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TABLE OF CONTENTS

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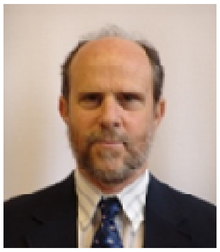

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Researchers, faculty, information scientists and librarians have been evaluating journals for the better part of the last 100 years. But, arguably, it wasn't until Thomson Reuters developed its citation indexes that it became possible to do computer-compiled statistical reports on the output of journals and the frequency of their citations. Then, in the 1960s, they invented the journal "impact factor", often abbreviated as IF, for use in their in-house analyses as part of their *Science Citation Index*®. Around 1975, they began publishing the information in their *Journal Citation Reports*® (*JCR*).

The *JCR*® provides quantitative tools for ranking, evaluating, categorizing, and comparing journals, of which impact factor is but one. Basically, impact factor is a measure of the frequency with which the average journal article has been cited, generally over a period of three years, and is calculated by dividing the number of current-year citations to the source items published in that journal during the previous two years. IF is frequently used to describe the relative importance of a journal within its field and is useful in clarifying the significance of total citation frequencies. What's more, it tends to level the playing field by eliminating biases related to a journal being large or small, and whether issues are published more or less often.

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IMPLEMENTATION OF AN ELECTRONIC LAB NOTEBOOK TO INTEGRATE RESEARCH AND EDUCATION IN AN UNDERGRADUATE BIOTECHNOLOGY PROGRAM

Rupa Iyer, University of Houston; William Kudrle, University of Houston

Abstract

Although Electronic Lab Notebooks (ELNs) are becoming more widely used in industrial settings, in the educational domain their adoption has been limited. For the last 5 semesters, the biotechnology undergraduate laboratory at the University of Houston has utilized a custom ELN solution based on a free and easily installable content management system. This study evaluated the implementation of and experiences with this ELN for biotechnology research projects as they were integrated into the educational laboratory courses. Also analyzed was an example of how the ELN might be used to enhance undergraduate research experiences in a classic experimental scenario. Finally, desired general characteristics for ELNs in educational laboratory settings were examined, resulting in an assessment of how well this particular platform met the desired characteristics.

Background

Computers are routinely utilized in laboratories for controlling instrumentation as well as collecting and analyzing data. In many research and industrial laboratories, these instruments are either directly or indirectly networked with electronic lab notebooks (ELNs) where investigators can further process and analyze data, perform simulations, and store records for use with publications or patents [1]. In many cases where the volume of data is large, ELNs are increasingly becoming a competitive necessity because of the enhanced productivity and data management capabilities they provide [2].

The use of ELNs in university settings is relatively uncommon, with estimates at only 4% overall as of 2008 [3]. The authors of this current study propose that lowering ELN costs and minimizing the need for technical expertise could increase the use of ELNs in education. A more widespread use of ELNs could then potentially provide the following benefits to undergraduate laboratory education:

- Students will be more prepared after they graduate to move on to industrial, research or other lab settings where ELNs are routinely utilized.
- Integrating research into the undergraduate curriculum will become easier by providing access to computer-based tools. Engaging undergraduate students in research activities and including more natural science, math, computer science, and engineering concepts develops greater competency for the interdisciplinary nature of today's research environments [4-5].
- The lab instructor is provided with a single entry point for reviewing data versus multiple lab notebooks that need to be reviewed separately.
- An ELN enhances communication among student researchers in a format similar to popular social networking websites with which most students are already familiar, thus leading to potentially greater engagement of students with research projects.

Two examples of how an ELN based on the freely available content management system (CMS) of Drupal version 6 (drupal.org) has been used in biotechnology education at the University of Houston [6] are presented here. This is followed by an example of how an ELN might be used for the scenario of a classic design of a lab experiment. Possible criteria for ELNs in an educational laboratory setting are considered along with an examination of how well Drupal meets those criteria.

Implementation in a Biotechnology Undergraduate Laboratory Class

The Drupal-based ELN has been used to enhance the laboratory teaching and research capabilities of students in the biotechnology program at the University of Houston since the fall semester of 2008. The biotechnology laboratory curriculum is an interdisciplinary, research-based curriculum that demonstrates the life cycle of a typical biotechnology product. Using the pesticide degrading bacterium *Brevundimonas diminuta* as an anchor organism, the curriculum follows a logical progression starting with isolation and identification of pesticide–degrading soil microbes, gene cloning, gene expression, bio-processing of the gene product, and commercial applications [7].

For the lab, a research paper is required where students collect soil samples from various locations in the greater Houston area and follow established protocols for isolation of pesticide-degrading microbes. Since this activity is repeated every time the course is offered, the area covered for soil sampling is potentially larger every year and provides students with a unique opportunity to contribute to a valuable database of pesticide-degrading activity. Providing access to data from their peers and discussion of this activity in their research papers is designed to enhance their research experience. Using Drupal in conjunction with the networking capabilities of the world-wide-web, collaboration on this research potentially connects students locally, regionally, and globally with other laboratories to investigate contaminated soils and further provides an exciting opportunity for students enrolled in the class to become active participants in an ongoing research project. This Drupal ELN is referred to as the Platform for Education and Research Collaboration, or PERC.

In the PERC implementation, each student records a name, location, short description, date, and time of collection for each sample point along with the results of testing the sample for the presence of two pesticides, Methyl Parathion or Paraoxon-degrading bacteria (Figure 1). The data point results can be edited only by the student and those with administrator privileges (usually the faculty and the lab manager), but are viewable by all of the students. Students can compare notes and results to make a more informed analysis of the results of the project as a whole as well as how their own data compare with data from others.

In terms of Drupal modules, the book module was used to present the background and procedures, the CCK module for custom data types, the views module for presentation of the collective data, and the faceted search module for data filtering capabilities. With a faceted search, the students can easily drill down to data points using the filter for semester, for positive or negative results, and student name. To provide a visual display of locations of the data samples, the location and Google maps modules were used to display the sample locations on a geographical map (see Figure 2). Color-coded pins denote the results – yellow for both negative, green for both positive, red for positive Paraoxon, and blue for positive Methyl Parathion test results.

Beginning with the fall 2009 semester, data results were accumulated starting with the greater Houston, TX, area. These data will be available over successive semesters, thus providing a data set concerning pesticide contamination that can be enhanced in the future to ever-larger geographical areas.

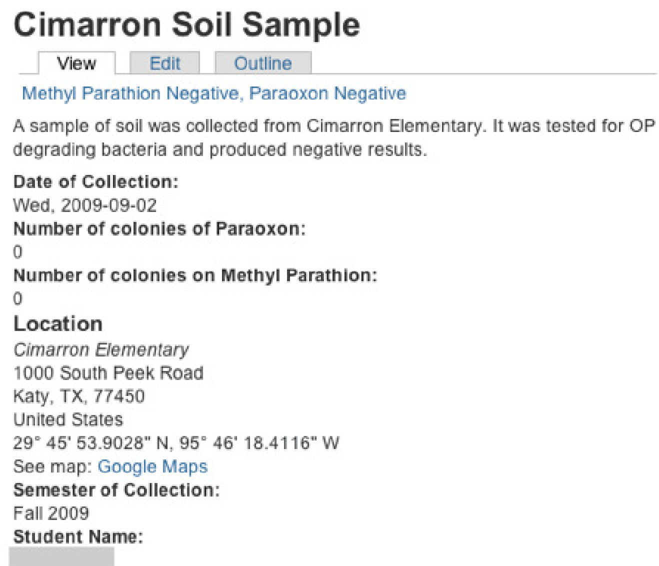


Figure 1. Data description of one sample location

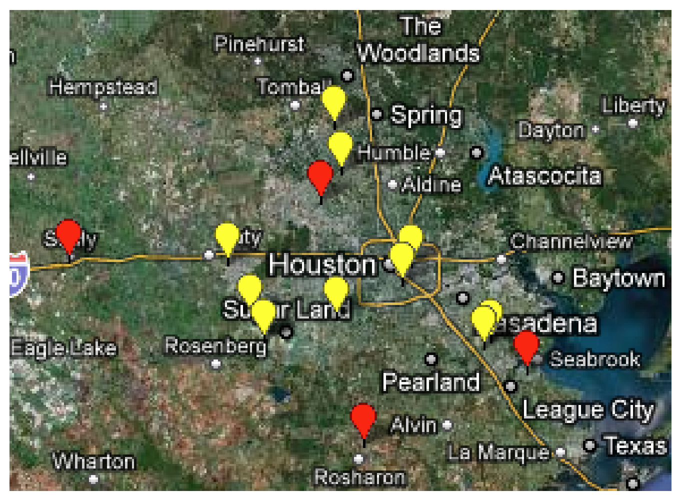


Figure 2. Locations of samples on Google map

A short survey was given to students from the fall 2009 and fall 2010 semesters, a summary of which is shown in Table 1. The columns (A, B, C, D, and E) correspond to the choices of Strongly Agree, Agree, Neutral, Disagree, and Strongly Disagree, respectively. Ease-of-use received the most positive feedback and, for all questions, the majority of the students saw positive benefit in the use of the ELN. In the area asking for suggestions for improvement, the most consistent comment was to introduce the ELN earlier in the semester, which the authors did in subsequent semesters.

Table 1. Results from the Fall 2009 & Fall 2010 student survey

Question	A	B	C	D	E
The ELN was easy to use	7	14	1		
The ELN helped me to have a better overall understanding of the course content	7	9	4	2	
The ELN helped me in writing my final course paper	3	9	8	2	
The ELN helped me in understanding the data from other students	5	11	4	2	
My experience with the ELN will be helpful in obtaining employment	3	12	3	3	1

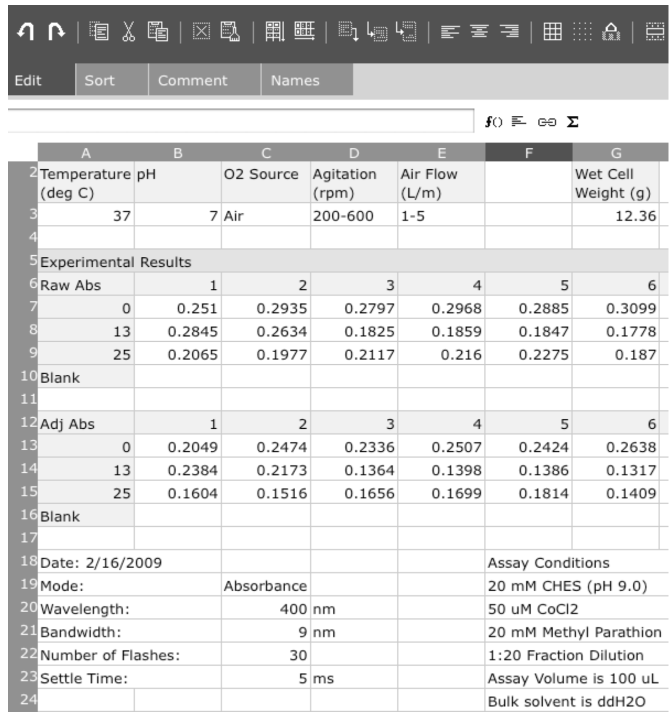
Implementation for Special Projects

The ELN is also used to store and share data for individual laboratory projects. Students in the course for Special Topics in Biotechnology at the University of Houston investigated various parameters that affect recombinant protein production by the transformed bacteria, *Escherichia coli* strain DH5α. Documentation for the experiment used an earlier version of a Drupal ELN, where the students uploaded their data via Excel spreadsheets and Excel graphs. The authors also enhanced the presentation below using native Drupal modules for the spreadsheet and graphing capabilities in order to highlight the possible ELN capabilities of this platform.

In the experiment, students used bio-fermenters to grow transformed bacterial cells. Through upstream and downstream production and purification, recombinant protein was extracted. Student teams manipulated one specific variable in the experiment—e.g., pH, temperature, aeration—in order to test its impact on cell growth and, ultimately, the protein yield. Each student team was responsible for manipulating a specific variable and recording the associated data. Students then presented a paper that proposed optimal conditions for cell growth.

For the optimized Drupal ELN, the experimental write up has four major sections: 1) Background and Procedures, 2) Data, 3) Graphs, and 4) Images. This ELN implementation is publicly available for review at mylabbook.org/bmb300, along with details about the modules used and technical details concerning how to create a similar ELN project.

For the data-collection aspects of the experiment, a spreadsheet was used (the sheetnode module) based on a template. The data were extracted from designated cells in the spreadsheet for analysis and displayed on other pages of the ELN. The students were still free to fill in other cells with any data that they deemed relevant to the experiment, or they could use the formula functionality of the spreadsheet to perform computations on the data. When the student is entering data into the spreadsheet, it would look similar to Figure 3. Note that only the first 16 rows of the spreadsheet are used for data extraction and rows 17 and beyond are used by the researcher to annotate additional private information in a freeform manner as desired.



	A	B	C	D	E	F	G
2	Temperature (deg C)	pH	O2 Source	Agitation (rpm)	Air Flow (L/m)		Wet Cell Weight (g)
3	37	7	Air	200-600	1-5		12.36
4							
5	Experimental Results						
6	Raw Abs	1	2	3	4	5	6
7	0	0.251	0.2935	0.2797	0.2968	0.2885	0.3099
8	13	0.2845	0.2634	0.1825	0.1859	0.1847	0.1778
9	25	0.2065	0.1977	0.2117	0.216	0.2275	0.187
10	Blank						
11							
12	Adj Abs	1	2	3	4	5	6
13	0	0.2049	0.2474	0.2336	0.2507	0.2424	0.2638
14	13	0.2384	0.2173	0.1364	0.1398	0.1386	0.1317
15	25	0.1604	0.1516	0.1656	0.1699	0.1814	0.1409
16	Blank						
17							
18	Date: 2/16/2009					Assay Conditions	
19	Mode:		Absorbance			20 mM CHES (pH 9.0)	
20	Wavelength:		400	nm		50 uM CoCl2	
21	Bandwidth:		9	nm		20 mM Methyl Parathion	
22	Number of Flashes:		30			1:20 Fraction Dilution	
23	Settle Time:		5	ms		Assay Volume is 100 uL	
24						Bulk solvent is ddH2O	

Figure 3. Spreadsheet in edit mode using the sheetnode module

Graphing can also be done directly from data in the spreadsheet based on a custom module that the authors developed (Figure 4) using the flot module. The flot module is based on a third-party Javascript module of that name used for plotting—which rhymes with "plot" and in Danish means "lovely"—which reflects the aesthetic display. These customizations are available on the www.mylabbook.org website as free downloads and are in the process of appropriate integration with the extension modules available on the Drupal.org website as well.

In addition to graphing, the custom module utilized web services to get basic statistics for the data, with the results shown at the bottom of Figure 4. Web services allow the data and results to be passed between computers that are appropriately configured. Computations do not need to be run natively within the ELN platform, but can utilize computations done on another computer. In the case of using Drupal for an ELN, this allows utilization of the CMS strengths for data collection, presentation, and collaboration, while offloading computational needs for more sophisticated analysis to other platforms and software packages.

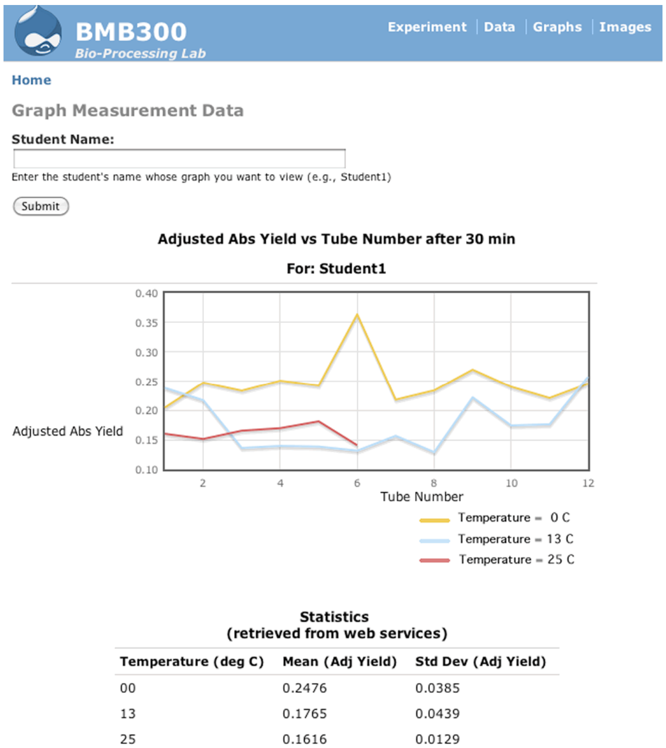


Figure 4. Customized flot module displaying data from the spreadsheet

For this experiment, it was also helpful to provide images of the gel results. The uploading of images and other files is available in the core functionality of Drupal. A table of the image descriptions was created which provided a table of the image descriptions that can be filtered by student. At this time, image display within the table is not available, but by clicking on the hyperlink of the image name, the image from the experiment will be displayed.

Classic Design Implementation

The last scenario to be covered concerns a simpler experiment that is easily broken out into the classic experimental stages of hypothesis, design, experiment, and analysis. It provides a model for other simple experiments and is based on a write-up posted on student pages at the University of Nebraska (used with permission) [8]. The objective of the experiment is to show that when a vegetable (potato) that is naturally high in the catalase enzyme is heated, there is less and less active catalase. The teacher and student write-ups are available from the student pages, and the content from these write-ups has been incorporated into the sample website which can be found at mylabbook.org/bmb200. Four main sections were created for this experiment – 1) Background and Procedures, 2) Data, 3) Graphs, and 4) Questionnaire.

The Background and Procedures section provides the explanation for the experiment and a description of the procedures to carry out the experiment. Hyperlinks are embedded in certain sections of the experimental procedures explanation to bring up the appropriate form that is completed for the data collection. A screenshot of the first page of the Background and Procedures section is shown in Figure 5. The hyperlink from the procedures section brings the student to the form, where data for temperature, test tube number, and time to float to surface are input. Presentation of this data is available in a tabular format along with appropriate filters of the data display, if desired. In Figure 6, a table of the data is shown as filtered for Student1.

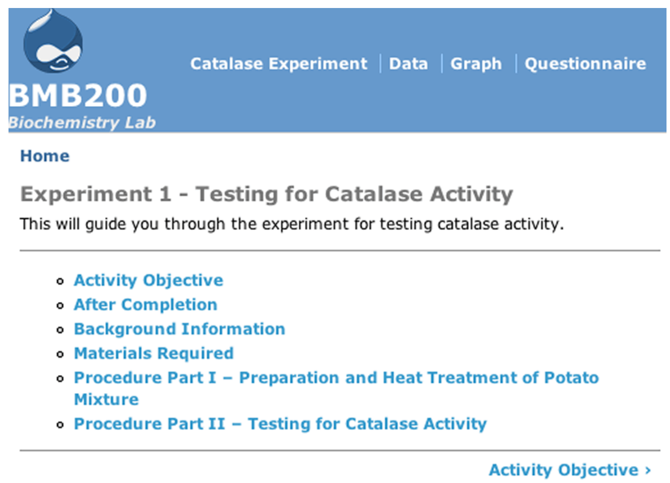
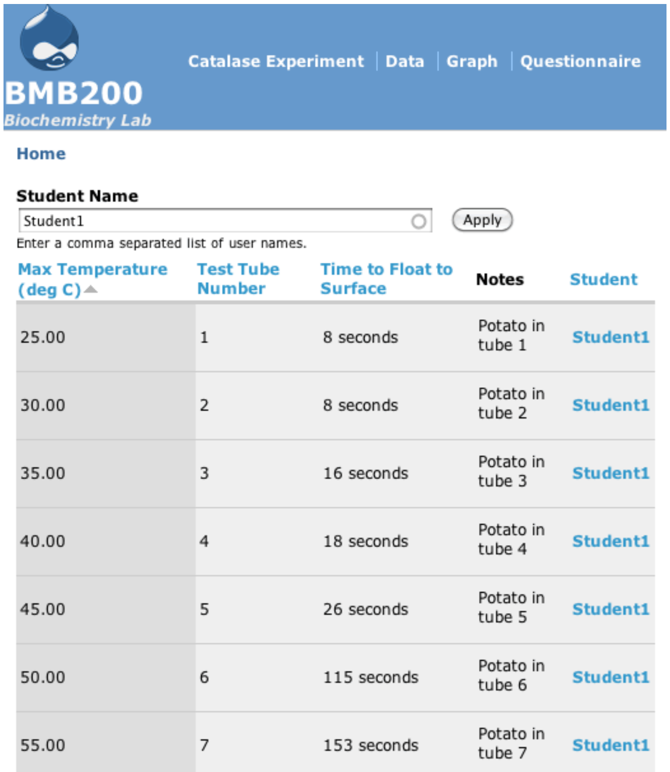


Figure 5. Explaining background and procedures for the experiment using the book module

Following the collection of the data, one of the teaching points for the laboratory experiment is the graphing of the results to give a visual representation of the data. The output is shown in Figure 7, using the data shown in Figure 6, as a bar chart to highlight the increased changes at higher temperatures.

At the conclusion of the experiment, the laboratory procedures suggest that the student answer some questions. The resulting questionnaire for the student is shown in Figure 8. When the student fills out the questionnaire, the content will automatically be emailed to the designated recipient, assumed to be, in this example, the lab instructor. This feature would most likely be restricted to availability only after a login by the student, in order to provide a measure of accountability for the answers.



Max Temperature (deg C)	Test Tube Number	Time to Float to Surface	Notes	Student
25.00	1	8 seconds	Potato in tube 1	Student1
30.00	2	8 seconds	Potato in tube 2	Student1
35.00	3	16 seconds	Potato in tube 3	Student1
40.00	4	18 seconds	Potato in tube 4	Student1
45.00	5	26 seconds	Potato in tube 5	Student1
50.00	6	115 seconds	Potato in tube 6	Student1
55.00	7	153 seconds	Potato in tube 7	Student1

Figure 6. Experimental data filtered for Student1 using the views module

Appropriate Information Technology for Laboratory Education

In determining appropriate information technology for enhancing laboratory education in a wide variety of settings, several criteria could be relevant.

