. This avoids the typical microwave problem of excessive heating of the outside edges of the load (sample) which creates an under cured condition. Using the hexagonal applicator significantly improves the distribution of heat throughout the load.

Advancement in the waveguide system is an additional approach to improving homogeneity of field of distribution of heat. The slotted waveguide system improves the homogeneity by reducing the variance of reflection in the waveguide during transmission. During transmission the slotted waveguide variance in reflection of waves from the beginning of a cycle to the end of a cycle can be minimized to less than 3% (Feher, Thumm & Drechsler, 2005, p. 55). The slotted wave guide uses a wide slotted rectangle tube to spread the field of distribution of microwaves in the applicator which improves reflection as well as the homogeneity of temperature in the load.

Three Research Studies

There are three research studies completed in 2005 that provides the credible basis for the concept of industrial microwave processing of carbon fiber composites. First, the experimental trials by Feher and Filsinger (2005) use a T-shape profile of carbon fiber pre-preg as the load. This experimental trial provides valuable data about the heat dispersion on angular surfaces. Figure 4 shows the actual sample material with the inset showing the temperatures of 191° C on the T-profile and 184° C - 185° C along the base (Feher & Filsinger, 2005, p. 51).

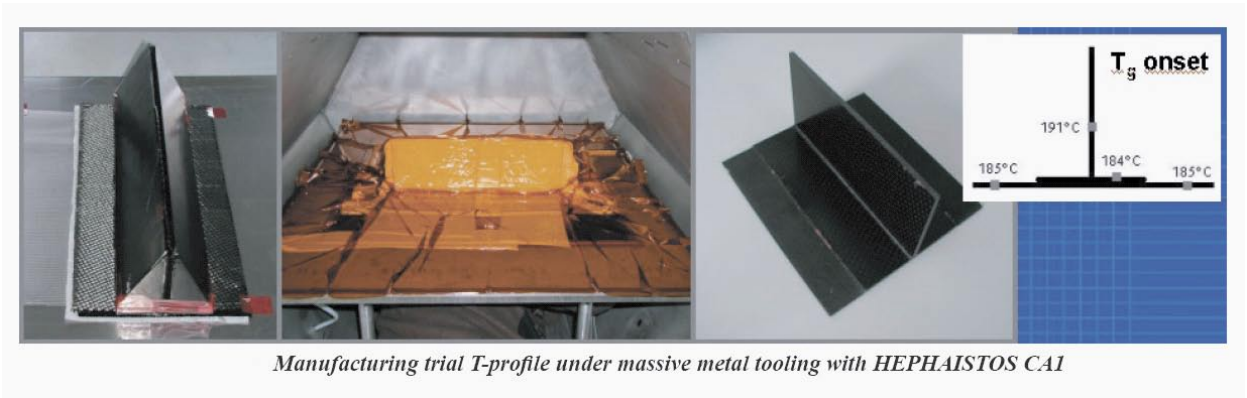
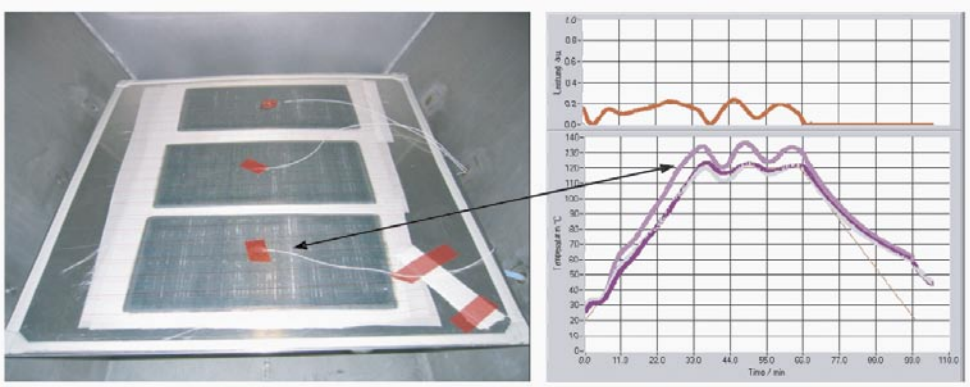