1. *Low cost*: Educational communities are often more constrained by budgets than are businesses, as educators try to incorporate new and relevant technologies. The cost of capable commercial electronic lab notebooks can often be substantial [9], which usually precludes the commercial options that are used by most of the industrial or large research institutions that use ELNs.
2. *Sustainable*: Again, because of budget constraints of the educational community compared to the industrial community or some other sectors, it is often challenging to find technologies that are useful to the educational community which also stay current with the growth in technology.

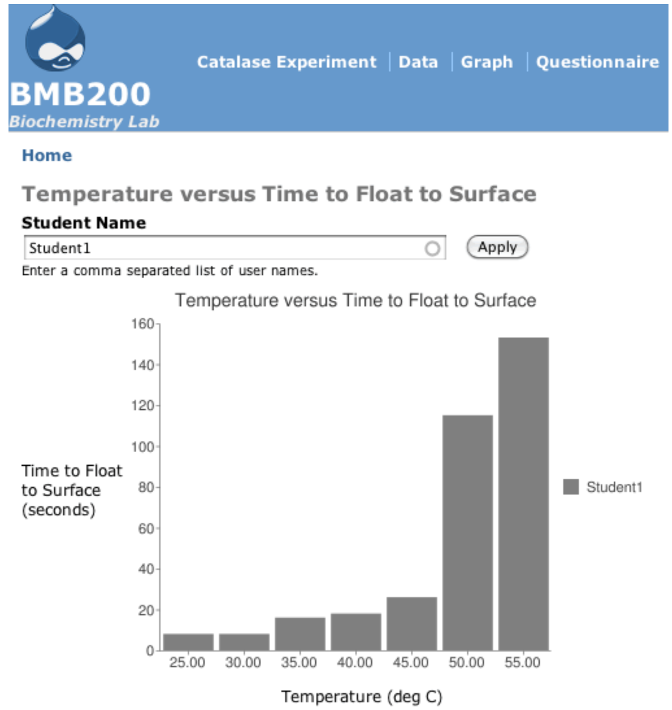


Figure 7. Data plotted for Student1 using the charts and graphs module with Google charts

3. *Low barrier to implementation*: New technologies usually involve learning curves, even if they can provide significant advantages. The easier that a technology is to set up and utilize, the more likely will be its uptake.
4. *Easily extended*: It is difficult to assess *a priori* all of the scenarios to which an ELN might be put to use. Therefore, it is important that it be as adaptable as possible.
5. *Appropriate analytic modules*: Inherent in the nature of ELN is the need for analytical capabilities. This will vary according to the particular application, but capabilities like statistical analysis will be commonly used.
6. *Research collaboration capabilities*: With the increasing popularity of social networking even within scientific and technical communities [10], collaborative capabilities are desirable not only for sharing results among researchers, but also for bringing an element of familiarity to many students.
7. *Semantic Web friendly*: Although not a common requirement, there is extensive literature explaining the benefits of the Semantic Web (sometimes referred to

as "Web 3.0") to the scientific and technical communities [11]. This capability may play an important role in the future of sharing scientific data, so it would be advantageous to have this capability.

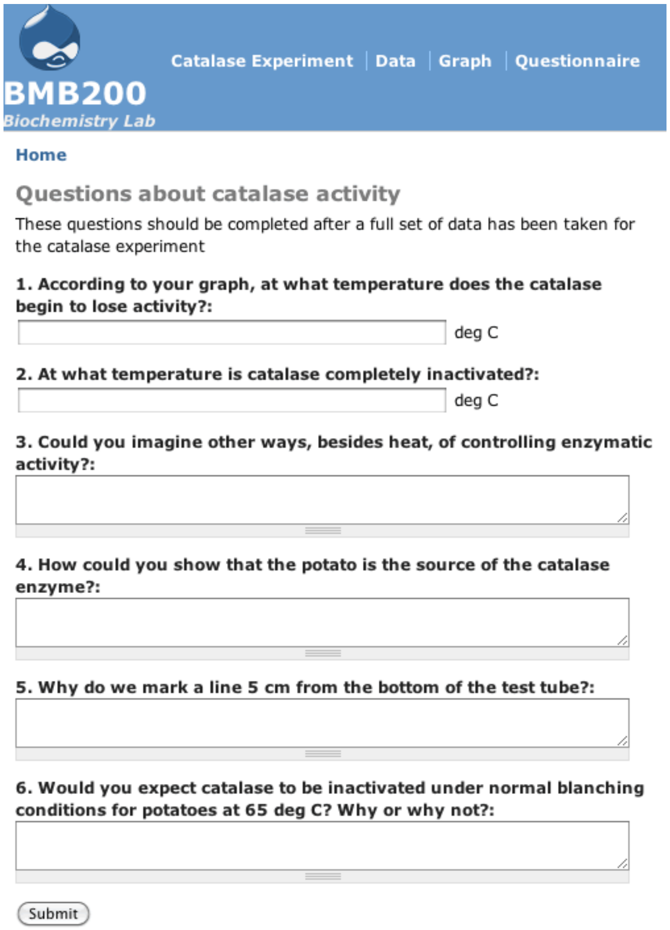


Figure 8. Questionnaire to be filled out at end of experiment

Among approaches to fulfilling these desired characteristics for ELNs in educational settings have been wikis and blogs [12]. These platforms can be edited and extended in a free-form manner by anyone with appropriate permissions and which provide ease of sharing with others. They have limited capabilities for automatically building the information architecture, however, and robust research collaboration and analytical capabilities are not available in the popular wiki or blogging platforms. A promising avenue for an open-source online ELN was the use of Google Wave [13], but recently Google has dropped continuing support for this platform. Other open source CMS platforms that deserve consideration as an ELN platform would include Ruby on Rails (rubyonrails.org) and Plone (plone.org). In regards to the lower cost commercial options for ELNs, they do not have as robust a feature set or match the criteria given above as do many of the freely available open-source CMS platforms, and so were not considered here.

Since this paper presents examples using Drupal, it is appropriate to assess how well Drupal meets these given criteria for laboratory information technology for education.

1. *Low cost*: The fact that Drupal is free and open source makes it attractive when compared to the available commercial electronic lab notebooks.
2. *Sustainable*: Drupal is widely used in many sectors; has the backing of many commercial organizations, consultants, and volunteer developers; and, has a thoughtful and flexible technical architecture. These all support sustained development independent of academic funding.
3. *Low barrier to implementation*: Drupal is written in the PHP scripting language, which is the most popular language for developing websites [14] and is available on most shared-hosting services or can be easily set up without much IT expertise by those familiar with basic website construction.
4. *Easily extended*: With over 12,000 available extension modules as of October 2011, Drupal can be adapted for numerous different use-cases without programming. If customization is desired, custom modules can be developed with a relatively easy learning curve [15].
5. *Appropriate analytic modules*: Existing Drupal extension modules can fulfill the analytical needs of many situations in laboratory education. However, other languages such as Ruby, Python, Java, and C++ have attracted more development for scientific or mathematical purposes. Drupal can often still take advantage of functionality in other languages by using web-service modules as an interface to appropriate analytical web services, as demonstrated in the bioprocessing sample setup presented earlier in this paper.
6. *Research collaboration capabilities*: The widespread use of Drupal as the basis for social networking websites has brought maturity and variety to the tools that are currently not available among most research platforms.
7. *Semantic Web friendly*: Drupal is the first widely used CMS to incorporate into its core platform the automated production of RDFa data annotations consistent with the Semantic Web, as of the Drupal 7 release. It also has several mature modules for fea-

tures like SPARQL queries and RDF vocabulary import and export.

Further information about specific Drupal modules that might be of interest for lab management and scientific research are available at www.mylabbook.or.

Conclusions

In conclusion, the authors have presented how a free and relatively easily implementable CMS with ELN capabilities was used to enhance an existing undergraduate laboratory course and empower students for contributing to an ongoing research project. Also shown was how this platform might be used for a bioprocessing lab and, subsequently, in a more generic lab experiment. Several advantages are available in these approaches as compared to paper notebooks, including ease of sharing data and pictures in real time among students, spreadsheet capabilities for data collection and analysis, automatically generated graphs, analytical capabilities through web services, hyperlinks to information sources, and more extensive social networking and collaboration features. The initial student surveys about this approach suggest that it has been valuable in its ability to share data collectively within a given class situation. Furthermore, the authors showed the desired characteristics of an ELN in an educational laboratory setting and examined how well the Drupal platform matches these criteria. It should be noted that all implementations discussed in this paper, except for web services, have been on an outside Internet hosting company using a shared hosting plan, and so did not require extensive special configuration or a dedicated IT staff. The authors have developed an accompanying website at www.mylabbook.or with working versions of the second and third ELN scenarios along with areas for continuing documentation and discussions of this approach.

Appendix

Abbreviations used:
CCK – Content Construction Kit, a Drupal module that allows customized content types
CMS – Content Management System
ELN – Electronic Lab Notebook
Flot – Javascript module for plotting data, rhymes with "plot" and is Danish for "lovely"
IT – Information Technology
PERC – Platform for Education and Research, as presented in this paper
RDF – Resource Description Framework, a data storage standard for the semantic web
RDFa – RDF for annotating web content
Sheetnode – Drupal module for the spreadsheet
SPARQL – Recursive acronym for **S**PARQL **P**rotocol **and R**DF **Q**uery **L**anguage, a data query language for the semantic web

Acknowledgments

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Biographies

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INTEGRATION OF MOTION CONTROL TECHNOLOGIES INTO A PROGRAMMABLE LOGIC CONTROLS COURSE

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Abstract

In this study, the author developed new motion-control teaching components for inclusion in an advanced programmable logic controller (PLC) course. The proposed motion control teaching components consisted of a human-machine interface (HMI) terminal, a commercial industrial control trainer (ICT), a stepper motor drive, and an ac servo motor drive. For the first exercise, a lesson on a PanelView HMI terminal from Rockwell Automation was given to the class. The students practiced with PanelBuilder32 software in order to program the HMI terminal to operate the PLC. Programming with an ICT, from Bytronic Inc., was the second exercise to help students become familiar with various motion control components such as the permanent-magnet dc motor (PMDC) and linear and rotary solenoids. The stepper motor control laboratory assignment was next given to the class. The students learned how to use the special module for the stepper motor drive. Next came the ac servo motor. The Ultraware setup and programming software for Ultra-series ac servo motors was examined. The final design project was given to three student groups of four members each. Each group built a four-level elevator using a stepper motor as the prime mover and any additional sensors as necessary. The main focus of the elevator project were application of the HMI terminal for elevator control and accurate position control of the stepper motor. The assessment method for these motion control components is also presented in the conclusion of this paper.

Introduction

Penn State Berks offers a year-long PLC course for both EET (Electrical Engineering Technology) and EMET (Electro-Mechanical Engineering Technology) students. The fundamentals of PLCs course (EET220) is taught in the spring semester, with the advanced topics course (EMET430) in the fall semester. The fundamentals of PLCs course covers introduction of PLC hardware (SLC500 and I/O modules) and PLC programming, with basic instructions such as bit, timer, counter comparison, arithmetic, move, and logical functions. In this paper, the author introduces the newly developed motion control teaching components for the advanced topics course.

Table 1. Proposed Topics of the Advanced PLC Class and Laboratory

Week	Topics: Class	Topics: Lab
1	PanelView / Communications	PanelView
2	PanelView / Communications (continue)	PanelView (continue)
3	Motor Drives	Programming with ICT
4	Motor Drives (continue)	Programming with ICT (continue)
5	Motor Drives (continue)	Stepper Motor Drive
6	Motor Drives (continue)	Stepper Motor Drive
7	PID	Stepper Motor Drive (continue)
8	PID (continue)	Oven Temperature Control
9	PID (continue)	Oven Temperature Control (continue)
10	Ultraware	Automated PLC Controlled Lighting
11	Ultraware (continue)	Automated PLC Controlled Lighting (continue)
12	Fuzzy Logic	Motor Control for Waste Water Treatment
13	Fuzzy Logic (continue)	Motor Control for Waste Water Treatment (continue)

The topics of the class and lab are listed in Table 1. The students learn about the PanelView operator terminal and PanelBuilder software to design control panel applications for the PV550 HMI terminal [1], [2]. The laboratory assignments are based on the user manuals from the manufacturer and customized descriptive problems. Four major motor types—the induction motor, brushed/brushless dc motors, and the stepper motor—are included. The characteristics of these motors and application methods are emphasized. The Ultraware class provides an opportunity for students to program and run the digital ac brushless servo system widely used in industry.

The ICT laboratory provides numerous topics that students can apply to real-world problem solving. In order to interface sensors to the PLC, scaling and mechanical adjustment techniques are required. The design of proper timing for overall system control is very important in writing a working ladder logic diagram. The PID concept may be hard for students with lecture only. The newly proposed teaching components help students visualize the effectiveness of the PID function in automation and process control through a series of laboratory exercises. The concept of fuzzy logic is introduced at the end of the semester since advanced PLCs such as ContolLogix offer it. The PLC laboratory at Penn State Berks is equipped with six SLC500 PLC training stations; each station has a 10-slot modular chassis from Rockwell Automation.

PanelView - PV550 HMI Terminal and PanelBuilder32

The main objective of this teaching component is to provide students with the opportunity to learn how to use an HMI terminal. Since the PLC lab at Penn State Berks is equipped with PV550 monochrome terminals, the class focuses on how to use PanelBuilder32 software with the SLC500 PLCs. A couple of exercise problems are given to the class to practice with PanelBuilder32 software. The students learn how to control their ladder logic diagrams through not only I/O devices on the PLC training station, but also the PV550 HMI terminal for future motion control projects.

ICT System

The ICT laboratory exercises provide students with techniques for parts detection, sorting, and assembly. The ICT from Bytronics is designed to sort an aluminum peg from a plastic ring, then assemble these two components and check for correct assembly. These components are initially placed randomly on the chain conveyor. The chain conveyor moves them to the assembly chute. Then, the plastic components are detected by the sort area infrared (IR) sensor and ejected by a linear solenoid down the plastic ring hopper. In the meantime, the aluminum peg remains on the conveyor and goes down to the belt conveyor through the feeder chute. The plastic ring hopper is positioned above the belt conveyor in order to engage the peg with a hole in the ring. The inductive- and capacitive-type proximity sensors and IR sensors are positioned along with the belt conveyor to check for the correct assembly. The properly assembled parts proceed into the finished parts tray, but incomplete assemblies are rejected by a linear solenoid into the recycle bin. A picture of the ICT system connected to a SLC500 PLC is shown in Figure 1.

Two I/O modules, 1746-OW8 and 1746-IB16, are used to control the ICT through the SLC500 PLC. The details of the modules installed are listed in Table 2. The step-by-step laboratory assignments enable students to complete ladder logic programming exercises which control all of the ICT processes such as detection, sorting, queuing, and counting.

Step 1. <u>Sorting Routine</u>: Component detection and sorting are common practices in industrial control. First, detect the plastic rings moving along the chain conveyor and redirect them to the plastic ring hopper. Second, detect the metal pegs and lead them to the assembly chute.

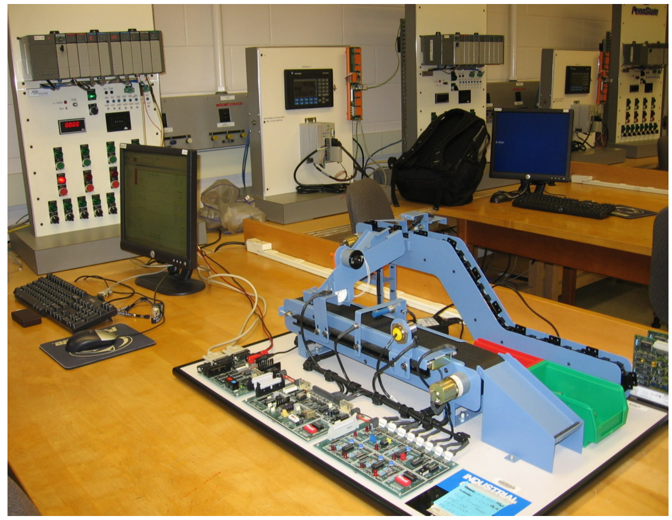


Figure 1. Industrial Control Trainer (ICT) from Bytronic

Table 2. Details of SLC500 Ten-Slot Modular System

Chassis Slot Location	Part Number	Description
0	1747-L541	SLC 5/04 CPU – 16K Mem. OS401
1	1746-OA16	16-Input (TRIAC) 100/240 VAC
2	1747-SDN	DeviceNet Scanner
3	1746-IB16	16-Input (SINK) 24 VDC
4	1746-OB16	16-Output (TRANS-SRC) 24 VDC
5	1746-IB16	16-Input (SINK) 24 VDC
6	1746-OB16	16-Output (TRANS-SRC) 24 VDC
7	1746-OW8	8- Output (RLY) 240VAC
8	1746-IB16	16-Input (SINK) 24 VDC
9	1746-NT4	Analog 4 Ch Thermocouple Input

Step 2. <u>Queue Counting</u>: Counting is required in almost all industrial applications. Since the maximum queue length in the assembly chute is five, once the queue has been filled, the chain conveyor should be stopped.

Step 3. <u>Operation Timing</u>: The sort and queue counting routines developed in the previous steps are combined together in this step. The queue count should decrease as the plastic rings are taken into the assembly area.

Step 4. <u>Plastic Ring Detection and Sorting</u>: A single plastic ring is detected and rejected during this stage. The inductive proximity sensor detects the metal peg, and the capacitive proximity sensor detects the presence of a plastic ring assembled onto a metal peg.

Step 5. <u>Metal Component Detection and Sorting</u>: The existence of an aluminum peg is discovered and expelled into the reject bin.

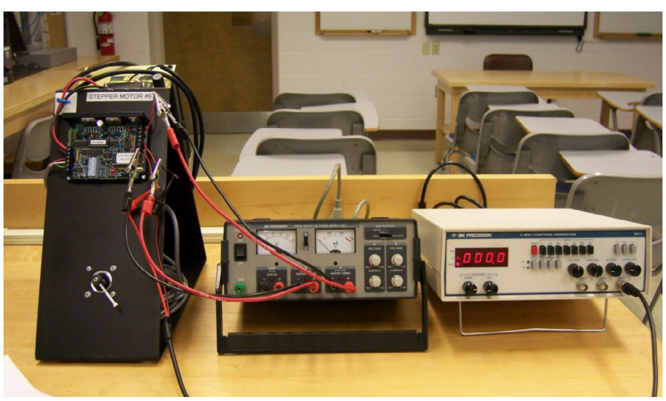
Step 6. Component and Assembly Detection and Sorting: The single plastic ring, aluminum peg, and assembled parts are identified. Single parts are expelled to the reject bin and assembled parts are accepted.

Step 7. Complete System Control – Component Queue Handling: A queue of parts travelling along the belt conveyor is identified to complete the system control.

Stepper Motor Drive

There are numerous stepper motor drive applications in the automation and process industries. The shaft of the stepper motor can be held in any fixed position, providing precise positioning control. The stepper motor can rotate in both clockwise (CW) and counter-clockwise (CCW) directions. An electronic circuit, indexer or translator with power amplifier, is inherently required for the stepper motor to drive it.

The objective of this teaching component is to provide students with various real-world techniques to drive a stepper motor. The STP-DRV-4035 micro stepping drive from Automation Direct [3] and the 1746-HSTP1 stepper controller module [4] are used for this lab. The experimental setup of the stepper motor drive and a sample PV550 screen are shown in Figure 2. In order to control the stepper motor properly, the I/O data tables of the stepper controller module must be configured [4]. The module can be configured to determine which inputs are used, the active level of inputs used, and if a quadrature encoder is used. In addition, the module should be configured to select whether the output of the module is a pulse train with direction command or CW and CCW pulse trains, and to select between configuration mode and command mode.



(a) Stepper Motor Drive Setup

(b) Sample PV550 Screen to Control a Stepper Motor

Figure 2. Experimental Setup of the Stepper Motor Drive and PV550 Screen

Ultraware and Ultra3000 Digital Servo Drives

Ultraware is a Windows software application that provides a complete setup and programming environment for the Ultra3000 digital servo drives [5], [6]. The goal of this teaching component is to provide real-world experiences for students by driving and controlling the Ultra3000 digital servo drive with Ultraware setup and programming software. Another goal is to learn about and test the IMC110 termination panel and SLC servo control module [7], [8]. The termination panel provides an easy connection to a user -side dc power supply, emergency stop, drive feedback, and fast I/O to the SLC servo control module in the SLC500 PLC. The basic analog velocity control functions are exercised along with the SLC500 PLC. Sophisticated control functions such as the preset current and position control and the position follower control with encoder and indexing control are skipped in this exercise due to time limitations.

Final Project

At the beginning of the class, the importance of the final project is addressed. In the previous semester, the final project was a group effort with topics proposed by the students and then carefully selected by instructor. Due to the limitation of the hardware availability on the PLC trainer, the previous projects were merely static simulations of various real-world applications. The proposed motion control enhanced teaching components include a final project to design and build a four-story elevator system controlled by an SLC500 PLC. Three groups of four students each build their own four-story elevator system. The prime mover of the elevator system is assigned to the stepper motor. The same types of stepper motor and translator are given to each group. Each group has the freedom to select the sensor types and the ladder logic program with which to control the elevator system. The requirement of the elevator system is limited to the basic operation of the elevator such as moving up and down, and stopping at each level without the operations of opening and closing the elevator door. In this project, the students learn about group work, project scheduling, selection and interfacing of sensors, scaling and application of stepper motor drives.

Assessment

The assessment of the newly developed motion control teaching components consists of an in-class presentation of each topic and written lab report. Six teams with two students per team select one topic to present the activities. The demonstration of their ladder logic diagram is very important and serves to verify the correctness and effectiveness of the program. The formal laboratory report includes the design approach, the generated report, and the logic diagram from RSLogix500. The assessment rubric is shown in Table 3.

The format of a report of the laboratory project design exercise consists of:

- Objective – The objective section should include a brief assertion of the goals of the project design exercise. It should contain the essence of the design and not a sequential list of assigned tasks or requirements.

- Design Input – The design input section should summarize all requirements imposed on the design project and any other pertinent data.

- Design Output – The discussion should outline how the requirements of the project were met. With it, students should include ladder logic diagrams, ladder logic instructions used, process flow charts, and other pertinent data. They should define what parts (rungs, pages, etc.) of the project design were done by which team members. Students may reference the project handout provided at any point and it will be included with their report in an appendix. Students may also refer to other sources; however, they must be sure to declare them in a reference section.

- Design Verification – The design verification section should address how the requirements were verified. It should include information on the process of verification and what equipment was used to test and debug the design. It should include truth tables, field device list, graphs, figures, and/or diagrams.

Table 3. Assessment Rubric

Assessment	Points	
Objective	5	
Design Input	5	
Design Output	5	
Design Verification	10	
Design Validation	10	
Conclusions	15	
References	5	
RSLogix500 Project Report	25	
RSLogix500.rss File	10	
Uniqueness Demonstration	10	
Total	100	

- Design Validation – The design validation section should summarize the results from design verification testing and indicate whether all of the requirements were met. If any requirements could not be met, list them in this section. The students should refer the RSLogix500 project report.

- Conclusions – The conclusions section should also summarize what students learned by executing the project and should identify problems encountered other than equipment problems during the laboratory session.

- References – The references should be any resources relevant to the assigned laboratory topics.

- RSLogix500 Project Report – The RSLogix500 report should reflect the following options in the configuration and ladder options dialog, as shown in Figures 3 and 4.

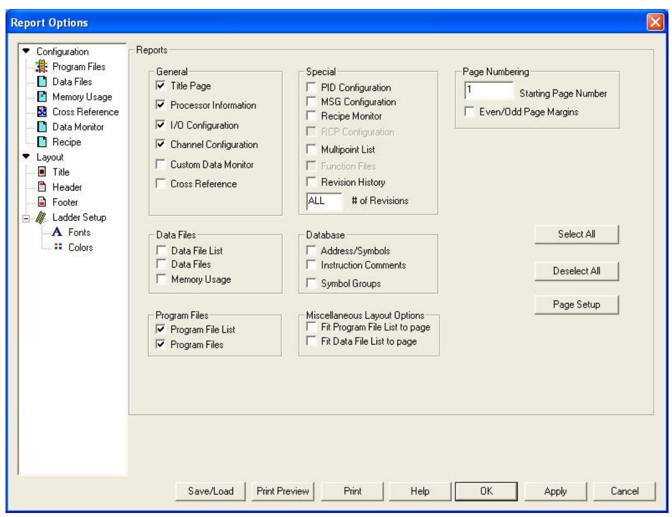


Figure 3. RSLogix500 Project Report Options

- RSLogix500 File – The ladder logic diagram should include a title, such as 'Laboratory #_Your Name .rss', and as many rung comments as possible. The developed and tested file should be submitted via ANGEL, the Penn State proprietary course management system.

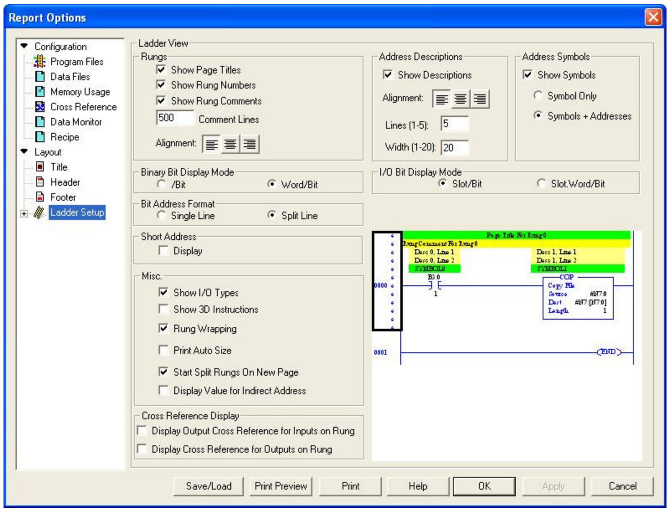


Figure 4. RSLogix500 Ladder Setup Options

- Uniqueness Demonstration – The developed and tested ladder logic program should be demonstrated and its operation and uniqueness shown to the instructor during the lab activity.

Conclusion

The newly developed motion control teaching components provide students not only with fundamental theory but also hands-on experience through lab work. The various hands-on laboratories were designed to develop essential technical skills which could apply to real-world motion control applications. The major skills that students can develop through the newly developed advanced PLC course are scaling of analog I/O signals along with the selection of the correct sensors, creation and use of I/O data tables, and use of advanced PLC instructions. Students additionally must acquire team work ethics, time management skills to complete projects, and organizational skills. The students expressed only optimistic opinions on the newly developed motion control teaching components, saying that they enjoyed themselves tackling the challenging assignments.

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Biography

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GOLDEN-I HAZHAT TRAINING PROJECT

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Abstract

This paper describes the use of a head-mounted computing device (Golden-i) [1] for field-worker training purposes. The purpose of this project was to provide the firefighters at the Texas Engineering Extension (TEEX) firefighting school with a reference tool that can be used in addition to performing critical tasks. Golden-i provides a hands-free device that can be activated and controlled using voice commands. Golden-I aids firefighters by quickly referencing necessary instructional materials, while performing critical tasks such as repairing gas leaks.

Introduction

HAZHAT is a device and application system designed for purposes of training students of the Texas Engineering Extension (TEEX) firefighter and rescue school's Hazardous Materials program. An integral part of the Hazardous Materials (HAZMAT) program at TEEX is that trainees must apply skills learned in the classroom by donning a HAZMAT protection suit and responding to mock hazardous situations. To supplement the HAZMAT trainee's training, HAZHAT can be worn while participating in mock disaster exercises.

HAZHAT is a head-mount display unit designed for use in HAZMAT applications. While wearing/using HAZHAT, trainees have access to numerous documents that contain detailed instructions on how to react in certain situations. This type of reference material is useless for experienced HAZMAT personnel, but has the potential to be very effective for undergraduate trainees of the HAZMAT program. The reference documents that are housed in the HAZHAT devices help remind trainees when they forget what to do in the middle of a mock disaster scenario. This will help the trainee gain a more positive, effective, and efficient learning experience.

Program

Trainees in the field of Hazardous Material (HAZMAT) emergency services are in need of a device and application system that provides information on what to do in disaster scenarios. This device must be small enough to fit on the head of the trainee (the trainee will also be wearing a HAZMAT suit) and the application needs to have hands-free operability. All documents on this device must be easily accessible through voice commands.

Design Implementation

The HAZHAT Training Application is a prototype to show the potential of such an application using the Golden-i hardware. This application delivers a solution that is educationally useful for the client at the TEEX Hazardous Material Training Center. The HAZHAT Training App was built to deliver instructions wirelessly through a simple user interface. The design contains digital renderings of all of the figures in the Chlorine Rail Car Leak manual [2] ,which is currently being used by the school .The figures are centered in the middle of the eye piece for optimal viewing purposes. A black border was added around each figure because it has become known that the human eye cannot see the entire screen on the Golden-i. Each figure is accompanied by descriptive instructions to support a trainee during a training exercise.

Each descriptive instruction is transferred from the manual and is accurate per the customer's request. The HAZHAT Training App was also designed to provide information via voice-activated commands on each page of the manual. The trainee can continue with the exercise while the instructions are read through built-in speakers at the ears. Each instruction screen contains visual buttons that can be selected via voice commands. The voice commands on each screen include 'previous instruction', 'reread instruction', and 'next instruction'. These voice commands allow the trainee to have complete control over the instruction manual. A novice trainee can take as much time as needed with each instruction and is able to replay the instruction as many times as needed. An expert trainee might run through the instructions and be able to complete the exercise via simple diagrams. The HAZHAT Training App opens up a new frontier as old manuals become digital and mobile on hands-free devices such as the Golden-i.

System Requirements

The following section will discuss the items to be delivered. Each item is discussed in terms of meeting specific functional requirements. The descriptions include what features are available or not.

Application on Golden-i

The HAZHAT Training App was developed for Kopin's Golden-i hands-free computer. This hardware is incredibly powerful. Applications developed will pave the road for commercializing the Golden-i. This application was developed [3] specifically for the Golden-i; the HAZHAT Training App will not work on any other platform. Therefore, the demonstration was implemented through the Golden-i.

Automated Manual

The initial purpose of the HAZHAT Training App was to digitize and automate the Chlorine Rail Car Leak manual in order to assist TEEX Training trainees during exercises [4]. This application allows for the training documentation to be mobilized with the trainee and for trainees to acquire more experience and knowledge with training exercises as well as allowing the trainee to not worry about remembering which tactic to use in a certain situation. The automated manual includes diagrams from the original document. However, due to time constraints, no new figures were created. The HAZHAT Training App is as accurately detailed as the original training manual.

Voice Controlled

The HAZHAT Training App is voice controlled with on-screen voice-activated buttons. The buttons can be seen as highlighted text within the figures or commands that allow the user to progress through the instruction set. The Golden-i is a hands-free device. The application will not be motion controlled due to the environment in which it will be used.

Text to Speech

Due to the fact that a real-time operating system (RTOS) [5] was used, polling is not applicable to the implementation of this strategy. Although an RTOS utilizes interruptions, it can be thought of in terms of scheduling events. The Golden-i shell is an RTOS application created for the Windows CE core of the Golden-i headset. The shell has a predefined class hierarchy. When creating an application for the shell, the classes in this hierarchy define all of the tools at the disposal of the user. Keep in mind that the shell was created for demonstration purposes, so the hierarchy is far from completed. Modifying the schedule of different events was not possible, but instead the available classes were applied to produce the desired functionality.

The developed strategy was based on button-pressed events and call-back functions. Although many other features of the shell were used, the transitions using button-pressed events defined the structure of the application. The application for this project was to utilize Golden-i to train field workers in quickly referencing necessary instructional material, while simultaneously performing critical tasks of repairing a critical piece of equipment in a hazardous environment such as a gas leak from the fuel tank of a car. The ability to transition between multiple instructions defined in a chlorine dome tank car repair manual is needed. Chlorine domes are broken into three main sections that can be seen in Figure 1.

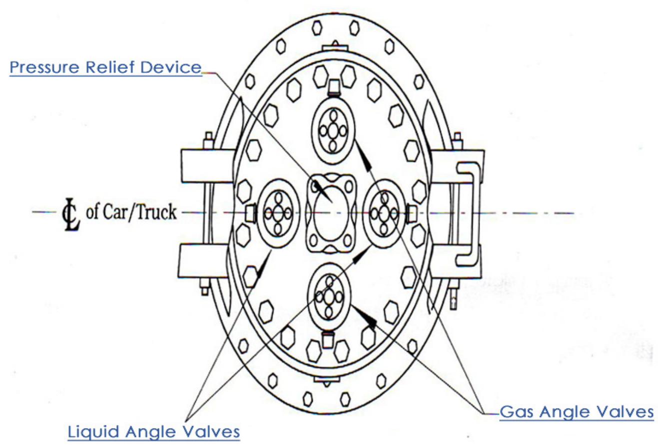

Figure 1. Chlorine Dome

The user can determine which one of the three sections—pressure relief device, liquid angle valves, and gas angle valves—is leaking. The system provides the user with the option to choose the leaking section. The class GISpeechButton is used to define each section as a speech command. Once the sections are defined as speech commands, a call-back function is created to correspond to each speech command. Once a speech command is given, a button-pressed event occurs and the proper call back function for that command is executed.

Figure 2 shows the manway cover gasket and three instruction actions. One is to immediately report a leak to the chlorine supplier. It is not advisable for persons to handle this condition without special training. Second is to tighten the manway cover stud nuts using wrench socket 113, wrench extension, wrench bar adaptor, and wrench bar. The third is to test for leaks.

When the speech command is given for the manway cover gasket, the user must be able to navigate through each instruction set. One thing to note is that only one image is given for all three instructions. A decision was made that only one instruction should be displayed at a time. So, when the user transitions to this instruction set, he/she will see the image and only the first instruction. This is shown in Figure 2.

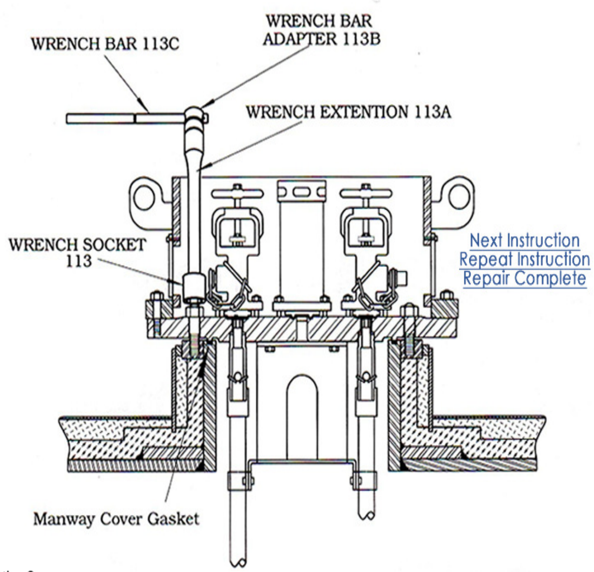

Figure 2. Manway Cover Gasket: Instruction One

For instruction one, the user needs to have three options: the ability to call the next command, repeat the command, and denote that the repair is complete. The options are shown in Figure 3. Up to this point, the significance of the repeat command relates to a feature that has been neglected. Using the speech vocalizer of the shell application, each instruction will not only be shown to the user, but it will also be vocalized to the user. If the user wishes to vocally hear the command again, he can call the speech command (Repeat Instruction). The speech command (Repair Complete) will simple return to the start of the application and allow the user to select a new instruction set.

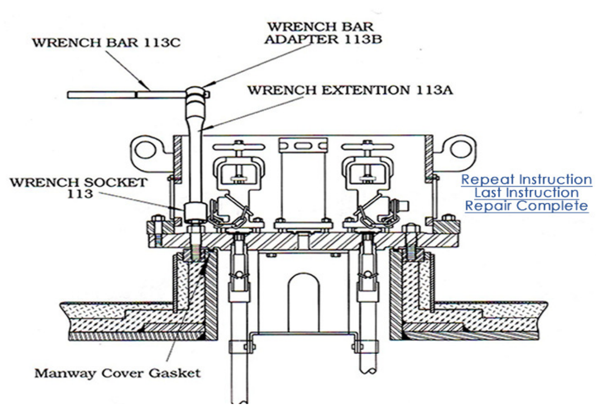

Figure 3. Manway Cover Gasket: Instruction Three

As the user progresses to more instructions, a new speech command (Previous Instruction) is added allowing the user to return to the previous command. This is shown in Figure 3, the third instruction for the manway cover gasket.

Another aspect to note in Figure 5 is that there is no longer a command (Next Instruction) for the manway cover gasket instruction set; instead, only three instructions options are given. The user only has the option to repeat previous commands or finish the repair ;this description excludes the Repeat Instruction. The transition through the example given for the manway cover gasket instruction set defines the standard use for all instruction sets.

Hierarchy Chart

The hierarchy chart shown in Figure 4 details the six instruction sets available and the transition from identifying the source of the leak to choosing the repair instructions. As can be seen, each instruction set has a variable number of instructions that call for either device 6 or device 24 assemblies. In the case of the angle valve packing instruction, it calls for a device 6 assembly .This specific process is detailed in Figures 5 and 6. The process is broken into two figures for easy viewing.

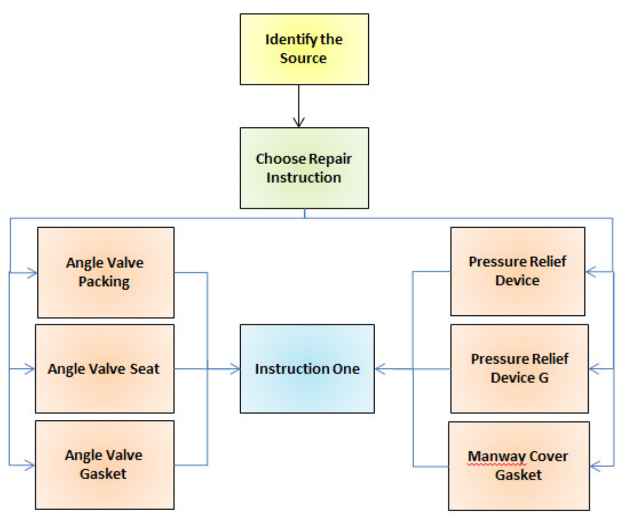

Figure 4. Hierarchy Chart (1 of 3)

For the last hierarchy chart, a discussion on inputs is not applicable. No specific inputs are passed to each function. However, a speech command can be seen as an input to the function, but this is not how they are described.

What is not shown in these charts is the button-pressed function. The button-pressed function has variables passed through it related to the speech command being called. Every function shown in the hierarchy chart has multiple button -pressed events that can occur. When a button-pressed event occurs, the parameters describing the particular button being pressed are checked through the condition of an "if" statement. The conditions are met for a particular statement if the desired call-back function is executed. For now, the functions shown in the hierarchy chart do not return any specific values. The only outputs that can be identified for each function are speech vocalization and image outputs but, again, no variables are returned as outputs.

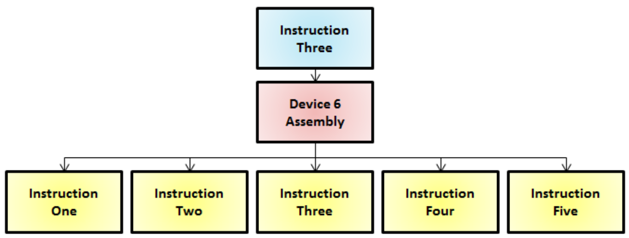

Figure 5. Hierarchy Chart (2 of 3)

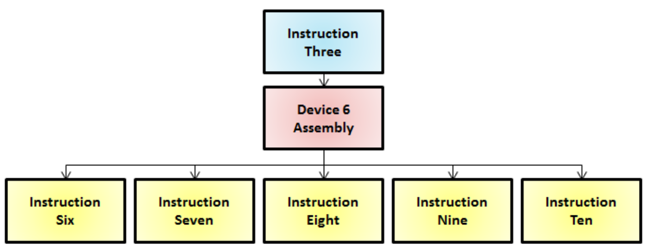

Figure 6. Hierarchy Chart (3 of 3)

Testing

Testing of the HAZHAT application has been limited to mostly functional requirements. The unit performed satisfactorily by a novice trainee to conduct a rigorous testing process using the testing documents residing on a static disk memory on the Golden-i system. One of the testing challenges had to do with the impact of wearing the oxygen mask and Golden-i unit under the HAZMAT suit. Due to a lack of physical space inside the helmet/face mask, it takes time for the trainee to get used to the new Golden-I unit. The oxygen mask changes the first-responder's voice; so it will take a few minutes for the voice recognition software to adapt to the new voice pattern. Figure 8 shows one of the students testing the Golden-i unit with the HAZMAT suit.

The team was surprised to see the DSP-based voice-recognition software work so well. The third test conducted had to determine whether or not the first responder wearing the Golden-i headset could see the miniature display through the HAZMAT face shield—the face shield is connected to the oxygen mask as a single unit. This test was a little difficult since it does require wearing the unit and "test driving" it multiple times. During the first few trials, the responder was not satisfied with the challenge of trying to read the information, which led to graphical changes in the software unit to make it more graphically user based, less text based, simpler and more enjoyable to use. Getting the first responder involved in the process of software redesign truly helped this test to be successful.

Figure 7. HAZHAT Test

The next phase of the project was focused on integration of wireless connectivity between the responder in the field and the master trainer in the main office away from the testing site. In addition to that focus, other features are being reviewed which would allow the master trainer the opportunity to watch what the responder on site is viewing at the same time.

Conclusions

For each image, it was decided that the user should have the ability to call a zoom function. The zoom function would take advantage of the shell's image viewer. When this command is called, the user would be able to use head movement to move through different sections of the image and, once a section of interest is found, the user could zoom in for a closer look. This functionality has already been created; it simply needs to be added to every instruction available. This is a time-consuming task and requires the creation of multiple functions and new speech commands.

Finally, with respect to the overall functionality that a group such as the TEEX HAZMAT group would require, is the integration of voice, video, and file transfer. The idea is that not only can an expert on the ground visually see what the user is doing, he or she would be able to talk to the user. The expert would also have the ability to send an instruction set similar to the one created in this study but for specific models of angle valves and pressure relief devices.

Acknowledgements

The authors wish to thank the Kopin Corporation and Motorola Solution Group for their equipment donation and for technical expertise, and the Texas Engineering Extension Services-HAZMAT team for their involvement and support of the senior student project on this unique initiative. Three senior electronics engineering students worked on this project as their semester class project. They are Chris Sartori, an instrumentation system engineer currently working with British Petroleum; Troy Kensinger, who is working as a software engineer for Google; and Greg Carter, who is working as a hardware engineering for Halliburton. Neither the university nor TEEX endorse any products used in this project.