Figure 4 – T-Profile Trial

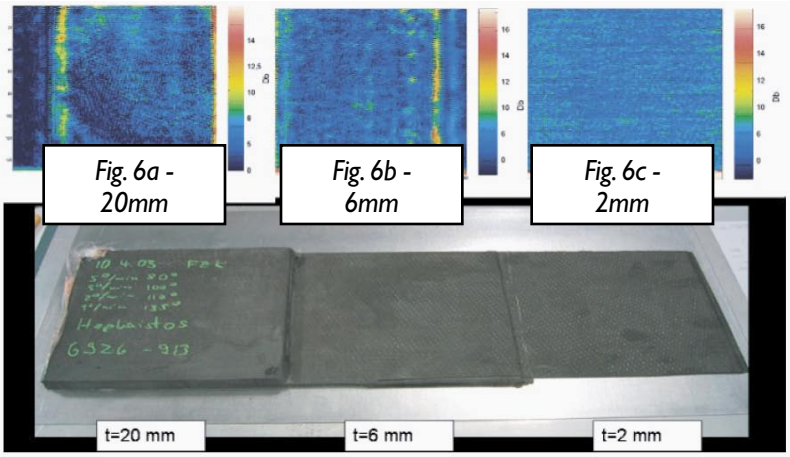
Second, the experimental research study completed by Graber, Feher, Drechsler and Filsinger (2005) uses three samples of 2 mm thickness prepreg material to simultaneously test the field of distribution of temperature in the applicator. Figure 5 shows the correlation of temperature curves of each load throughout the cure cycle (Graber et al, p. 63). Although the temperature curves were consistent during the cure cycle, the first set of trials showed inferior curing at the edge of the loads. The primary reason is the cold tooling which took heat away from the test samples. Subsequent trials were completed using dry stacked preform fabric preheated to 105° C and liquid RTM-6 resin heated to 105° C for 10 minutes then injected into the preform fabric (Graber et al, p. 63). The results were excellent with no areas of poor curing.



Curing trials on 2 mm thick prepreg material in the Hephaistos CA-01 system. On the right: Power input over time (red line on top), and temperature curves of the 3 sensors visible in the left picture (on the bottom). The power was controlled according to temperature sensor in the centre

Figure 5 – Three Load Trial

Lastly, ultrasound color scans for trials of three thickness loads also completed by Graber, Feher, Drechsler and Filsinger (2005, p. 64) are shown in Figure 6a – 6c. Figure 6a shows the 20 mm sample with significant attenuation of the field of distribution of temperature. The resulting cure is inferior on the corresponding side of the sample with high attenuation. Figure 6b shows the 6 mm sample with an even temperature dispersion and area of low attenuation. Figure 6c is the 2 mm sample and displays an excellent homogeneity of heat.



Ultrasound C-scans: Stepped thickness panel of prepreg material with 2, 6 and 20 mm thick sections. The laminate quality in the 2 mm thick section (on the right) is good, the 6 mm thick part (in the middle) shows single defects, and the 20 mm thick part (on the left) shows major gradients in attenuation across the laminate.

Mechanical Test Values

In addition to the homogeneity of temperature displacement, the Graber et al experimental trial accomplished a second objective - mechanical test values. Using a inter laminar shear strength (ILSS) test with Hexcel 913 UD (Uni-Directional) material and a heating rate of 3° C/minute compared to the autoclave of 10° C (vacuum pressure), the difference in results is significant (Graber et al, p. 63). The ILSS value for the microwave material equals 41 N/mm^2 (Graber et al, p. 64). The autoclave material value equals 32 N/mm^2 (Graber et al, p. 64). The increase of ILSS value using the microwave is 9 N/mm^2. Based on analysis of Graber et al data, it represents a 28 percent improvement in shear strength.

Conclusion

Based on the 2002 – 2005 research, a vacuum assisted process (VAP) reduces manual labor time and using a microwave reduces curing time. The research shows that manual labor time of 150 minutes in a traditional heating process can be reduced to 122 minutes in the VAP method (Feher & Filsinger, 2005, p. 51). This represents a 19 percent improvement. Using an autoclave, aircraft resin requires a minimum of 2 hours to cure (Graber, Feher, Drechsler and Filsinger, 2005, p. 63). Using the microwave process the total cycle time is 65 minutes for the curing to reach 180° C (Graber, p. 63). This represents a 46 percent reduction in cycle time compared to the minimum autoclave cycle time. The industrial microwave manufacturing process of carbon fiber composite plastics has the potential for reduction of cycle time and cost compared to the conventional autoclave process.