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TOWARDS ROBUST LOCALIZATION OF RTK-GPS TOPOGRAPHIC SURVEYS

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Abstract

Localization is performed to fit the observed GPS positions to the local datum at the survey site. Mathematically, localization is a coordinate transformation between the GPS and local systems. When RTK techniques are used for topographic mapping, localization is crucial as it adjusts observed GPS ellipsoid elevations to the local vertical datum, thus accounting for geoid undulations. Localization uses a set of coordinates of points in both WGS-84 and the local coordinate system. Commonly, the number of points that can be used in localization depends on the size of project area and the type of the adopted GPS hardware and/or software. These points should be well distributed in the project area. One measure of the quality of localization is the maximum values of horizontal and vertical residuals, which depend on the accuracy of the GPS-derived coordinates of the points. In this paper, the authors present the requirements for robust localization and addresses some related issues.

Introduction and Background

The global positioning system (GPS), which is known as the Navigation Satellite Timing and Ranging (NAVSTAR) system, is an all-weather, day-and-night satellite-based radio navigation system initially established by the United States Department of Defense in the 1970s for military navigation applications. GPS is the principal component of the global navigation satellite system (GNSS) and provides positions at any location in terms of coordinates defined in a geocentric earth-fixed reference frame such as the International Terrestrial Reference Frame (ITRF). Other components of GNSS include the Russian GLObal NAvigation Satellite System (GLONASS) and the European GALILEO project. GLONASS is a Russian space-based navigation system comparable to the NAVSTAR GPS. GALILEO is a European initiative, which provides accurate and guaranteed global positioning services under civilian control with the new L3 civil signal. It was anticipated to be operational in 2008 [1].

The NAVSTAR system is composed of 24 to 32 medium earth orbiting satellites, which transmit signals from space on the L-band in the microwave wavelength range. The transmitted signals can be received by a GPS receiver and used to calculate the precise time and location of the receiver. GPS satellites transmit the following information to the receiver: a) approximate orbital information (known as the almanac), b) time information, and c) precise orbital information (known as the ephemeris). The receiver uses this information set to determine the distances to each satellite (known as the pseudo-range). These distances along with the satellites orbital information at the time of transmission are utilized by the receiver to determine its position [2]. The three-dimensional coordinates of the antenna position and the receiver clock error can be solved for, provided that sufficient satellites (usually more than four) are simultaneously tracked and their positions are accurately provided. The position and velocity vectors of each satellite can be acquired from the broadcast ephemerides. With longer latency, more precise ephemerides are provided by the International GPS Services (IGS). Positioning accuracy can be improved with more observations either from other satellites that are simultaneously tracked or from the same set of satellites with longer observing times.

The range from an antenna to a satellite can be obtained from two GPS observables a) pseudo ranges (from codes) and b) phase ranges. The pseudorange observable is a measure of the distance between the satellite and the receiver's antenna, referring to the epoch of emission and reception of the codes [3]. The range can be determined by multiplying the speed of light by the total travel time, which is inferred from correlating the identical pseudo-random noise (PRN) of the received codes to the receiver-generated replica. On the other hand, the range can also be expressed by the total number of waves, including the integer and the fractional parts, multiplied by the wavelength of the carrier wave [4]. The phase observable is the fractional part of the phase difference between the received wave and that of the internal receiver oscillator. The integer part of the exact number of carrier waves from each satellite to the antenna, called the initial integer ambiguity, remains unknown and needs to be solved for. The correct ambiguity solution is a key to achieve higher accuracy in the kinematic GPS positioning. It is common to use both code and phase observations, provided that the receiver is equipped with such capabilities.

Localization or site calibration is a procedure performed to fit the observed GPS positions to the local datum at the survey site. Mathematically, localization is nothing but a coordinate transformation (2D- or 3D-conformal, affine, other) between GPS-based and local systems. This transformation can be a 3-parameter (small-scale projects) or a 7-paramter transformation (large-scale projects). When RTK techniques are used for topographic mapping, site calibration of the local geoid undulations (if geoid model is loaded) is crucial because the observed GPS ellipsoid elevations need to be adjusted to the local vertical datum in order to account for geoid undulations. The existing control points only give a separation at their location. Localization normally reports residuals from the least-squares adjustment without a geoid model, unless one is loaded. In this context, there are three sources of errors: the hybrid geoid model, the user's GPS-derived ellipsoid heights, and the published orthometric heights. Consequently, the observed GPS positions would be correlated to the local coordinate system, e.g., the State Plane Coordinate System (SPCS). In order to determine accurate orthometric elevations from GPS ellipsoid elevation observations, geoid undulation must be accounted for using existing control points. In addition, the published orthometric elevations at each of the established control points may not fit exactly with the geoid model. Therefore, the GPS software must be able to adjust for both of the variations in the geoid model and in the established control benchmarks given that the GPS observations are performed between the points.

Localization uses a set of coordinates of points in both WGS-84 and the local coordinate system, and it can be performed in the field during the data-collection phase or in the office at the network-adjustment phase. Commonly, the number of points that can be used in localization depends on the size of the project area and the type of the adopted GPS hardware and/or software. The points used in this process should be well distributed in the project area. One measure of the quality of site calibration are the maximum values of horizontal and vertical residuals, which depend on the accuracy of the GPS-derived coordinates of the points.

Study Area

The size of the study area was approximately 0.75km by 0.5km, and is located near the NCAT University campus in Greensboro, NC. Figure 1 shows the location of the study area as well the initial layout of the survey stations within the study area.

Prior to the field work, a site reconnaissance was performed using standard station visibility diagrams to determine the location of obstructions near each control station. Results indicated few obstructions above the target 15º horizon. Station visibility diagrams were input into the TGO planning software in order to determine the optimal times for observing the stations. The Sky plot and the positional Dilution of Precision at the base station location in the study area are shown in Figures 2 and 3.

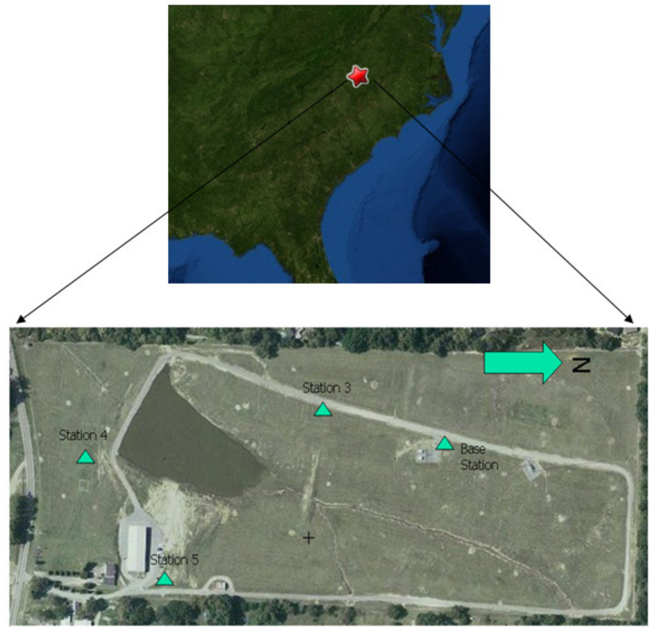

Figure 1. Study Area

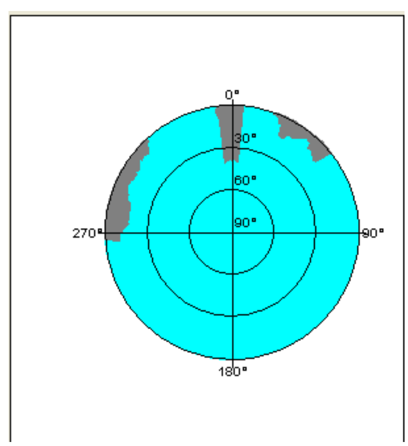

Figure 2. Sky Plot at the Location of the Base Station in the Study Area

Data Collection

The base station was placed on a fixed–height, two-meter tripod on NGS monument GRN1 A, which is a GPS horizontal First Order Class I monument with a vertical First Order Class II and an Ellipsoid order of Fourth Class II. The horizontal coordinates were established by the North Carolina Geodetic Survey in August of 2004 by GPS observations based on NAD 83(2007). The orthometric height was established by differential leveling and adjusted by Geoid09 in August, 2009. After allowing 15 minutes for the base to initialize, the station was allowed to establish a geodetic location from the satellites before starting the survey experiment.

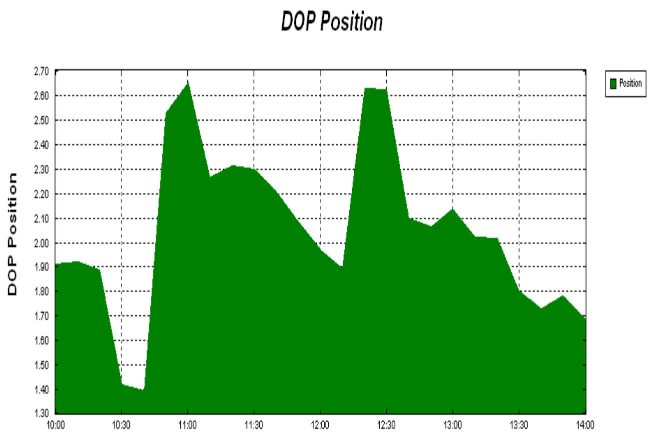

Figure 3. Positional Dilution of Precision

The three stations used for the localization are unpublished monuments that have been established by North Carolina Geodetic Survey using GPS, and the elevations were established by Geodetic differential leveling. The three stations (NCAT 3, NCAT 4 and NCAT 5) monuments are disks set in concrete, established in 2007. The experiment was broken into three different parts using 10 epochs, 25 epochs and 50 epochs of data, respectively (refer to Tables 1, 2, and 3). The rover was mounted on a two-meter, fixed-height pole with bipod and allowed to sit for approximately one minute prior to gathering data. For data collection, a Topcon Hiperlite+ unit (base and rover) was used and the processing was performed using TopSurv PC software. In the datasets shown in Tables 1, 2, and 3, the columns "Horizontal" and "Vertical" show the horizontal and vertical RMSE values, respectively, obtained for the base station and the three stations used in the study. The "US Satellites" column displays the number of NAVSTAR satellites used to estimate the positions in this study. The columns titled "Northing of the Base", "Easting of the Base", and "Elevation of the Base", show the estimated northing, easting, and elevation of the base stations along with the corresponding residuals with the rover setup at stations 1, 2, and 3, respectively. It is worth mentioning that all occupations were done with different initializations and that the calibration points were observed for at least three minutes using stable setups (i.e., bipod).

Table 1. Dataset 1 (10 epochs)

Base Station	PDOP	Horizontal	Veritical	US Satellites	Est of Elev	Northing of Base	Easting of Base	Elevation of Base
	1.60	2.122m	3.095m	9	0.00m			
Rover @ Station 3								
	1.70	0.018m	0.020	9		257377.208	542499.438	238.829
						-0.446	1.314	0.007
Rover @ Station 4								
	1.80	0.019m	0.024	9		257376.775	542500.729	238.834
						-0.013	0.023	0.002
Rover @ Station 5								
	1.90	0.018m	0.019m	9		257376.780	542500.729	238.800
						-0.018	0.023	0.036

Table 2. Dataset 2 (25 epochs)

Base Station	PDOP	Horizontal	Veritical	US Satellites	Est of Elev	Northing of Base	Easting of Base	Elevation of Base
	2.00	2.491	3.819	8	0.00m			
Rover @ Station 3								
	1.90	0.012	0.017	7		257377.213	542499.434	238.832
						-0.451	1.318	0.004
Rover @ Station 4								
	1.80	0.022	0.029	7		257376.782	542500.732	238.834
						-0.020	0.020	0.002
Rover @ Station 5								
	2.30	0.021	0.026	6		257376.770	542500.739	238.826
						-0.008	0.013	0.010

Table 3. Dataset 3 (50 epochs)

Base Station	PDOP	Horizontal	Veritical	US Satellites	Est of Elev	Northing of Base	Easting of Base	Elevation of Base
	1.80	2.441	3.370	7	0.00m			
Rover @ Station 3								
	1.60	0.013	0.018	8		257377.209	542499.427	238.829
						-0.447	1.325	0.007
Rover @ Station 4								
	1.60	0.020	0.026	9		257376.779	542500.717	238.826
						-0.017	0.035	0.010
Rover @ Station 5								
	1.90	0.021	0.025	8		257376.733	542500.731	238.844
						0.029	0.021	-0.008

Results and Discussion

It was evident in this study that the quality of localization was affected by the accuracy and consistency of the GPS coordinates of the control points. The results show that the residual in the horizontal coordinates were larger than that in the vertical coordinates. This was evident in Figures 4 through 9, which show that the residual in the easting and northing were relatively large for the three epochs of data collection. It was also noticed that: a) for small- to medium-size topographic surveys projects, using three horizontal and four vertical points for site calibration seemed optimal, given that the points should be well distributed within the project area; and, b) connecting the survey with existing control resulted in a refined localization model. The mathematics of localization suggests that there is a need to consider the geometric distribution of the control points within the project area. Furthermore, any systematic error in the control will translate into the localization, further compounding the geometric distribution problem as well.

Figure 4. Plot of the Residuals in Computed Values of Northing, Easting, and Elevation of Base Station (Dataset 1–10 epochs)

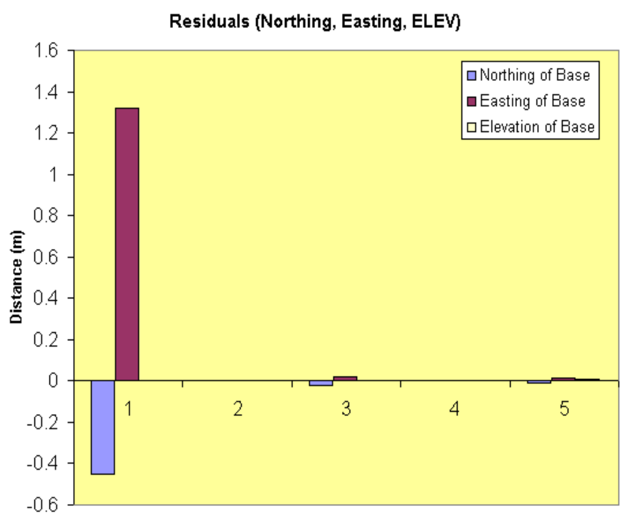

Figure 5. Plot of the Residuals in Computed Values of Northing, Easting, and Elevation of Base Station (Dataset 2–25 epochs)

In this study, the difference between the easting and northing computed for the base station was reasonable for all but that from Station 3 in all of the three experiments. The cause of this big residual difference remains unknown, but because the three stations used in this study are unpublished monuments that have been established by North Carolina Geodetic Survey in 2007, it was suspected that the monument of Station 3, which is a disk set in concrete, might have moved from its position.

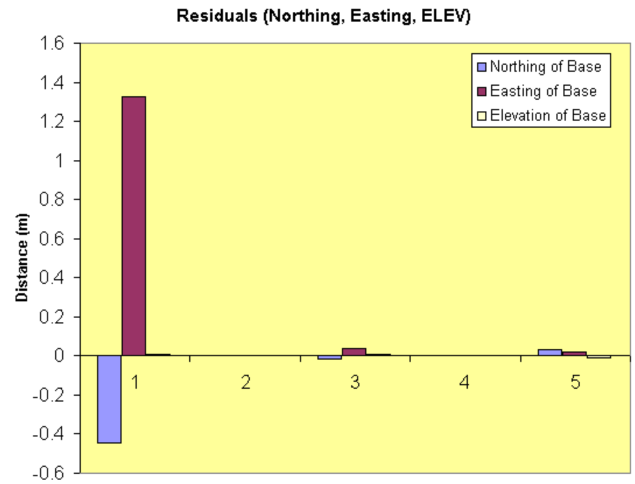

Figure 6. Plot of the Residuals in Computed Values of Northing, Easting, and Elevation of Base Station (Dataset 3–50 epochs)

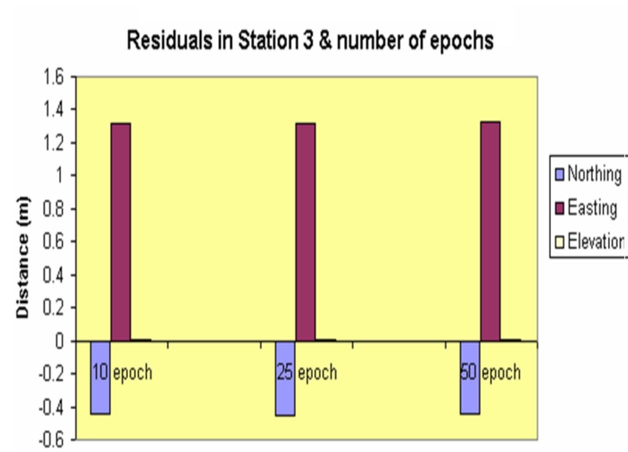

Figure 7. Plot of the Residuals in Computed Values of Northing, Easting, and Elevation of Station 3 (NCAT 3)

From this experiment the authors could not arrive at an ideal time for RTK control point observations; however, they did find that there is a need to have redundant observations with probably a minimum separation and a few independent RTK initializations. Recommendations from practicing surveyors suggest 2 to 4 hours, but no scientific ground to support that could be found. It is worth mentioning that the authors used existing published control points and assumed that they were network relative and consistent. In other words, the authors could not validate the control independently; rather they used it assuming that it was correct.

It is essential that the GPS software be capable of compensating for the variations in the geoid model and the variations in the established control benchmarks [5]. In order to accomplish this, GPS observations need to be connected between fixed benchmarks; specifically, vertical control points. In summary, localization is seemingly easy when you first approach it but, as you execute it, it quickly becomes complicated. Some surveyors suggest the use of more robust geodetic methods of data evaluation and not use localizations at all, excluding the most rudimentary tasks like searching for site control initially followed always by a more robust evaluation of the data.

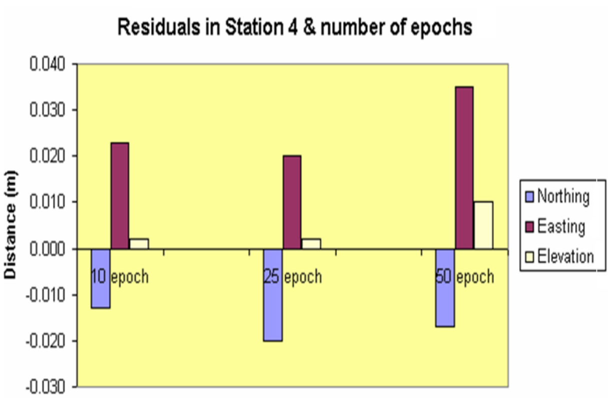

Figure 8. Plot of the Residuals in Computed Values of Northing, Easting, and Elevation of Station 4 (NCAT 4)

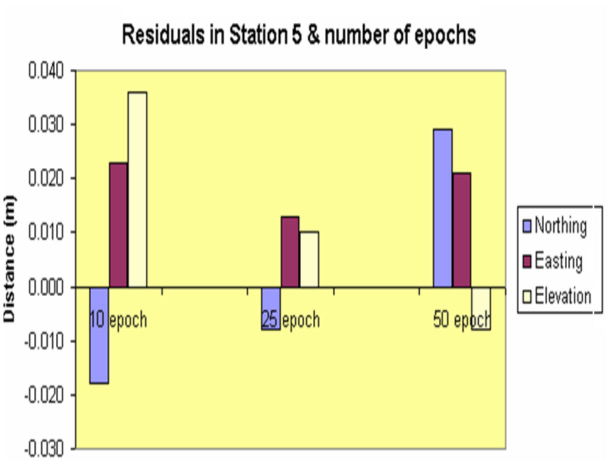

Figure 9. Plot of the Residuals in Computed Values of Northing, Easting, and Elevation of Station 5 (NCAT 5)

Summary

The quality of localization is affected by the accuracy and consistency of the observations and the GPS coordinates of the control points. Based on this study, it seems that the largest residuals are the planar, while the vertical remained at a minimum. For small- to medium-size topographic survey projects, using three horizontal and four vertical points for site calibration seems optimal, given that the points are well distributed within the project area. GPS software must be able to compensate for a) the variations in the geoid model and b) the variations in the established control benchmarks. In order to accomplish this, GPS observations need to be connected between fixed benchmarks (vertical control points).

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Biographies

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PERFORMANCE COMPARISON OF TRICKLING FILTER MEDIA FOR A MUNICIPAL WASTEWATER TREATMENT FACILITY

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Abstract

Proper treatment of a municipality's wastewater is an important part of any successful society. This work is part of an on-going research opportunity for undergraduate engineering technology students as part of an independent research course. Students participating in this applied research opportunity gain real-world experience with green projects. This project focused on the use of two media types in the existing trickling filters at a 1.04MGD wastewater treatment facility. Data were collected by undergraduate engineering technology students from the monthly discharge monitoring reports and then analyzed and evaluated to assess the difference in final total ammonia nitrogen effluent levels at the point of discharge. Preliminary data suggest that upgrading to the new cross-flow media in one of the existing trickling filters may provide additional reduction in the total ammonia nitrogen effluent levels.

Introduction

As part of an on-going effort by the School of Engineering Technology at Youngstown State University to provide an opportunity for undergraduate engineering technology students, the authors developed a plan for the students to work with faculty on an applied research project. Students taking ENTC 4895 Independent Engineering Technology Projects learn to integrate theory and practice through a supervised research experience. Students are involved in project formulation, field and laboratory research, quantitative methods for the collection, analysis, and interpretation of research data, and the culmination of the project with the preparation of a written report and an oral presentation at a national or regional meeting or at the university's QUEST – a forum for student scholarship held each spring semester.

The introduction of applied research opportunities for undergraduate students presents unique challenges in the implementation and coordination of the project [1-3]. A 2002 study [4] indicates that educational institutions continue to face challenges in the implementation of undergraduate research opportunities into the undergraduate curriculum.

Project Overview

Trickling filter systems for a wastewater treatment facility can be an efficient filtration method to remove pathogens from wastewater. Typical trickling filter systems rely on a biofilm consisting of living mixed microbial cultures that attach to solid materials in a fixed environment and consume toxins in the wastewater [5]. A larger surface area, allowing for greater contact time along with the presence of oxygen, creates favorable conditions for biofilm growth. The type of filtration media used for biofilm growth can influence the total ammonia-nitrogen effluent levels, which is the main focus of this study.

Nitrogen plays an important role in the structure and make-up of all living organisms. In the aquatic environment, nitrogen exists in the inorganic forms of nitrate, nitrite, ammonia, and nitrogen gas, in addition to many forms of organic nitrogen [6]. Aqueous ammonia can be toxic to fish and other aquatic organisms at relatively low concentrations. Therefore, ammonia must somehow be controlled, converted to a non-toxic form, or removed from the wastewater.

This study focused on an existing Municipal Wastewater Treatment Plant's (WWTP) efforts to upgrade their plant processes in order to maintain compliance with the ammonia nitrogen effluent limitations in the National Pollutant Discharge Elimination System (NPDES) permit. The WWTP has periodically failed to meet certain organic and hydraulic effluent limits set forth in the existing NPDES permit. A new NPDES permit has been issued for the WWTP with more stringent effluent limits which require multiple plant modifications. The initial plant modification involved the installation of new trickling filter media in one of the two existing tricking filters. In June, 2010, rock media was replaced with a new 60º cross-flow media, and was fully functional by October, 2010. Data were collected from the WWTP's Discharge Monitoring Reports (DMRs) and used to identify the impact the new cross-flow media had on the total ammonia-nitrogen concentration levels in the effluent.

Plant Description and Process Modifications

The existing WWTP (see Figure 1) is a secondary treatment plant utilizing the trickling filter process and permitted to process 1.04 million gallons per day (MGD) with an average daily flow of 0.6 MGD.

The WWTP's existing Biological Treatment Process begins with sewage flow from the main interceptor line into the headworks of the WWTP. The sewage influent then passes through the comminutor and primary screening units and into a splitter box before being distributed into the two primary clarifiers. Effluent from the primary clarifiers is then distributed (via a splitter box) into the two trickling filters, which are operated in parallel.

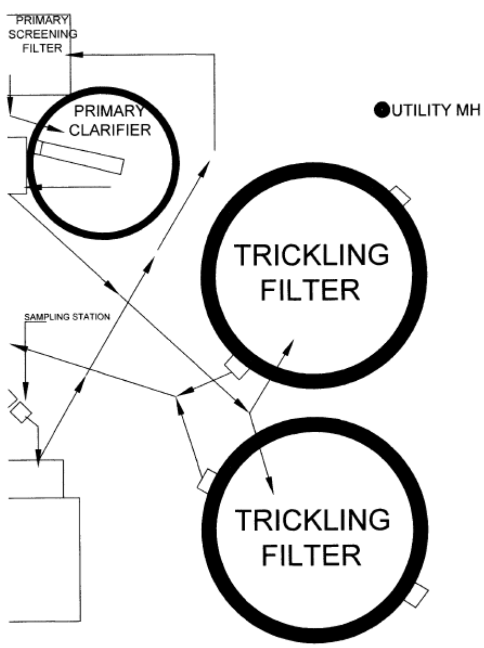

Figure 1. Trickling Filter Schematic and Flow Path

Effluent from the trickling filters is split into two waste streams, one of which is discharged to the secondary wet well with the second being sent to the raw sewage wet well to be recycled. Trickling filter effluent is pumped from the secondary wet well into final clarifiers. Effluent from the final clarifiers then proceeds to the chlorine contact tank for disinfection and discharge into the receiving stream. Sludge from both the primary and final clarifiers is then pumped to the anaerobic digester. Finally, the digested sludge is pumped from the anaerobic digester to the sludge drying beds and then to a landfill.

This WWTP requires plant process modifications to address the permit violations and more stringent parameters set in the updated NPDES permit following the Clean Water Act of 1977 [7]. More specifically, these new limitations are made effective August 1, 2010, for total Residual Chlorine and July 1, 2013, for total Ammonia-Nitrogen. The reduction in total ammonia-nitrogen can be seen in Tables 1a and 1b.

Table 1a. Ammonia-Nitrogen Permit Levels

August 1, 2010-June 30, 2013			
	NPDES Effluent Limitations		
	Mass Units (lbs/day)	Concentrations (mg/L)	
Discharge Parameter	Average Monthly	Average Monthly	Instantaneous Maximum
Ammonia-Nitrogen			
05/01-10/31	41	5	10
11/01-04/30	124	15	30

Table 1b. Ammonia-Nitrogen Permit Levels

July 1, 2013-July 31, 2015			
	NPDES Effluent Limitations		
	Mass Units (lbs/day)	Concentrations (mg/L)	
Discharge Parameter	Average Monthly	Average Monthly	Instantaneous Maximum
Ammonia-Nitrogen			
05/01-10/31	37	4	8
11/01-04/30	110	12	24

In June of 2010, the trickling filter containing rock media was temporarily shut down, the rock media removed, and replaced by 60º cross-flow media. Combining high surface area with maximum mixing/redistribution points per unit volume of media, cross-flow media facilitates superior process performance in the treatment of wastewater. Each sheet in a module is completely corrugated at a 60° angle from horizontal and assembled in a cross-corrugated pattern with adjacent sheets, creating a minimum 95% void-to-volume ratio. The modules are fabricated from rigid, non-flammable PVC sheets, which are UV-protected, resistant to rot, fungi, bacteria, acids, and alkalis commonly present in municipal wastewater [8]. The new cross-flow media replaced an existing rock media which had a minimum 50% void-to-volume ratio. The second trickling filter contained the random-dump (plastic) media that has a 95% volume-to-void ratio [9].

After the rock media was removed, a one-foot riser was installed off of the base of the tank to prevent clogging and to allow for greater oxygen circulation. The cross-flow media was assembled in modules and cut to fill the remaining tank volume, after which a grate was placed on the uppermost layer to protect the media. Installation can be seen in Figure 2. The project was completed in October, 2010, after the initial seeding acclamation period; the new trickling filter media was then fully operational.

Figure 2. Cross Flow Installation

Analysis

The existing WWTP had trouble meeting the total ammonia-nitrogen effluent limitations of the NPDES permit, particularly during the dry season (May 1 – October 31). The DMR's ammonia-nitrogen monthly averages for trickling filters utilizing rock- and random-dump media were 8.80mg/L for the dry season and 9.14mg/L for the wet season (see Table 2).

Table 2. Media Comparison Results

Media Comparison Results	Rock and Dump Media		Dump Media		Dump and Cross Flow	
	Avg	Med	Avg	Med	Avg	Med
Ammonia-Nitrogen						
5/01-10/31	8.80	8.69	12.05	13.00	N/A	N/A
11/01-04/30	9.14	9.14	N/A	N/A	7.78	7.35

The NPDES permit levels during the dry season were 5 and 15mg/L, respectively (see Table 1a). During the months when the WWTP only operated with only one trickling filter containing the random-dump media, the data revealed a spike in ammonia-nitrogen concentrations, as can be seen in Figure 3 for September, 2010. After the new cross-flow media was installed in the second trickling filter and put back into operation, the spike in total ammonia-nitrogen levels continued as the new cross-flow filter media was seeded, allowing the biofilm to grow and mature on the media. Figure 3 displays the actual total ammonia-nitrogen monthly averages along with the permitted levels. Table 2 summarizes the DMR's monthly averages for the various combinations of trickling filter media utilized during this research project. As indicated in Figure 3, this study was limited to a comparison of the data for the wet season (11/01–04/30) based on limited data available on the performance of the trickling-filter media combination of one filter with random-dump media and one filter with the cross-flow media.

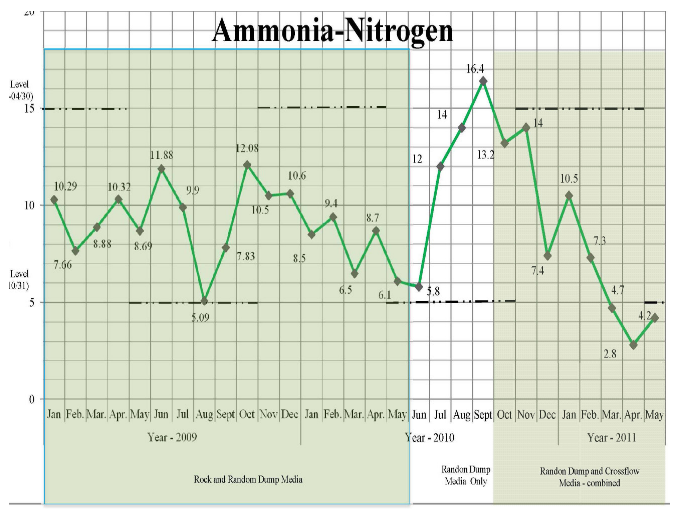

Figure 3. Actual Ammonia-Nitrogen Effluent Levels

From January 2009 through May 2010, there were two trickling filters in operation, one with rock media and one with random-dump media. The average total ammonia-nitrogen concentration for the wet season was 9.14mg/L (see Table 2). From June 2010 through September 2010, there was only one trickling filter in service which had the random-dump media only. The total ammonia-nitrogen concentrations during the dry season (5/01–10/31) averaged 12.05mg/L (see Table 2). From October 2010 through April 2011, both trickling filters were in operation with one filter with random-dump media and one filter with cross-flow media. The total ammonia-nitrogen effluent concentration during the wet season (based on available data) was 7.78mg/L (see Table 2).

The data suggest that the new WWTP process with the two trickling filters, one with random-dump media, and one with cross-flow media, had reduced the average monthly total ammonia-nitrogen effluent concentration from 9.19mg/L to 7.78mg/L.

Summary and Conclusions

This research project provided an opportunity for two senior-level undergraduate Civil and Construction Engineering Technology students to evaluate an existing WWTP, collect and analyze data with regards to modifications to the trickling filter media, and to evaluate the impact of the flow media to address total ammonia-nitrogen effluent concentrations levels. Based upon the limited data from the upgraded trickling-filter media, they suggested that the use of the cross-flow media made a positive impact on lowering the ammonia-nitrogen effluent concentrations from the WWTP. However, additional data collection and analysis will be required to fully evaluate the impact of cross-flow media on the ammonia-nitrogen effluent concentrations.

As part of the actual WWTP evaluation, four Biological Treatment Process Alternatives were being considered for this facility. These included:

- Two-stage (Series Operation) trickling-filter process;
- Two-stage trickling-filter/moving-bed bioreactor (MBBR) process;
- Two-stage trickling-filter/ICEAS sequencing-batch reactor (SBR) process; and
- Single-stage ICEAS SBR process.

Future research will involve the evaluation and monitoring of the WWTP facility's compliance with the NPDES permit limits as upgrades and modifications are made to the facility. This future research will focus on the determination of correlation between rainfall intensity and flow rate, rainfall intensity and ammonia-nitrogen concentration, and determination of peaking factors.

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PROFESSIONAL DEVELOPMENT OPPORTUNITIES FOR ELECTRICAL ENGINEERING TECHNOLOGY EDUCATORS IN VHDL AND FPGA DESIGN

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Abstract

Hardware Description Languages (HDLs) and Field Programmable Gate Arrays (FPGAs) have revolutionized the way digital logic design is taught and implemented. Traditional ways of teaching logic design using discrete components (TTL: Transistor-Transistor Logic and CMOS: Complementary Metal Oxide Semiconductors) have been replaced by Programmable Logic Devices (PLDs), which include Complex Programmable Logic Devices (CPLDs and FPGAs). Today, a more standard development process is widely used in industry. The process uses HDLs as a design entry tool to describe digital systems. The two most widely used HDLs in industry are VHDL (Very High Speed Integrated Circuit Hardware Description Language) and Verilog (Verifying Logic). Although most traditional electrical and computer engineering programs have updated their curricula to include topics in HDL and programmable logic design (FPGA/CPLD), two-year and four-year electrical engineering technology programs have fallen behind and are moving slowly in updating their curricula. This paper presents information on two-day VHDL and FPGA workshops designed to educate faculty in electrical engineering technology as part of a National Science Foundation Advanced Technological Education grant.

Introduction

Programmable Logic Devices in general and FPGA-based re-programmable logic designs became more attractive as a design medium during the last decade and, as a result, industrial use of FPGAs in digital logic design is increasing rapidly. Due to this technology change in industry, the need for highly qualified logic designers with FPGA expertise is increasing at a fast rate. According to the United States Department of Labor, the job outlook is on the rise and will continue to expand for at least the short- to medium-term future [1]. To respond to industry's need for FPGA design skills, universities are updating their curricula with courses in HDL and programmable logic design. Although most traditional electrical and computer engineering programs have updated their curricula to include these topics, only 19.5% of 4-year and 16.5% of 2-year electrical and computer engineering technology programs at U.S. academic institutions currently have a curriculum component in HDL and programmable logic design [2-5]. Additionally, experience with traditional high-level programming languages such as C will be helpful to students wanting to learn HDLs and work with PLDs. To effectively meet the workforce needs of the next generation, electrical and computer engineering technology curricula must be current, relevant, and teach technology that is widely used in industry. To meet this goal, the authors pursued the development of a digital logic design curriculum for the EET program in the School of Technology at Michigan Tech University. Faculty involved in developing and teaching the new curriculum must be well-informed of advances in technology currently used in industry. Likewise, industry wants to have qualified and well-educated employees coming out of academia who are ready to implement their knowledge on day one of employment. As a result, while academia needs to be fully aware of the current state-of-the-art of knowledge requirements, industry must be driving the curriculum development. Therefore, in this curriculum development process, a strong link between academia and industry must be established. This partnership is a "two-way street" with advantages for both parties. The Electrical Engineering Technology (EET) program is collaborating with Altera's [6] University Program and those faculty members leading the project attended a set of training workshops developed by Altera. These workshops are targeted toward professional individuals and college faculty seeking knowledge and expertise in programmable logic design. Faculty members having the opportunity to attend these workshops, gain the knowledge and expertise needed to teach both VHDL digital Design and Programmable Logic (FPGA) design courses. Exposure to industry-taught courses can help faculty members to impact the learning experience of undergraduate students by providing them with skills that are highly marketable and appreciated by industry. This industry-led faculty training program has resulted in digital logic design curriculum development in the electrical engineering technology programs. This curriculum revision led to the addition of two new courses beyond the current course in Digital Electronics. As a result, the EET program introduced two new three-credit-hour courses: Digital Design Using VHDL and Topics in Programmable Logic. The new curriculum will provide students with a hands-on educational experience well respected by industry. The principal investigators of the project shared their knowledge and expertise in digital logic curriculum development by offering this professional development opportunity to interested faculty members at similar institutions as part of the dissemination plan.

Research Background

Historically, EET programs have included a traditional logic design course that covers topics in combinational logic and sequential logic circuits. The course is based on discrete components such as TTL and CMOS. And although these topics represent fundamental concepts in logic design and optimization theory, they are far from the most current industry practice in applied logic design. Topics that have been traditionally taught in logic design courses are outdated and less important to current employers. The time spent teaching Boolean algebra and how to minimize Boolean expressions using Boolean algebra or Karnaugh Maps (K-Maps) could be better spent teaching current and industry-relevant topics in logic design. This line of thought applies to both the design of combinational circuits and the design of sequential circuits [2]. For the curriculum to adequately meet the current needs of industry, EET programs must teach digital logic using VHDL and FPGAs [7]. Consequently, students will be equipped with design skills that are current, relevant, and widely used in industry.

Recent research supports the idea that the proposed curricular shift is industry-relevant. In one study, Furtner and Widmer [2] conducted an employer survey to rank currently taught logic design concepts at Purdue University. The survey included questions about many topics that are heavily explained in logic design courses such as Boolean algebra, design simplifications using K-Maps or Quine Mclusky, and design implementation using discrete gates. Each was given a low priority from the employer perspective. On the other hand, topics that cover designing with a hardware description language such as VHDL or Verifying Logic (Verilog) received high-priority rankings from employers [2]. There is definitely a great need for community colleges and universities to continually update their programs and resources, and provide ongoing faculty development to include the latest information about digital logic design. Additional studies [8] identify faculty development as a major concern for academic institutions and suggest faculty development through industry consulting and training. Similarly, in another study [7], researchers built an industry-academic collaborative partnership to train almost 200 faculty members with innovative teaching methodologies, which had a great impact on student learning. This industry-academia partnership helped faculty members become more active partners, mentors, and facilitators of the student learning process. Universities [9] and Community Colleges [10] need to develop such programs allowing their faculty to advance professionally. The approach described here for faculty development targets faculty members who acknowledge the need to update the digital logic design curricula at their institutions, but who do not have the time to pursue it on their own. The project's approach is to combine digital logic design best practice in industry with practical curricular planning. Participating faculty members are provided with the latest digital logic expertise using a series of educational resources and professional development sessions aimed at "educating the educator".

A recent survey was sent to the employers who hire electrical engineering technology graduates of both two-year and four-year institutions in order to assess how well this educational initiative aligns with their current and future human resource needs. This survey was designed to judge the necessity of providing the type of training identified as important. Forty organizations responded to this survey. Overwhelmingly, the survey respondents identified the ability of technicians and technologists to be able to work with FPGAs as a critical skill. Results from the assessment survey further showed that almost 80% of the respondents view knowledge of VHDL and FPGAs as a critical skill for making a technician more employable and marketable. As a result, there is a great need for training community college and university technology professors in VHDL and FPGA design in order to provide them with the latest digital logic expertise. Through the training program described here, the participating faculty members are not only getting trained on VHDL and FPGA design, but are also receiving access to curricular components that have already been developed at Michigan Tech University, learning best practices for using innovative strategies, and learning about those tools most effective for teaching digital systems design using VHDL and FPGA technologies.

Faculty Workshop Objectives

The goal of this workshop is to combine technical information from the vendor with training on practical curricular planning and strategies for developing courses like those developed at Michigan Tech University under this project. The participating faculty members learn introductory material on the impact of teaching engineering technology students relevant skills in hardware modeling and FPGA design. In subsequent sessions, the faculty members learn fundamental concepts of VHDL and gain knowledge on FPGA design environments using Altera's Quartus development software. Participants gain hands-on lab experience in modeling basic building blocks of digital systems and learning FPGA design flow from HDL design entry and circuit simulation to verifying the correctness of the design. Participating faculty members tour the Re-configurable Computing Lab and learn the hardware and software necessary to establish a re-configurable lab at their respective institutions. Michigan Tech faculty members assist participating faculty members in further development of their own curricula through a post-workshop follow-up. Curricular materials developed at Michigan Tech are made available for use by participating faculty members both during and after the workshop.

The first summer faculty workshop was offered in September, 2011. The project PIs conducted an intensive, two-day workshop on VHDL and FPGA design. There was an overwhelming positive response to the opportunity announced on the Engineering Technology Division (ETD) listserv, which forced the PI to close the registration after only two hours following the announcement. All ten seats were taken and a waiting list of 15 more participants was created. Representatives from seven institutions from six states (Indiana, Illinois, Kentucky, Pennsylvania, Virginia, and Georgia) engaged in the hands-on learning experience, working with both the software and the hardware. The workshop provided faculty members of community colleges and four-year electrical engineering technology programs with the opportunity to expand their expertise in VHDL and FPGA design. The participants will utilize their new skills gained through the workshop to develop new courses in digital logic design, using VHDL and FPGAs, at their respective institutions. The workshop participants learned how to:

- identify the importance of teaching engineering technology students relevant skills in hardware modeling and FPGA design;
- demonstrate an understanding of the fundamental concepts of hardware description languages and gain knowledge on programmable logic devices (PLDs);
- gain hands-on expertise with the hardware and software necessary to establish a re-configurable lab at their respective institutions;
- gain hands-on lab experience by practicing modeling basic building blocks of digital systems and learn FPGA design flow; and,
- develop potential curricular resources to be used at their respective institutions.

Faculty Workshop Curriculum Modules

Hands-on learning was infused into a sequence of instructional modules, as shown in Figure [1]. The first module focused on Quartus software development; the second module focused on an introduction to VHLD; and the third module focused on advanced topics in VHDL. Each module had an associated laboratory exercise to enforce the learning experience of participants. The following is a description of each module, relevant topics that are covered and expected learning outcomes. The breakdown of the workshop into three modules allowed participants to pick and choose components to match his or her learning needs. All of the laboratory exercises were conducted using the Altera® Development and Education (DE2) board, which provides an ideal vehicle for learning about digital logic, computer organization, and FPGAs. Featuring an Altera Cyclone® II FPGA, the DE2 board offers state-of-the-art technology suitable for laboratory use [6]. Altera also provides the Quartus® II development software free to universities [6]. Both DE2 FPGA evaluation boards and Quartus Development software were received as a donation from Altera Corporation.