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SAFETY

Personal and Professional Job Skills for Industrial Safety Managers

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Abstract
Graduating seniors often ask what skills are necessary to become a general industrial safety manager. Although that answer varies, it was time to ask a group of industries that question. Using a large industrial safety consortium, the following information is a composite of competencies divided into five categories. Information was gathered from 20 different companies ranging in employment size from 50 to 2,000. Company representation included job shop, continuous processing, assembly, and heavy fabrication.

The five categories are: 1) education and experience, 2) job/technical skills, 3) business skills, 4) leadership skills, and 5) coordination and organizational skills. This study requested information for what industry would call a general safety manager. This study was to aid curriculum developers in identifying competencies of a general safety manager.

Education and Experience
Education requirement differs according to the size of the company and the position being advertised. It appears that safety managers within a company that do not deal heavily into the environmental issues are not required to obtain educational degrees nor have extensive areas of certification. However, any company no matter of size, dealing with such issues indicated the need for some type of higher educational degree and specific certifications from a well-known safety training organization.

Formal education
Formal education requirements included such statements as a 2 or 4 year degree or equivalent in safety or related field. Safety in a related field was identified as engineering, industrial hygiene, supervision, and environmental science. Information was also gathered that indicated that the general manager should have qualifications appropriate to the level of risk on the site. If a degree was not required, the wording was such as to stipulate a strong educational background in the health and environmental sciences. Certification requirements varied greatly, but companies indicating such named Hazard Communication and Hazardous Waste as of great concern. It was found that in order for a company to be flexible in hiring a general safety manager; several companies said that "relevant experience and a good track record may be an acceptable alternative".

Job and technical skills
The information indicated that safety managers should possess sufficient, relevant, and detailed knowledge of general safety. The manager should be able to apply this knowledge to solve safety problems. Safety managers should be able to use a broad range of information technologies such as spreadsheets, database and presentation software, and utilize Web based applications and internet resources. A desirable candidate for safety manager should be able to systematically collect, store, and retrieve safety information. General safety managers should be very knowledgeable about 29CFR-1910 OSHA General Industry Standards. They should be able to maneuver through the subparts of the regulations and know where to look for answers. A manager should be able to develop policies and procedures to ensure compliance with standards and health training. A few industries mentioned that a general safety manager should understand how to research problematic issues using basic research methods.

Information received from industry stated that a safety manager must have a "sufficient command of the English language" and should understand issues related to workforce diversity. A few industries indicated that a safety manager must understand cultural differences. The manager should be able to interact with all levels of managers and with all workers.

Good written communication skills are required by managers along with good technical report writing. Companies want managers to be comfortable and confident in making all levels of workers understand the communications they receive.

Basic knowledge of testing and testing procedures was mentioned by most of the companies. The safety manager should be able to use direct reading instruments correctly. The manager should be able to read and understand data received from direct and indirect equipment. The manager should also be able to conduct basic sample testing and interpretation of information. It was felt by many companies that a basic knowledge of risk analysis and risk management was an additional preference for hiring. A manager should be able to audit various work sites to ensure conformance with safety, health, and environmental requirements according to corporate policies. Companies believed that their new safety hire should be able to provide technical assistance in controlling losses from injuries, liabilities and property losses.

Business skills

Strategic thinking was a business skill that companies thought to be very important. The information indicated that a safety manager should be able to make strategic plans, taking care to understand and predict the views and needs of the industry. Along with being able to create a strategic plan, a manager must be able to set metrics by which to measure success. Companies used the terms innovative, inventive, and imaginative to describe what is needed from a general safety manager. The safety manager should be able to apply these terms in approaching new or difficult safety tasks. The safety manager should also be analytical. Companies described analytical as being able to approach a safety problem using a logical, systematic, and sequential approach. Managers should be able to network and develop strong positive relationships with outside agencies that provide information and training for employees. Industry wants safety managers to understand cost and value analysis of reasonable safety objectives.

Leadership skills

Companies indicated that a manager must be persuasive. Managers should be able to persuade or influence others and be convincing. The manager should be able to influence the direction of a meeting or plan and show creativity in presenting ideas. The individual must be able to function as a change agent and be able to elevate concerns to achieve desirable results. It was expressed by several companies that collaboration was important for la safety manager. Collaboration was described as possessing the ability to integrate health safety and environment

initiatives into daily operations and encourage mutual and constructive participation. Leadership by managers included the ability to focus on the desired end result; setting challenging goals, focusing effort on the goals and meeting or exceeding them. According to industry, safety managers should possess leadership skills in mentoring, coaching and developing others to realize their full potential. It is also very important that safety managers be able to select, manage, and monitor safety teams and team building activities. A safety manager must be able to evaluate safety performance of workers and use corrective action for deficiencies. This individual must be able to conduct mock safety inspections and investigate accidents according to company policy. Safety managers should take leadership responsibility in being proactive in all site safety issues. Companies responding indicated that a manager should lead by example. This included the manager's work ethics, ethics in general, and willing to step out of their personal comfort zone. A company manager in safety should be able to represent the company with OSHA, DOT, and other regulatory officials in a professional manner.

Coordination and organizational skills

Safety managers must be able to coordinate the development efforts of individuals working in the health, safety and environmental area for the company. The safety manager should be able to define and monitor critical project activities so as to manage projects of the complexity normally encountered in industry. Companies want a safety manager to be able to coordinate job analysis efforts and write safety procedures based on the findings. Industries also indicated that a multi-tasking individual would be best in a safety managerial situation. It was expressed that a logical, sequential type person is most desirable for filling the position of general safety manager. Organizational skills in scheduling and setting agenda's for safety meetings are a must for general safety managers.

Summary

The companies that responded did not mention many specific topics as one might think. As one reviews the information, you could come to the following conclusions about the categories. Education requirements for the general safety manager were in the range of 2 to 4 years with no specific safety area required. Thought to be interesting of the usual engineering and industrial hygiene requirement was the area of supervision as an acceptable substitute. One company made the statement that they would consider a person that could communicate over a highly educated safety expert who could not communicate to the worker.

In the job and technical skill area, a well rounded person with knowledge in word processing was interesting along with being able to find the information versus automatically knowing it. As part of the job skill area, a mastery of the English language and knowing cultural diversity indicates what is happening in the United States with the impact of immigration. The more technical requirement of risk management, testing, and loss control is understandable because of bottom line profits and loss.

The business skill require by a safety manager seemed interesting in light of strategic plan trends in all business and industries today. The mentioning of cost analysis seems to indicate that even in a safety education programs, there must be room for accounting or engineering economics.

Interesting too was the amount of emphasis placed on leadership and organizational skills. Working with other, influencing, and achieving results was stressed in many of the industrial responses. Industry seems to want an individual that can convey as message, back it up with data, and be willing to step out of ones comfort zone to follow it through. Overall, this study did not prescribe a specific list of traditional OSHA topics taken from most safety texts. What this study did indicate is the general areas by which curriculum developers could customize a safety program to their specific geographic and particular industrial situation.

Safety Curriculum: Teaching Ethics and Incorporating a Discourse on Ethics in a Senior Project-Oriented Capstone Course

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Abstract
Ethics is an important curriculum topic in the education of occupational safety and health professionals. Generally, people within the profession seem to operate within the scope of recognized legal and ethical standards. Unethical behavior, however, occurs enough to warrant inclusion in the profession's educational curriculum. Often the dilemma faced by the safety professional is not of their own making but a result of someone else's actions. These ethical dilemmas are often complex issues not always having obvious straightforward solutions. As a result, a majority of accrediting organizations require ethics to be taught in the classroom. One National Association of Industrial Technology (NAIT) accredited occupational safety program includes instruction on ethics within the core safety curriculum. In addition, the program requires all students to complete a project-oriented capstone course. Students are assigned to a variety of industrial safety projects at various manufacturers. This industrial safety project has provided real-world experience for the student. It has also provided opportunities for exposure to real-world ethical issues. In order to benefit the student and reinforce the student's previous instruction in ethics, a roundtable discussion of ethics has been incorporated into this capstone course. This paper will provide an example on teaching ethics and incorporating ethics in a capstone course.