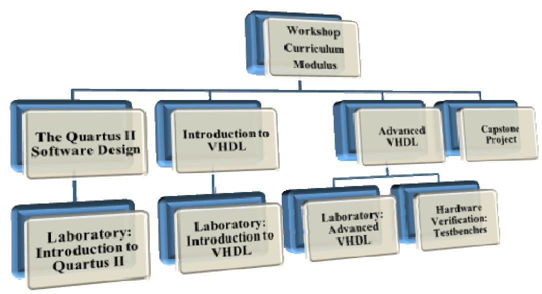

Figure 1. Workshop Curriculum Modules

The Quartus II Software Design Series

This module of the workshop provided extensive training on how to use Quartus® II development software to develop an FPGA or CPLD. Faculty members were able to create a new project, enter in new or existing design files, and compile their designs. Faculty learned how to plan and manage I/O assignments and apply timing analyses of their designs in order to achieve design goals using Quartus® II development software [6]. Additionally, faculty members learned how to constrain and analyze a design for timing using the TimeQuest timing analyzer in the Quartus® II software. This included understanding FPGA timing parameters, writing Synopsys Design Constraint (SDC) files, generating various timing reports in the TimeQuest timing analyzer, and applying this knowledge to an FPGA design. The workshop component objectives were to have class participants be able to:

- make pre-project decisions to prepare for Quartus II design;
- create, manage and compile Quartus II projects;
- use Quartus II tools to view the results of compilation;
- plan and manage device I/O assignments using Pin Planner;

- use the basics of the TimeQuest timing tool;
- review compilation results in various Quartus II software reports and graphical viewers;
- understand the TimeQuest timing analyzer timing analysis design flow;
- apply basic and complex timing constraints to an FPGA design;
- analyze an FPGA design for timing using the TimeQuest timing analyzer;
- write and manipulate SDC files for analysis and controlling the Quartus II compilation;
- use Quartus II software RTL Viewer to verify correct synthesis results;
- incorporate Altera structural blocks in VHDL designs;
- write simple testbenches for verification; and,
- create parameterized designs.

Introduction to VHDL

This module of the workshop provided an introduction to VHDL language and its use in programmable logic design. The emphasis was on the synthesis constructs of VHDL. Faculty members gained a basic understanding of VHDL. The course was laboratory intensive and included a hands-on experiment to design, test, and simulate and synthesize a basic logic circuit as part of Quartus® II development software [4]. The workshop component objectives were to have class participants be able to:

- understand simulation versus synthesis environments;
- build basic VHDL models using the VHDL design units (entity, architecture, configuration, package);
- use behavioral modeling constructs and techniques to describe logic functionality; and,
- use structural modeling constructs and techniques to create hierarchical designs.

Advanced VHDL

In this module of the workshop, faculty members learned how to write efficient coding techniques for VHDL synthesis, particularly for Altera® devices. The faculty member gained experience writing behavioral and structural code and learned how to effectively code common logic functions including registered, memory, and arithmetic functions. As part of the course topics, faculty members learned how to write testbenches to verify the functionality of the design [6]. The workshop component objectives were to have class participants be able to develop coding styles for efficient synthesis when:

- targeting device features;
- inferring logic functions;
- using arithmetic operators; or,
- writing state machines.

Hands-on Laboratories Exercises

A set of five laboratory exercises was developed. These labs consisted of an introduction to the Altera Quartus II software used to code, compile, and program the Altera DE2 FPGA Development Boards; an introduction to the basics of the VHDL language; an advanced VHDL primer; a lab focusing on testbenching a design; and, finally, a complete project to create a reaction timer using VHDL and the FPGA development board. Following is a description of each laboratory exercise.

Lab 1: Introduction to Quartus II

This lab was designed to familiarize the participants with the use of many of the common aspects of the Quartus II software through a complete design phase. Participants learn to create a new project, create a new VHDL file, use the MegaWizard Plug-In Manager, compile the design, plan and manage I/O assignments, apply a timing analysis using the TimeQuest Timing Analyzer, write Synopsys Design Constraint (SDC) files, and program a design onto the Altera DE2 FPGA Development Board. Specifically, in this laboratory exercise the participants create a new project, name it, and learn all of the appropriate project settings for using the Altera DE2 FPGA Development Board. Then, they create a new VHDL file and paste the VHDL code provided to them in order to create the top-level design entity for this circuit. Next, the MegaWizard Plug-In Manager is used to create a four-bit, three-by-one multiplexer component. The appropriate pins are then assigned to the inputs and outputs of the design. Basic use of the TimeQuest Timing Analyzer is then shown including: creating a timing netlist, setting timing constraints, adding SDC files, editing SDC files, and running the timing analyzer. Finally, the circuit created is programmed to the Altera DE2 FPGA Development Board and the participants work the switches and see the multiplexer in action.

Lab 2: Introduction to VHDL

This laboratory exercise is used as an introduction to the VHDL language including entity declaration, process statements, behavioral coding, structural coding, port mapping, component declaration, and signals, among others. There is a lot to learning any programming language, but the authors found that the best teaching approach for VHDL is through clear and concise examples. The goal of creating this laboratory exercise was that the participant should be exposed to a wide variety of programming styles and techniques in order to form a solid foundation to build upon later. If the participants were simply asked to write their own code in the exercise based upon what they learned from the lecture portion of the workshop, they would have no way of knowing if the code they wrote was well written or even standard practice. Instead, this laboratory exercise manual acts as a compendium of basic VHDL programming styles and techniques that can be referenced at a later date in order to employ correct usage and syntax. For this laboratory exercise, the participant creates a ripple-carry four-bit full adder/subtractor. This circuit is made up of a number of smaller design elements including: exclusive OR logic gates, two-input AND gates, and three-input OR gates. These are arranged to create four one-bit full adders with the ability to add the two's compliment of one of the numbers (subtraction) if desired. The participant is also instructed on how to simulate inputs and outputs to the circuit using a Vector Waveform File (vwf) including using both Functional and Timing simulator modes. In the end, the project is programmed to the Altera DE2 FPGA Development Board and the participants can physically interact with their ripple-carry four-bit full adder/subtractor.

Lab 3: Advanced VHDL

This laboratory exercise was created after reviewing the Altera laboratory manual titled Advanced VHDL Design Techniques. Using Altera's materials as a reference, the topics were selected to be suited to an advanced VHDL laboratory exercise. The topics include: operator balancing, resource sharing, preventing unwanted latches, pipelining, and state machine encoding schemes. These advanced VHDL techniques are used to improve the speed and efficiency of the code and its implementation on the hardware. In this laboratory exercise the participants create two separate designs and use them to demonstrate the varying advanced VHDL techniques. The first design is a multiplier that demonstrates operator balancing and resource sharing. First, the code is compiled and analyzed as-is. The maximum specified clock speed is recorded for the design using the Timing Analyzer Summary, and use of the Register Transfer Level (RTL) viewer is introduced to observe the number of multipliers used in the design. Resource sharing is introduced by using parenthesis to group mathematical operations. Once recompiled, the participant can see the effect that this technique has on increasing the maximum available clock speed and by reducing the number of components necessary. Next, the code is modified to make use of pipelining, by using temporary registers, which increases the maximum available clock speed again. The second design used in this laboratory exercise is then created and compiled. This code first demonstrates creating unintentional latches by not properly setting up the state machine. The State Machine Viewer is then introduced as a tool used to visually identify state machine operation or problems. Then, different state machine encoding schemes are used to illustrate how they affect the maximum clock speed of the design. The various encoding schemes used for demonstration are One-Hot Encoding, Minimum Bits, Gray Encoding, Johnson Encoding, and Sequential Encoding.

Lab 4: Testbenching

This laboratory exercise uses Mentor Graphics ModelSim software [11] integrated with Altera Quartus software. In this exercise a circuit design is loaded, a testbench code is written, and signal waveform graphs are generated. The circuit design used in this exercise is the full adder/subtractor circuit from Lab 2: Introduction to VHDL. The participants then copy and paste the testbench code provided into the file they created from the beginning steps of this exercise. The circuit and its inputs are then simulated and the participants are instructed on how to view the resulting waveforms efficiently. The testbench file is then edited to test other input conditions and the results are viewed after simulation.

Lab 5: Capstone Project

This lab acts as a capstone to the entire VHDL and FPGA Design Workshop. This integrating experience develops participant competencies in applying VHDL and FPGA technical skills in solving a design problem. It covers various topics previously discussed and adds even more advanced techniques and algorithms. It gives a good real-world application of what can be accomplished with FPGAs.

Assessment

Assessment is a vital part of any curriculum reform project and helps provide useful information for workshop enhancements and determining if the workshop has met its objectives. Formative evaluation occurred during workshop delivery and was used to make adjustments for subsequent workshop offerings. Embedded assessment was used to measure each workshop objective and determine whether goals were met. Assessment of the effectiveness of the faculty workshop training sessions offered was conducted anonymously using pre- and post-surveys. Assessment data collected and analyzed from the workshop will be used for continuous improvement actions to be implemented in year-two faculty workshops. The authors used a pre-test/post-test design and pre-survey/post-survey employing both direct and indirect measures of student learning. The indirect assessment instrument also included questions about participants' satisfaction, while the direct assessment instrument included a set of small design problems and multiple-choices problems.

Direct Measures of Student Learning

Participants were given the same instruments for the pre-test and for the post-test. The average on the pretest was 40% correct answers. On the post-test, following the two days of instruction, the average on the test rose to 72% correct answers. It is clear that these participants made substantial progress towards mastering course concepts during the two-day workshop.

Indirect Measures of Student Learning

Participants were given the indirect measure instrument prior to the beginning of instruction. The only relevant pre-test portion (Mastery of Course Outcomes) yielded the following scores on a five-point scale with 5 indicating "Complete Mastery" and 1 indicating "No Mastery".

Table 1. Quality of Instruction Participants' Feedback Assessment Results

Quality of Instruction (5= Strongly Agree, 1=Strongly Disagree) Measurable Outcomes	**Post-Test Overall Rate**
The instruction was clearly presented	4.86
Any questions I asked were	4.71
The materials provided helped me to learn	4.86
The pace of the course was appropriate for	4.57

Table 2. Introduction to VHDL Participants' Feedback Assessment Results

Introduction to VHDL (5= Strongly Agree, 1=Strongly Disagree) Measurable Outcomes	**Pre-Test Overall Rate**	**Post-Test Overall Rate**
Ability to implement basic	2.57	4.71
Ability to implement	1.86	4.57
Ability to use software tools to	2.57	4.57

It is clear from these results that participants made substantial progress towards achieving course outcomes as a result of the instruction. This conclusion is supported by both direct and indirect measures. It is also clear that these participants valued the quality of the instruction.

Table 3. Advanced VHDL Participants' Feedback Assessment Results

Advanced VHDL Design Technique Learning Objectives (5= Strongly Agree, 1=Strongly Disagree) Measurable Outcomes	**Post-Test Overall Rate**
Write synthesizable VHDL	4.43
Control state machine implementation	4.57
Optimize a system design, using	4.29
Create a test bench and run a simulation	4.71

Table 4. Quartus II Software Design Participants' Feedback Assessment Results

Quartus II Software Design Series: Foundation Learning Objectives (5= Strongly Agree, 1=Strongly Disagree) Measurable Outcomes	**Post-Test Overall Rate**
Create a new Quartus II project	4.86
Create design components using	4.71
Compile a design and view results	4.86
Use settings and assignments to	4.71
Make pin assignments and evaluate	4.71
Use the TimeQuest timing analyzer	4.71

Conclusion

In this paper, the authors present the findings related to the offering of a two-day VHDL and FPGA design workshop for electrical engineering technology faculty as part of National Science Foundation Advanced Technological Education grant. Curricular resources and workshop materials were made available to faculty in other electrical and computer engineering technology programs. The educational materials were shared directly with participating faculty who attended the workshops and made available electronically through a project website. This professional development activity provided both two-year and four-year electrical engineering technology faculty with the pedagogical and subject-matter knowledge, digital teaching tools, and teaching strategies to attract and effectively prepare students for STEM careers in reconfigurable electronics and other advanced electronics fields. For the United States to remain competitive in electronics technology, universities and community colleges need to continually update programs and facility resources, and provide ongoing faculty development to include the latest information about reconfigurable systems. There was an overwhelming positive response to the opportunity announced on the Engineering Technology Division (ETD) listserv, which forced the study's principal investigator to close the registration after only two hours following the announcement, since all seats were taken. Assessment results showed that participants made substantial progress towards achieving course outcomes as a result of the instruction using both direct and indirect measures. Additionally, workshop participants valued the quality of the instruction, grading the quality of instruction at 4.86 on a 5-point scale.

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DEMONSTRATION OF THE DESIGN OF A FIRST-STAGE AXIAL-FLOW COMPRESSOR BLADE USING SOLID MODELING THROUGH A CLASSROOM PROJECT

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Abstract

This paper presents a classroom project to design and analyze a first-stage axial-flow compressor blade using performance analysis, blade design, and solid modeling tools. Step-by-step instructions were used to provide a sample blade design project template. The first step of the design project was to conduct a parametric design-point performance analysis of the axial-flow compressor of a single-spool gas turbine engine to produce 12,500N of thrust at sea level. A performance analysis suggested that an axial-flow compressor with a pressure ratio of 6 and a mass flow rate of 38.7kg/s was required. The second step of the design project was to evaluate the compressor design using a simplified design tool. An initial six-stage constant mean radius axial-flow compressor was adopted. The Compressor Preliminary Analysis Program (COMPR) software package was used to calculate the blade profiles and flow angles for the rotor and stator of each stage at different radial based on a free-vortex design. The third step of the design project was to conduct a three-dimensional CAD design of the first-stage rotor blade using SolidWorks based on the blade profiles obtained in the second step. The fourth step of the design project was to conduct a stress analysis on the assembled first-stage rotor with 1508 rad/s rotation using ANSYS. Results indicated that for the initial design configuration, the maximum principle stress inside the blade exceeded the material limits for rotational speed of 1508 rad/s. As a result, the rotational speed of the first-stage rotor was reduced to 1370 rad/s. This reduced the total pressure ratio for the first stage and it was calculated that 7 stages of an axial-flow compressor would be needed to meet the design specifications. This paper provides a template for designing the first-stage compressor blade with emphasis on application of solid modeling using Solid Works and ANSYS.

Introduction

According to the Accreditation Board for Engineering and technology (ABET) requirements [1], all mechanical engineering students should be able "to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability". Students also should be able to "use the techniques, skills, and modern engineering tools necessary for engineering practice". One way to teach design and analysis is to do classroom projects using solid-modeling tools such as, but not limited to, SolidWorks [2] and ANSYS [3]. Design of an axial-flow compressor's first-stage blade provided a good teaching example in solid modeling.

Axial-flow compressors are used in medium- to large-thrust gas turbine jet engines. The compressor rotates at very high speeds, adding energy to the airflow while at the same time compressing it into a smaller space. The design of axial-flow compressors for aircraft engines is a great challenge, both aerodynamically and mechanically [4]. Obtaining a high temperature rise in a stage is desirable to minimize the number of stages for a given overall compressor ratio. High blade rotational speeds, high axial air velocity, and high fluid deflection in the rotor blade will produce a high temperature rise in a single-stage compressor [5] and, in turn, produce higher compressor pressure ratios and performance for gas turbine engines. However, these factors were limited by blade material, structural stress, and aerodynamic load. For example, the first-stage compressor blade normally has large blade height and experiences large centrifugal stress due to its high speed of rotation. It also experiences high aerodynamic loads from high axial velocity. The design of the first-stage compressor blade requires solid modeling with the capability of structural and thermal analysis.

One of the senior mechanical engineering classes, ME 412-Analysis and Synthesis of Gas Turbine Engines and Components, taught at Alabama A&M University, is designed to provide students with a basic working knowledge of aerothermodynamics of gas turbine engine propulsion with a focus on component performance characterization and compressor and turbine design. Students are required to analyze on- and off-design performance and to characterize the operation of gas turbine engine propulsion systems and components. At the end of the one-semester course, students are required to complete a semester classroom project to design and analyze a first-stage compressor blade. Over the years, it has been found that students entering gas-turbine theory class did not have enough training in solid modeling and analysis. In order to complete the design process, it was necessary to spend a significant amount of time teaching the prerequisite materials such as using SolidWorks and ANSYS to conduct solid modeling. However, the goal of the gas-turbine theory class was to learn engine performance and compressor design. A significant amount of time should be spent on performance prediction and design analysis. It was necessary to develop a sample project template to conduct solid modeling and analysis so that learning efficiency could be improved.

The scope of this study was to provide students with a quick and handy sample project template to conduct first-stage compressor blade design using SolidWorks and ANSYS tools. The sample project could be extended to provide a quick tutorial reference for other solid-modeling and analysis applications throughout the mechanical engineering curriculum.

Classroom Project Definition

The ME 412 classroom semester design project was to design a first-stage compressor blade of an axial-flow compressor for a low-cost turbojet engine to deliver 12,500N of take-off thrust at sea level. For the first step of the design, students were required to conduct a gas-turbine engine parametric performance prediction (cycle analysis) and select engine component design parameters using the well-known software PERF [6]. PERF is a user-friendly program for calculating the variation in an engine's performance with changes in flight condition and throttle. The theoretical background of engine performance prediction, PERF, is described by Mattingly [7]. For the second step of the design, students were required to use COMPR software [8], apply the constant tip radius design, calculate the mass flow rate, number of stages, stage and overall pressure ratio, hub and tip radius of each stage, and mean radius flow angle for each stage. Hub and tip flow angles and reaction for each stage were analyzed based on the free-vortex velocity distribution. Students were also required to sketch flow path areas and radii for all stages. COMPR is a multistage axial-flow compressor design. This program calculates the mean-line design of multistage axial-flow compressors. Blade geometry and profiles were calculated based on axial-flow compressor analysis in Elements of Gas Turbine Propulsion [7]. COMPR can analyze the three fundamental types of mean-line design: constant hub radius, constant mean radius, and constant tip radius. Each of these designs can be analyzed using the user-selected swirl velocity distribution including free vortex, exponential, and first power. For the third step of the design, students were required to use SolidWorks and ANSYS to complete the first-stage three-dimensional blade design and rotational structural stress analysis.

Blade Design and Analysis

Preliminary cycle analysis on performance calculations using PERF indicated that a single–spool, all-axial arrangement was satisfactory for providing the required engine performance. The compressor pressure ratio was 8 and the turbine inlet temperature was 1200K. The design conditions were P=1.01bar and T=288K. Assume the absolute velocity entering the first-stage rotor has a zero-degree angle (Alpha Angle) with the axis, the axial velocity entering the first-stage rotor would be 150m/s, and assume the rotational speed N=240 rev/sec. Further assume that the hub-to-tip ratio for the first-stage rotor is 0.5, the mean radius for the first-stage rotor is 18cm, the work done factor is λ=0.93 for each stage, and the polytropic efficiency of the compressor is 0.90.

Starting from the preliminary analysis results, the design and analysis of the first-stage compressor blade is divided into four steps: 1) Apply the gas-turbine engine performance analysis tool, PERF, to refine parametric studies of engine components and obtain critical design-point performance parameters for an axial-flow compressor; 2) Recalculate the required number of stages And conduct compressor design using COMPR, obtain blade geometry and three-dimensional blade profiles; 3) Conduct solid modeling using SolidWorks to construct a three-dimensional blade for the first stage of the compressor based on blade profiles; 4) Conduct a stress analysis using ANSYS for the blade design, then modify and improve design parameters in step 1 according to the results of the structural analysis to complete the design.

<u>Step #1</u>: Refine/reselect design-point thrust and performance calculations using the gas turbine engine performance analysis tool, PERF, compressor parametric studies were conducted. Choosing the design parameters listed in Table 1, a performance calculation was conducted, as shown in Figures 1(a) and 1(b). The goal was to reach a thrust of 12,500N at sea level.

<u>Step #2</u>: Obtain first-stage blade profiles using the simplified version of the compressor design package, COMPR, conduct the compressor-blade profile design using COMPR based on the design-point analysis results obtained in the performance prediction.

1. Open the program Compressor Preliminary Analysis Program (COMPR) in Figure 2.

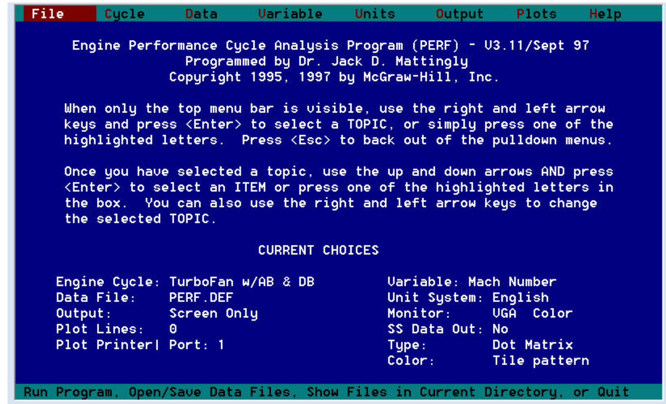
Table 1. Design Point Parametric Analysis Using the Performance Calculation Tool

Mass flow rate	16.99kg/s
Number of stages	7
Overall pressure ratio	8.0
Turbine inlet temperature	1200K
Design Point Ambient Pressure *Pa*	101,000 Pa
Design Point Ambient Temperature *Ta*	288K
First Stage Hub radius	r_h= 0.12m
First Stage Mean radius	r_m= 0.18m
First Stage Tip radius	r_t= 0.24m
First Stage Hub/Tip	0.5
Height of First Stage Blade	120mm
Chord of hub, mean, tip	49.2mm
First Stage Rotor angular velocity	1508 rad/s
Polytropic efficiency of the compressor	0.9
Work done factor	λ= 0.93
Axial velocity	150m/s
Absolute velocity axial angle	0°
Thrust	12,500N

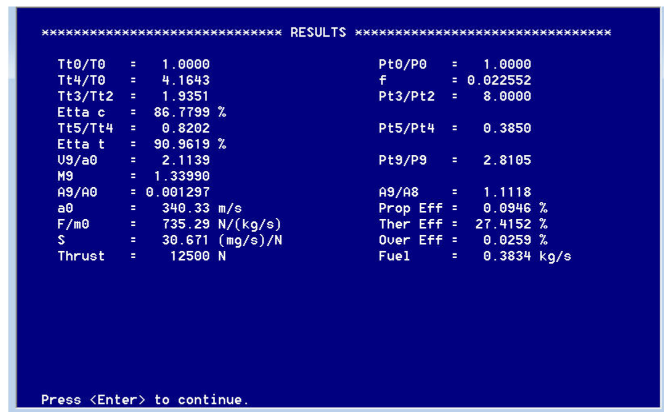
2. In the design-type section on the front screen of the program, select that it is a mean radius design. Ensure that the unit system is in metric by selecting SI Metric.

3. In the View/Edit Data section select initial. Once in Initial, change the data areas to number of stages to 6, mass flow rate to 17 kg/sec, Rotor Angular Velocity to 1508 rad/sec, and Alpha 3 for last stage to 0, as in Figure 3.

4. After ensuring that the initial conditions are correct, close the Initial Data window and return to the front screen of the COMPR Program. On the front screen, select the Perform Calculations button. A Constant Mean Radius Design window will appear; input the desired tip radius of 0.24 meters and click OK, as in Figure 4.



a) PERF Software Interface



b) PERF Results Window

Figure 1. The Graphical Interface Using Performance the Calculation Package

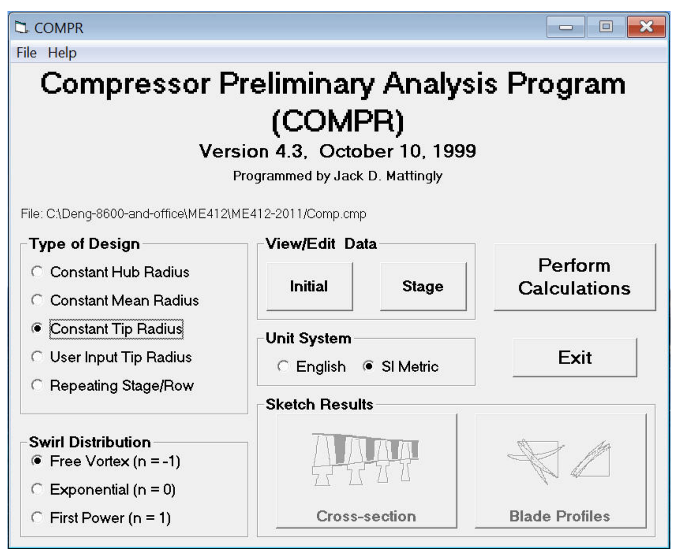


Figure 2. COMPR Design Program Initial Screen

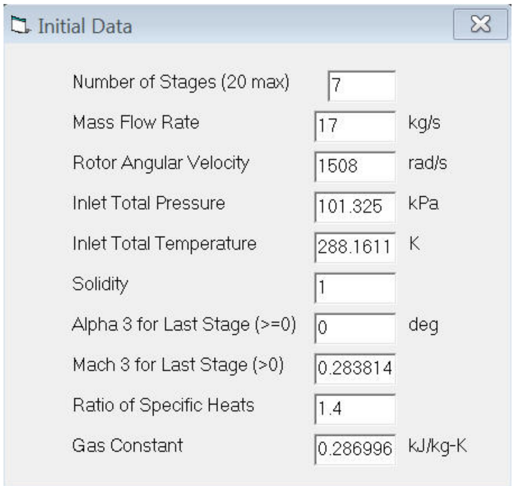


Figure 3. Initial Data Screen from COMPR for Setting the Initial Conditions of the Compressor Inlet.

Figure 4. Constant Tip Radius Design Window from COMPR

5. After verifying that the Design Mean Radius is ok, the Calculations for each individual stage data will appear in the Results window. To continue to the next stage's data, click on the Next Stage button located at bottom of the Results window. Repeat this for the remainder of the stages, as in Figure 5.

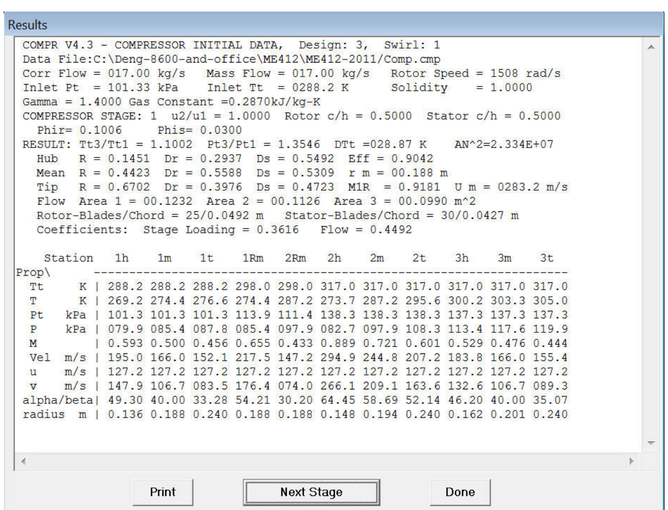


Figure 5. Stage 1 Data from the Results Window of COMPR

6. Clicking "Done" will close the Results window after all of the results from each stage have been reviewed. Once back at the front window of the COMPR, the student should notice that the Sketch Results section of the program has turned to color. Clicking Cross-Section will open the Sketch Pad window that has a cross-sectional area of the general sketch views of how the compressor's cross-sectional area changes, as in Figure 6.

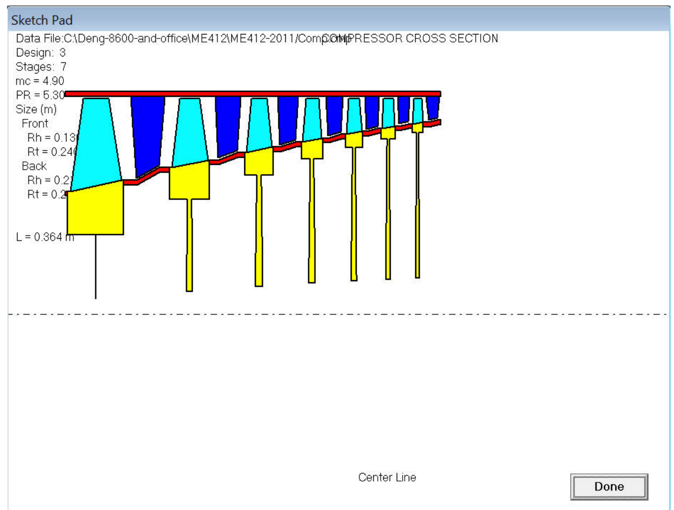


Figure 6. Sketch Pad Window from COMPR Showing the Cross-Sectional Area of the Compressor from Stages 1 to 7

7. Check that the cross-sectional area is complete. Close the Sketch Pad window. On the front window, click Blade Profiles. The Blade Description window will open. In the Blade Description window, specify that you want to see the blade profile for Stage 1, as in Figure 7.

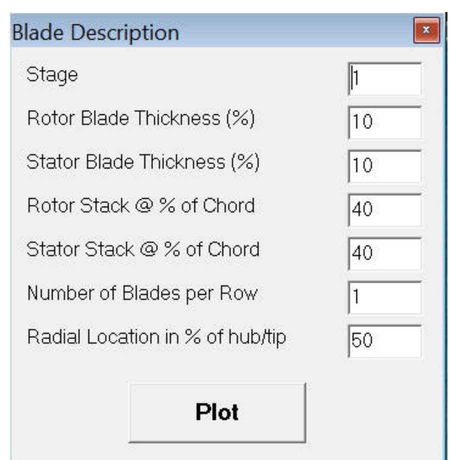


Figure 7. Blade Description Window for Selecting the Specific Stage and Viewing the Blade Profile for That Stage

8. Clicking the Plot button in the Blade Description window will open the Sketch Pad. The Sketch Pad gives two profiles, the one on the left is for the blade profile of the rotor and the right side is for the stator blade profile, as in Figure 8.

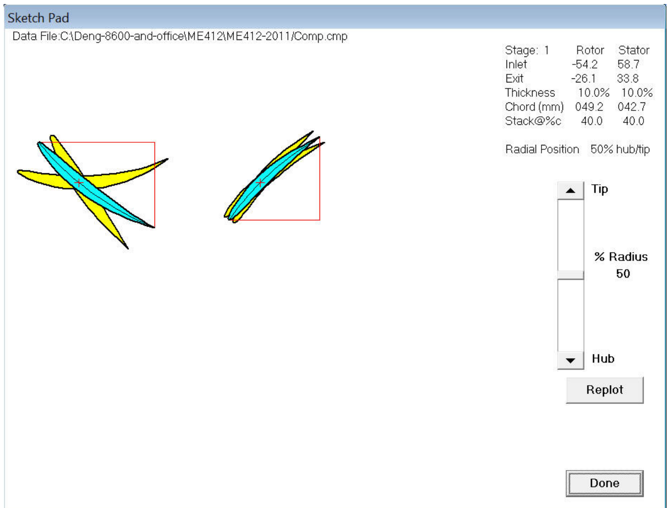


Figure 8. Sketch Pad Window from COMPR Showing the Rotor Blade Profile on the Left and the Stator Blade Profile on the Right

9. In the Sketch Pad window, three photos will be produced to develop a 3D model of the rotor blade. First, on the left side, slide the bar to the hub with % Radius reading 0, and click Replot. The blue image is the current viewing profile, as in Figure 9.

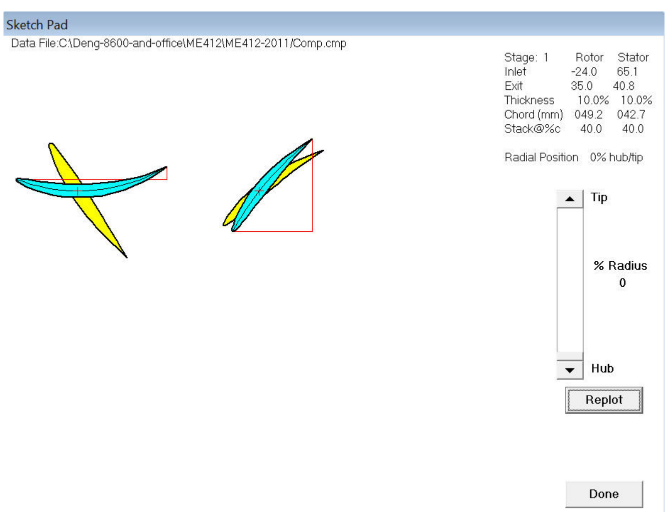
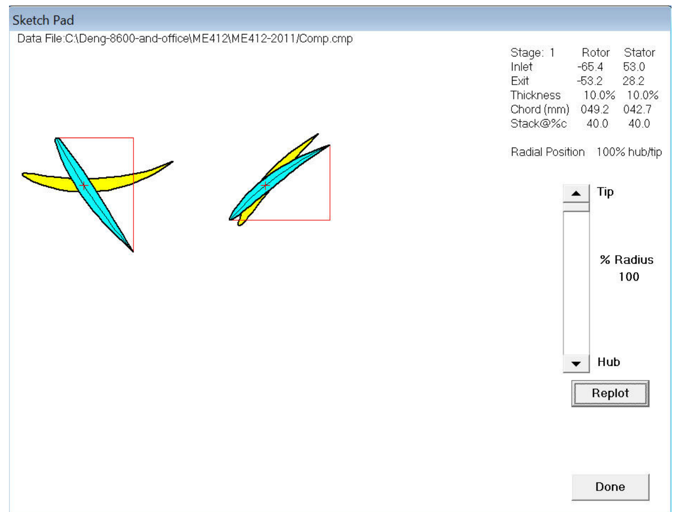
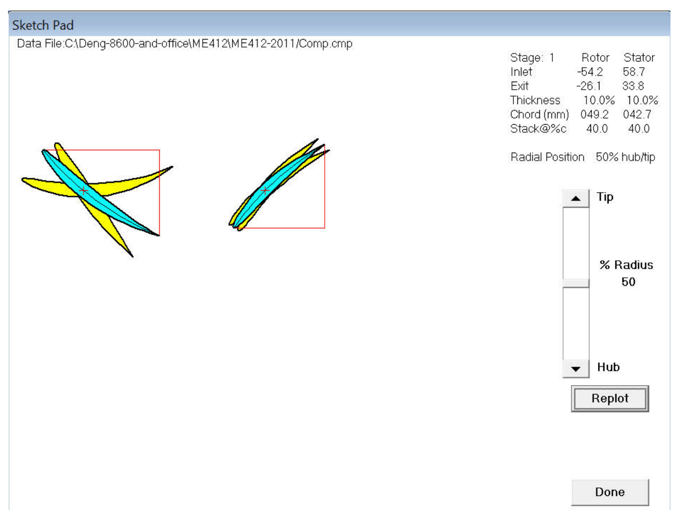


Figure 9. Blade Profile of the Hub Produced in COMPR

10. Once the Hub profile has been created, the mean and tip profiles will be created with the Mean profile at 50% and the Radius and Tip at 100%. Remember to click Replot after each change of the slide bar to produce the next desired profile, as in Figures 10(a) and 10(b). After this step, the blade profiles of the first-stage rotor were designed.



a) Tip Radius Position

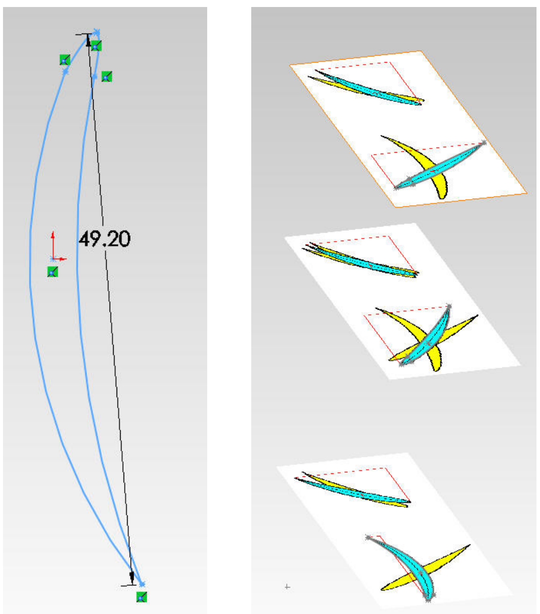


b) Mean Radius Location

Figure 10. Cross-Sectional Profiles of the Blade at Both the Tip and Mean Locations

Step #3: Generate a three-dimensional blade using SolidWorks. After saving each of the blade profiles, the images are to be imported into SolidWorks for a 3D modeling of the blades.

1. In a new part window in SolidWorks, select a top plane. In the menu select Tools → Sketch Tools → Insert Image. Select the Hub blade profile as the first image. Trace the profile using a combination of three -point arch and the spline commands. After the Hub has been sketched, repeat the steps but with images on new planes and the distance as shown in Figure 11 (a). Ensure that the chord length in SolidWorks is chord length given by the COMPR Program. After the trace sketches have been made, the images can be suppressed and the images will remain visible, as in Figure 11(b).



a) **b)**

Figure 11. 3D Iso-Views in SolidWorks

a) The Chord Length of the Blade Profile

b) The Hub, Mean, and Tip on Different Planes

2. From the Iso-view, select Loft as the feature to be created. In the Loft feature, right click and select the region selection, as in Figure 12.

3. Select the first sketch from the Hub sketch plane. Select the Mean profile next, followed by the Tip profile, as in Figure 13.

4. A preview of the Loft will begin to take shape, as in Figure 14.

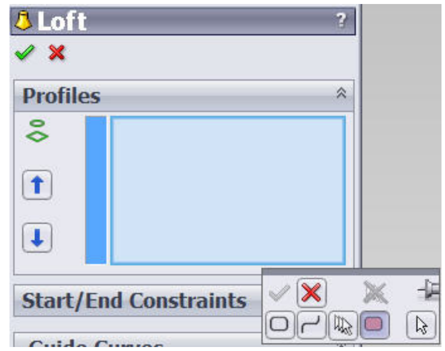


Figure 12. The Loft Feature in SolidWorks with the Pink Box for Selecting the Loft Region

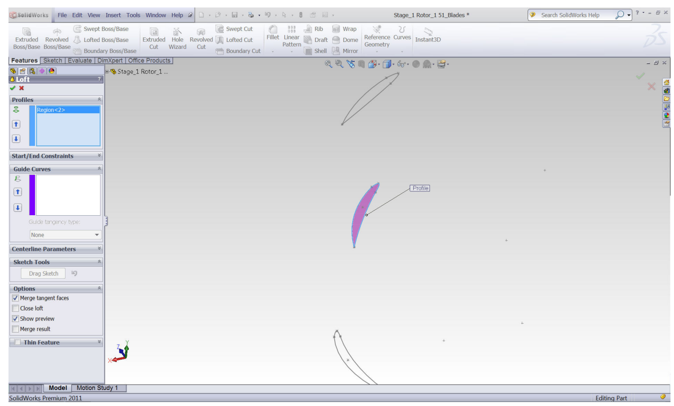


Figure 13. Loft Feature Using the Region Selection with all Three Profiles Selected

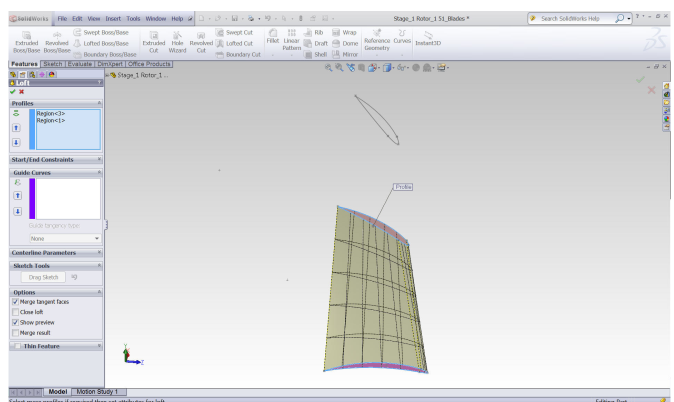


Figure 14. The Loft Beginning to Take Shape

5. After the Tip region is added into the Loft preview, the student should select the connecting lines to be at a common location on the profiles. For this blade model, the trailing edges of the blade profiles were chosen, as in Figure 15. Arrangement of the blade on the first stage rotor is shown in Figure 16.

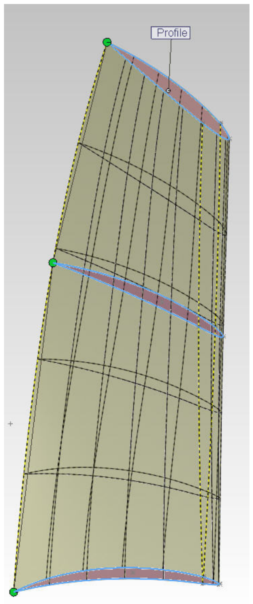
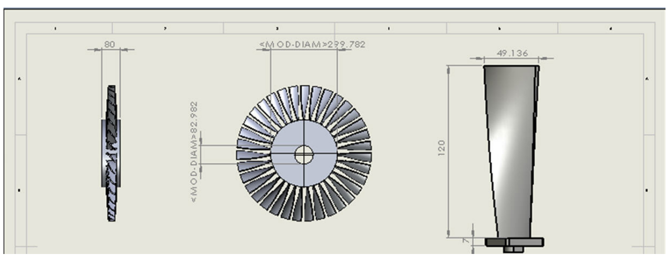
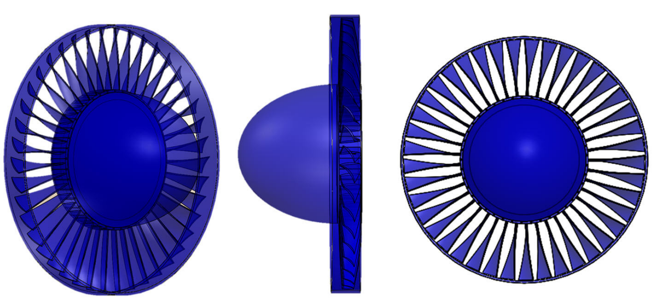


Figure 15. Preview of Complete Blade with the Common Location of the Trailing Edge on all Blade Profiles



a)

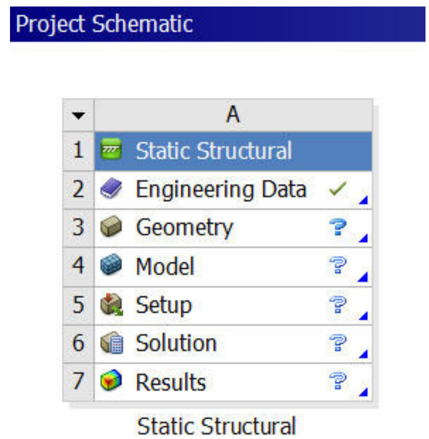


b)

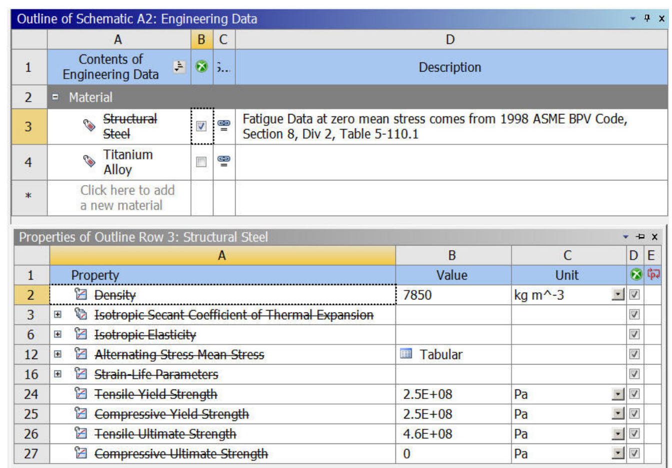
Figure 16. Arrangement of the First-Stage Blade on the First-Stage Rotor

Step #4: Perform an ANSYS/structural analysis. After completing the design of the rotor, save the model as an .igs file; this will allow the user to import the file directly into ANSYS.

1. Start ANSYS Workbench → Toolbox → Static Structural → Drag Static Structural to Project Schematic window, as in Figure 17(a). Right click on Engineering Data. Under the material group, right click on Structural Steel → Engineering Data Sources. Under Data Source → General Material → Select Titanium Alloy as shown in Figure 17(b).



a) ANSYS Static Structural Analysis Window



b) Material Selection

Figure 17. ANSYS Project Schematic Window

2. Right click on the Geometry column → Import Geometry → Browse → locate your saved CAD file → Double click on Model. File will import into ANSYS Mechanical analysis module.