Keywords
Ethics, Industrial Safety, Senior Capstone Course, and Code of Conduct

Introduction
The occupational safety and health profession can be described as a profession focusing on the prevention of harm to people, property, and the environment (ASSE, 2005). The safety profession is a multidisciplinary field applying scientific and technical knowledge of the physical world and knowledge of social sciences such as psychology and management for the practical benefit of all people. The safety professional may be involved in a wide range of activities from investigating accidents to inspecting fire protection systems to preventing stress in the workplace. Accordingly, the issues faced by the safety professional are diverse, complex, and ever-changing. Safety professionals are often faced with decisions that affect all corners of the workplace and even the public at large. Safety professionals must recognize that their ethical judgment as well as their technical judgment has a crucial impact on the workplace and on society. As a result, a majority of educational accrediting organizations require ethics to be taught in the classroom.

Ethics is an important curriculum topic in the education of safety professionals. Many national education accrediting boards include "an understanding of professional and ethical responsibility" among the general criteria for basic level academic programs. Safety professionals must be equipped by their education to fulfill their ethical obligations to the public at large, to their profession, and to their clients and employers (ASEE, 2000). For the most part, people within the profession seem to operate within the scope of acceptable legal and ethical standards. Unethical behavior, however, does occur often enough to warrant inclusion within the profession's educational curriculum. In many cases, these ethical abuses receive wide publicity. Usually the dilemma faced by the safety professional is on a smaller scale and is often not of their own making but a result of someone else's actions.

Ethics refers to standards of right conduct. Unfortunately, there is not always complete agreement as to what constitutes ethical conduct (Hartley, 2005). These ethical dilemmas may include conflict of interest issues, high-pressure tactics, production vs. safety, exaggerating claims, gifts from contractors, full information disclosure, broad interpretation of legal requirements, and issues of propriety information. These ethical dilemmas are complex issues not always having obvious straightforward solutions. Ethics education should include exposing students to examples of unethical behaviors. These case studies can make the student aware of the temptations and the consequences of these ethical dilemmas. Finally, ethics education for the occupational safety and health student should include an understanding of a practical model or guideline for handling these ethical dilemmas.

Ethics Taught in the Classroom

Ethics is introduced early in the required curriculum at one National Association of Industrial Technology (NAIT) accredited occupational safety and health program. This safety program serves approximately 60 students receiving a Bachelor of Science degree in Occupational Safety and Health Technology. The program includes instruction on ethics and professional code of conduct within the required curriculum. Students are formally presented with ethics as a classroom topic in one of the required safety management courses. During this course students are first introduced to ethics and potential ethical dilemmas in the field of occupational safety. Secondly, students are exposed to the impact that their decisions may have on their employer, employees, and the community. The objective is to help the students see that they are personally responsible for the decisions they make and that they support their decisions directly by their actions. Finally, students are exposed to several models and guidelines for assisting in determining the appropriate ethical behavior.

During the course students discuss the many definitions of the term ethics. Many of the definitions center around the following: Ethics is the study of morality within a context established by cultural and professional values, social norms, and accepted standards of behavior (Goetsch, 2005). The students also discuss ethical dilemmas specific to the workplace. The students participate in role-playing exercises that illustrate, as many argue, that these workplace ethical dilemmas are more complex than ethical situations in general because of the involvement of several groups such as customers, employees, employers, coworkers, competitors, and the public at large. The involvement of these various groups often results in conflicting and contradictory interests. The students also examine numerous case studies that expose them to several ethical problems and help them learn to recognize these ethical dilemmas. By definition the solution to an ethical dilemma is difficult to determine. The answer is often concealed in a gray area. Where an individual falls in this gray area usually depends on personal experience and external pressure. The student-led discussions typically begin to focus on how the safety professional knows if a particular behavior is ethical.

There are numerous models or guidelines for determining ethical behavior. The students are taught to distinguish between legal and ethical behavior. Just because a behavior is legal doesn't make it ethical. Several of the guidelines covered are described below (Goetsch):

- **Morning-After Test**. This test asks, "If you make this choice, how will you feel about it tomorrow morning?"
- **Front-Page Test**. This test encourages you to consider how you would react if your decision were printed as a story on the front page of the newspaper.
- **Mirror Test**. This test asks, "If you make this decision, how will you feel when you look at yourself in the mirror each day?"
- **Role-Reversal Test.** This test asks you to contemplate switching places with the people affected by your decision and consider how they would feel based on this decision.
- **Common-Sense Test**. This test has you listen to what your gut instincts and common sense are telling you. If one option or decision feels wrong than it probably is wrong.

The students are taught to use these guidelines when confronted with an ethical decision. The students practice implementing these guidelines while completing several team-based case study exercises. The students are taught that they are responsible for taking an active role in developing potential solutions to ethical issues they may encounter. Finally, the students discuss the importance of ethical leadership and that in many organizations the safety professional assumes the role of ethics officer. The safety professional is often the person who ensures that the ethics program and training is in place and functioning. The safety professional may monitor the organization to ensure that it's abiding by the stated values and code of conduct communicated by top management (Navran, 1997).

The occupational safety and health students in this program are provided additional opportunities to hone their skills at solving ethical problems in numerous other courses. Many of the upper-level (junior/senior level) courses integrate ethical issues within the course content. One such senior-level course is the project-oriented capstone course.

Ethics Learned In the Capstone Course

This occupational safety and health program requires all students to complete a senior project-oriented capstone course. In their final semester, students complete industrial projects at various manufacturing facilities in the local region. Each student works individually and completes a minimum of 100 industry-supervised hours on his or her project. Projects range from developing and implementing various safety programs to developing and conducting safety training for industry workers. Students complete a written project proposal that is approved both by the industrial supervisor and the faculty advisor. Upon completion of the project, the student completes a project report and presents the results of his or her project to the faculty of the department. Students must demonstrate the successful solution to a specific problem presented in the initial proposal. Upon project completion, the industry supervisor assesses the student's technical and management skills. The student is also assessed by the faculty advisor (for the written report) and by the entire faculty for the oral presentation.

This industrial safety project has provided crucial real-world experience for the student. It has also, on occasion, provided opportunities for exposure to real-world ethical issues and concerns. In order to benefit the student and to reinforce the student's previous classroom instruction in ethics, a roundtable discussion of ethics has been incorporated into this senior project-oriented capstone course. This roundtable discussion has included academic case studies, guest speakers, and always a discussion of the student's experiences during their project.

Near the end of the semester, the students engage in roundtable discussions centered on ethics. During these roundtable discussions students discuss ethical issues and concerns encountered during the completion of the project. Students express concerns about a variety of issues such as conflict of interest, safety and health liability, and whistle-blowing. More often students voice concerns about less dramatic yet critical ethical issues. Students discuss how to handle and acknowledge mistakes that they or others have made during completion of the project. They discuss issues of honesty pertaining to resume writing and what data to leave in or leave out of their final project report. During their professional careers the students are more likely to encounter these less dramatic ethical issues.

As a result of this exposure to ethical issues students are better able to understand the value of ethical behavior and begin to develop methods of resolving ethical dilemmas. Follow-up sessions are organized to provide the students with an understanding of the resolution of problems in ethics (Pfatteicher, 2001). Review of ethical guidelines from earlier class work is used to further develop the student's ability to creatively and analytically develop potential resolutions to the issues discussed in the previous roundtable session. The purpose of the follow-up discussions is not to provide the students with "answers" but to develop an understanding of ethical principles and professional codes of conduct. The comprehension of ethical guidelines and methods will hopefully provide the student with the ability to handle future ethical dilemmas they may face throughout their professional careers.

Conclusion

This occupational safety and health program agrees that ethics education should expose students to ethical issues in order to help the students recognize ethical dilemmas. Secondly, the program shares the view that students should understand the value of ethical behavior and how their projects and future work may affect other people and society as a whole. Finally, the program attempts to provide students with skills and knowledge that will allow them to individually develop potential resolutions to ethical dilemmas. The roundtable discussion of ethics during the project-oriented capstone course allows the program to complete the educational loop. This capstone project allows the student to demonstrate their technical skills in an industrial setting and allows the student to "practice" the implementation of ethical guidelines and codes of conduct if the need arises. The program has received favorable feedback from students and alumni regarding this closing session on ethics in the safety curriculum.

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