3. Under the Model submenu → Generate Mesh, a finite element analysis mesh was generated, as in Figure 18, for the first-stage rotor with designed blades.

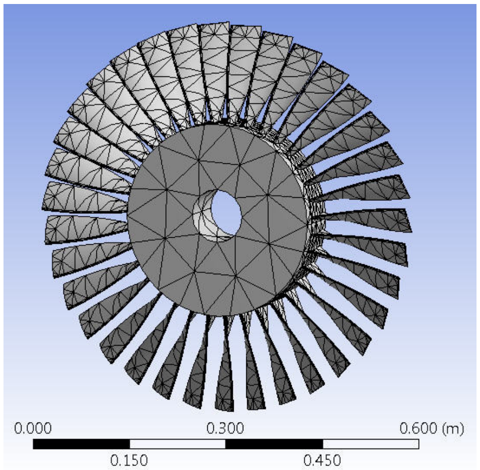
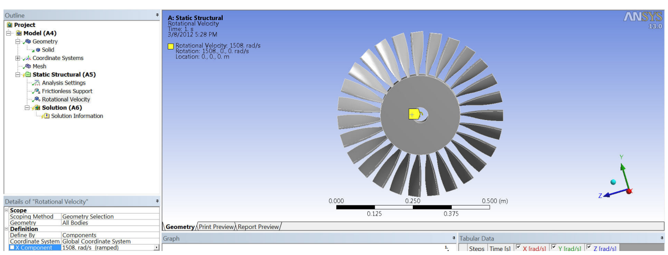
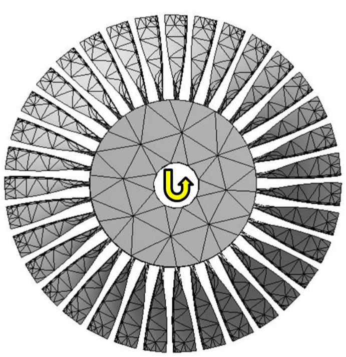


Figure 18. Finite Element Analysis Mesh for the First-Stage Rotor with Designed Blades

4. Right click again on the Static Structural in the Outline and choose insert. Insert a rotational velocity. Under definition change, define change Define by to components. In the “Z” direction change it from zero to 1508 rev/sec (students in this design used -1508 rev/sec to get the correct rotational. Specify Boundary Condition → Static Structural → Frictionless Support → Rotational Velocity (1508 rad/s), as in Figures 19(a) and 19(b).



a) Screen Shot of Boundary Condition Specification



b) Direction of Compressor Disk Rotation

Figure 19. Stress Analysis Boundary Conditions

5. Solving stress of the rotor blades using Solution→ Maximum Principal Stress. Results are shown in Figure 20.

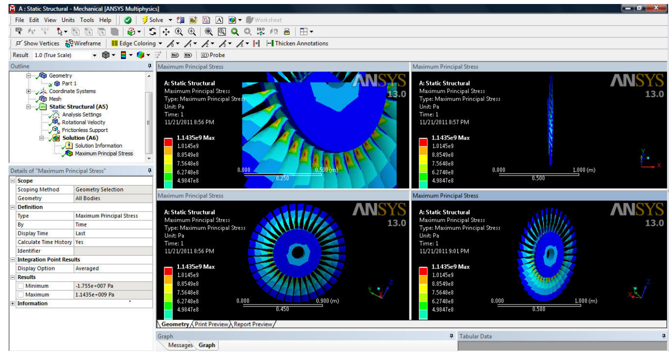


Figure 20. Maximum Principal Stress Solution for the First-Stage Rotor Blades

6. Obtain solutions for the total deformation of the first-stage rotor blades using Solution → Total Deformation, as shown in Figure 21.

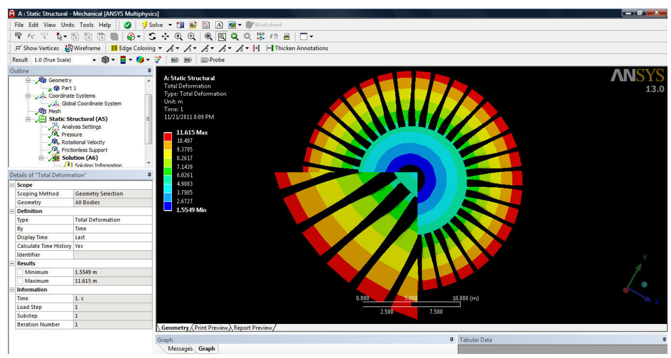


Figure 21. Total Deformation Solution for the First-Stage Rotor Blades

7. The comparison the Maximum Principal Stress to Titanium’s ultimate tensile strength showed that the maximum stress exceeded the material allowed stress limit if the rotational speed was 1508 rev/s. Therefore, the first-round design point rotational velocity was too high and resulted in the material failing at that rotational velocity. A few tries indicated that reducing the rotational velocity to 1370 rev/sec and modifying the design and analysis parameters, lowered the Maximum Principal Stress below the ultimate tensile strength. This allowed for the material to be within operational parameters for flight.

Conclusion

This study demonstrated the design of a first-stage axial-flow compressor blade using solid modeling through a classroom project. Step-by-step instructions using performance prediction tools PERF, COMPR, SolidWorks and ANSYS described the design of the first-stage axial-flow compressor blades. This sample project description provided a fast and easy access template for engine performance analysis and blade design using solid modeling and analysis efficiently. Use of this template will significantly reduce the time spent on learning how to use design tools to conduct solid modeling and analysis.

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BENCH-TOP AND INDUSTRIAL METAL LATHES: DIFFERENCES AND SIMILARITIES

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Abstract

Educators have extensively debated the importance of teaching machining fundamentals in engineering curricula. Some argue that hands-on skills are a thing of the past and engineers today need to concentrate more on core courses dealing with solid mechanics, dynamics, thermo, materials, along with exposure to design. Machining curricula, while still technically a part of many programs, have lost emphasis, perhaps in response to increased costs. This is not surprising given the high operating expenses associated with maintaining industrial laboratories containing equipment needed to provide students with experiential learning in manufacturing processes. Severe budgetary constraints have resulted in many schools trying to do more with less, and maintaining expensive laboratories with equipment that many feel is unnecessary becomes difficult to justify. Still, there is plenty of evidence to suggest that 21st century engineers can benefit from manufacturing curricula that include components of experiential learning.

A study was conducted at a Midwest university which compared two types of equipment: a bench-top metal lathe and an industrial lathe. Two questions were examined in the study: 1) what effect would the substitution of a 7”x12” bench-top metal lathe have on a student’s ability to produce small-scale parts within a .005” tolerance range? And, 2) what were students’ perceptions regarding the advantages and/or disadvantages associated with using a bench-top metal lathe compared to an industrial lathe in an educational setting? The results indicated that there were no statistically significant differences between parts produced on the bench-top and industrial metal lathe. Students, however, perceived the use of the bench-top metal lathe to be a suitable replacement for the industrial metal lathe.

Introduction

Mr. President, There is No Engineer Shortage, was the title of a recent article in the Washington Post by Wadhwa [1]. However, Brown [2] notes that Swoboda, a company that employs engineers, reports having some difficulty finding engineers with the skill sets necessary to keep their factory in peak operation. John Fuhs, vice president of sales and engineering at Swoboda, said that they are having a hard time finding “engineers who don’t mind working at a desk on the factory floor and implementing as well as designing projects” [2]. Fuhs goes on to say that his company prefers student interns from Germany who, he states, “know how to do their own CAD, machine design, and basic tool making. They’ll walk into a tool room and immediately start working” [2]. The experiences that Swoboda encountered are supported by studies conducted by the University of California at Berkeley, which, during the course of several interviews with machinists and engineers, found that the general belief was that engineering programs should continue to teach manual machining processes [3]. Clearly, program goals and needs will differ with some choosing to focus more on theory and less on application. Examples of the varying approaches can be found in programs ranging from engineering—with more of a focus on theory—to technology, industrial technology, and secondary STEM-based programs that use differing levels of theory mixed with application.

Specialized equipment found in most engineering and technology programs represents a sizable amount of a department’s budgetary expenditures, including indirect costs associated with having appropriate facilities to house this equipment. A report submitted to the Ohio Legislative Office of Educational Oversight [4] and a later study sponsored by MPR Associates in Berkeley, CA, [5] suggest that such costs may account for the relatively high price of engineering in the U.S. Given the current state of the economy, where federal and state governments are running huge deficits, this raises some concern about the long-term viability of these agencies to continue funding engineering and manufacturing programs.

Helping students acquire the necessary skills and knowledge needed for success within the work environment is a requirement of engineering/manufacturing programs, and finding ways to bring this about will require some creative thinking in lieu of using modern, costly equipment. Therefore, programs, with limited budgets, may have to become creative by resorting to more cost-effective approaches if they are to avoid becoming targets for budget cuts. Additionally, it is important to ensure that any cost-saving measures undertaken do not negatively impact program offerings and that equipment selection will still satisfactorily prepare students to enter the job market as qualified employees.

One viable alternative to costly industrial equipment may be to employ the use of virtual systems, but Carnevale [6] raises some question about the viability of virtual environments to provide students with the same skill sets that traditional methods of instruction could deliver. While the equipment needed by engineering/manufacturing programs may be expensive, there are less costly alternatives. One such alternative exists in the form of bench-top machine tools. Bench-top machine tools operate in a similar fashion to their full-size cousins; they have similar controls and are also much more compact and inexpensive than their full-size counterparts.

A recent study conducted at a Midwestern university's Department of Technology suggests that engineering/manufacturing programs facing budget cuts may be able to substitute bench-top metal lathes for the more expensive industrial-size equipment without negatively impacting the effectiveness of their programs. Bench-top metal lathes were selected for this study because of their reduced cost compared to an industrial lathe and their functional versatility, which includes machining operations such as turning, drilling, and milling. The ultimate goal of this study was to examine the feasibility of using bench-top metal lathes as a cost-effective alternative for industrial metal lathes in educational settings, without negatively impacting the quality of the program.

There are differences that exist between bench-top and industrial lathes. Size and price are certainly the most obvious; however, there are differences in features as well. Table 1 shows a comparison between the bench-top and the industrial lathes used in this study. In both instances, the exact model machines that were used in the study are no longer manufactured; however, equivalent systems were priced for comparison purposes. The specifications shown here are the same as the machines used in this study.

As Table 1 shows, the two types of lathes have many similarities and can perform similar tasks as long as the size of the work being done fits into the physical parameters of the bench-top lathe. It is important to note, however, that the prices shown are reflective of what an equivalent machine, with similar features, would cost today. Prices do vary depending on the manufacturer and machine specifications. For example, the bench-top lathe used in this study is one of the least expensive models on the market; other brands, such as some European-made machines, can cost several thousand dollars and is in the price of many mid-range industrial-size lathes. An equivalent industrial lathe produced in China can be purchased for around $8,000-$10,000. These import lathes generally have more accessories than the U.S.-built Clausing lathe used in this study.

Table 1. Bench-top Lathe and Industrial Lathe Comparisons

Specifications	Industrial Lathe Clausing 1300	Bench Lathe Cummins 7x12
Manufacturer	Clausing	Seig
Country of origin	United States	China
Swing over bed	13 inches	7 inches
Distance between Centers	24 inches	12 inches
Spindle bore	1 5/16 inches	.80 inches
Tailstock taper	3 MT	2 MT
Spindle taper	3 MT	3 MT
Tailstock travel	4.25 inches	2.5 inches
Cross-slide travel	6.75 inches	2.75 inches
Motor	5 HP	1/3 HP
Electrical	230 Volt 3 ph 60 Amp	110 Volt 10 Amp
Speed range	45-2000 RPM	0-2500 RPM
Drive	Hydraulic	Variable Speed
Range of threads	4-224 TPI	12-52 TPI
Gearbox	Quick change	Manual
Standard Accessories	Wrenches, oiler Other accessories must be ordered separately	3 jaw chuck, face plate, steady rest, turret post, change gears, dead center, wrenches
Net weight	1415 pounds	74 pounds
Footprint	33 x 60 inches	28 x 9 inches
Price in 2012	$12, 970	$595.00

For purposes of this study, a bench-top lathe was defined as a lathe designed for hobby or personal use and is theoretically capable of turning a cylinder that would not exceed 7 inches in diameter and 12 inches in length. In addition, the weight of the lathe would not exceed 100 pounds and so would be relatively portable. These limitations would allow for relatively easy storage and would not take up a lot of valuable facility space. Industrial lathes were defined as those lathes that are designed for heavy, production use within industry. The physical turning capacity that these lathes could handle would be in excess of 12 inches in diameter and 24 inches in length. The weight of the lathe would exceed 1200 pounds.

The following two questions were examined in this study.

1. What effect will the substitution of a 7"x12" bench-top metal lathe have on a student's ability to produce small-scale parts within a .005" tolerance range when compared to similar parts manufactured with industrial metal lathes?

2. What will students perceive as the main advantages and/or disadvantages associated with using a bench-top metal lathe in an educational setting when compared to the larger industrial metal lathe?

Historical Perspective

In the early years of American education, the common view of what a college education should provide—essentially the view held by educated, wealthy Americans—was quite different from the goal of education held by the middle and lower classes. Interestingly, parents who lacked formal educations but publically scoffed at higher education, still wanted their children to attend college and receive a degree that would provide advantages that they themselves did not achieve [7].

Interest in practical education—a trade obtained through an apprenticeship program—was not without its opponents. The differences between skilled labor and educated labor were largely due to the kind of education that the workmen received [8]. Under the terms of the Morrill Act, programs in the new colleges were supposed to follow a pattern of genuine work and students were not to be bothered with what was called "play work". The term play work, which was commonly used at that time to refer to a type of work that did not create what today is referred to as authentic learning tasks, is a subset of situated cognition [9]. Two of the central points of situated cognition theory are that learning environments should re-create the types of environment in which students will be working, and that the work performed within these environments should be the same type of work that will be expected of them when they enter the workforce. This view is consistent with that of education reflected in earlier apprenticeship programs, but it was not always consistent with the perception of education that many of the institutions of higher education of the day shared [10].

Apprenticeship programs were popular because they effectively trained students for the world of work in the trades. Therefore, it was not surprising that many of the industrial education programs started to integrate the concepts of an apprenticeship within their curricula. In this fashion, apprenticeships eventually became the foundations for cooperative education [11]. However, higher education of the day was most commonly focused on theoretical sciences and classical literature and, therefore, placed less emphasis on application or experiential learning activities. With the passage of the Morrill Act, higher education was forced to explore other options, as federal dollars were available only if colleges instituted these new curricula—applied agricultural and engineering. As a result, higher education changed its curricular focus in order to acquire the funds created by the Morrill act. And, this change necessitated hiring individuals who were skilled in industrial practices of the day. Such instructors were best able to ascertain whether the principles of science and mathematics taught in these programs were applicable to industry or whether they were mere play work that would not benefit the students, thereby ensuring "equal cultivation of the head, the heart, and the hands as representing a totality and completeness of instruction" [8]. The intent with industrial education was not to supplement a liberal education but rather to provide students with both a liberal and a practical education [12].

Educational movements are like pendulum swings, constantly changing direction but eventually returning to their earlier position. Though at one time industrial education supporters encouraged curricula that provided students with practical skill sets that could be immediately used in industry, one possible explanation is that the pendulum has swung to the other side in light of observations made by Swoboda [2]. It is rather interesting to note that similar thoughts were expressed in a Berkley study which suggested that little changed between 1992 and 2009 [3]. Engineering and manufacturing students who understand all of these subjects—solid mechanics, dynamics, etc.—while still being capable of operating the machine tools necessary for the construction of prototypes are more apt to make better decisions concerning design and relate better to other employees within the companies for which they work. One thing the present economy has demonstrated is that employees of the 21st century need to be able to adapt, and engineering/manufacturing programs must provide more flexibility in their curricula to ensure that students leave these institutions well prepared for the world that awaits them.

Methodology

Data Sources

Thirty-three students enrolled in an introductory manufacturing process course at an upper Midwestern university participated in an experiment designed to study the use of bench-top equipment as viable substitutes for an industrial-size machine. The survey developed for the study was administered online via Survey Monkey and included an adaptive feature which allowed for certain questions to be skipped when study participants selected a 'not applicable selection' response to any question on the instrument. For example, one question on the survey asked: "Have you used any kind of metal lathes?" A person who provided a negative response to the question would then skip the next four questions since they pertained to experience using metal lathes.

The instrument designed for the study was divided into four sections with the first section providing demographic information (13 items) related to gender, employment history, and educational level achieved. The three other sections of the student survey provided data about the three perception areas of tolerance, suitability of task, and comfort level (20 items). Section II of the survey contained six tolerance questions and required students to take measurements on a machined test bushing using both bench-top and industrial lathes. Each student attempted to manufacture the test bushing within the specified tolerance range of .005" (5 thousandths of an inch), which was determined based on the general tolerance requirements for a steam engine produced in an entry-level production processes class taught in the Technology Department at the university. All testing was conducted using the same two machines, one of which was a bench-top metal lathe and the other one being an industrial metal lathe.

Section III of the survey was designed to collect data about students' perceptions concerning the suitability of bench-top metal lathes when used in an educational setting. The nine Likert-type questions focused on:

- durability (construction, rigidity);
- suitability for teaching fundamental concepts of metal turning; and,
- machine specifications, such as controls and physical limitations on size of material that can be machined.

Section IV of the survey collected information about students' perceptions concerning issues of safety and comfort level with regards to working with the two lathes. Six Likert-type and short-answer response questions in this section focused on design/ergonomic issues of bench-top and industrial-size metal lathes and also the safety features found on both lathes.

Two questions guided the study: 1) what effect will the substitution of a 7"x12" bench-top metal lathe have on a student's ability to produce small-scale parts within a .005" tolerance range when compared to (their ability to produce) similar parts manufactured with an industrial metal lathe? And 2) what will students perceive as the main advantage and/or disadvantage associated with using a bench-top metal lathe in an educational setting when compared to a larger industrial metal lathe? The survey instrument was designed to help answer questions 1 and 2 of the study, and a pilot study was conducted to provide comparison data for research question 2 relative to the tolerances that could be achieved when manufacturing an aluminum stock on both the industrial and bench-top lathes.

Experiment

Prior to conducting the experiment, students were required to perform calibration settings on both of the lathes used in this study. Spindle speeds for both lathes were calibrated using a digital laser non-contact tachometer. An insert tool (TT style C2 grade carbide) was selected and installed in a tool holder that both lathes could accommodate and a sheet steel template was used to ensure that the tool angle was the same throughout the calibration process. Throughout the manufacturing phase of the study, the insert tool was replaced every time a new part was created in order to reduce the effects of tool wear on the process.

In order to obtain comparison data for the study, 66 bushings were created. Each student was asked to produce a total of two bushings, one using a 7"x12" bench-top metal lathe and the other on a 13"x24" industrial lathe. Following the lathe work, students were asked to take three measurements on each bushing. These measurements were:

1. The outside diameter;
2. The step diameter;
3. And the step length.

Participants

Thirty-two male students and one female student participated in the study. Students' work experiences varied, with seven (21.2%) students having worked in industry/business, two (6.1%) worked in education, 22 (66.7%) classified themselves as full-time students, and two (6.1%) students classified themselves as other. The students' highest level of educational experience varied, with 25 students (75.8%) having completed college courses without earning degrees, two (6.1%) as having an Associate of Science degree, three (9.1%) having completed a BA or BS degree, and three (9.1%) having obtained a technical certificate or degree. The students' level of training using machine tools varied, with a majority of them, 16 (64%), having received training at the college level. Eight students (32%) received training in high school, and the remaining students obtained training either in a technical school, they attended a workshop, or obtained training elsewhere. Only 23 participants (69.7%) stated that they used metal lathes. A majority of them (21 students) had less than two years' experience using a bench-top lathe. A smaller number, 17 students, indicated that they had experience working with larger industrial lathes. The selection of these students was important to this study because an earlier pilot study demonstrated that students who had a considerable amount of experience using metal lathes were able to successfully produce a product with a better tolerance range than students achieved in the study. Therefore, having students with varying experiences conduct similar work with metal lathes was needed in order to determine what role experience would play in producing a product that was within a .005" tolerance range on either lathe used in this study.

Data Collection

Data collection for the student portion of the study involved a brief training session on the use of the bench-top metal lathe, including a demonstration on the manufacture of the test bushing of the same dimensions that each student would be manufacturing on both test machines. Students were then allowed to participate in a two-hour laboratory activity in which they fabricated a test bushing on both the bench-top and the industrial lathes for a total of two bushings per student. Following the manufacture of each bushing, each student measured and recorded the physical dimensions of the bushing. When students completed the laboratory portion, they were asked to respond to the 34 items on the questionnaire. Each student spent approximately four hours participating in the study.

Data Preparation

Questionnaires were first viewed to identify any inconsistencies or missing data. Responses with missing information are generally not considered valid for statistical analysis [13], and consequently those responses were not included in this study. Data preparation included data coding, data entry, and verification. To ensure that data were entered correctly, every fifth questionnaire was checked for errors, once all of the data were entered.

Data Analysis

Analysis for this study was co-relational, using the physical dimensions from each student's test bushings as a co-variable that was compared to the same student's preference for the style of lathe she/he used. To analyze the data, a variety of statistical tests were performed such as descriptive statistics and Pearson correlation. In addition, a Multivariate Analysis Of Variance, or MANOVA, was considered to determine the difference between the criterion variables and demographics. The reliability of the three component sections of the Likert-scale portion of the questionnaire was determined following the pilot study using Cronbach's Alpha values and the responses from the pilot study.

Validity and Reliability

Faculty, industry personnel, and students not part of the study, assisted in reviewing a draft of the survey instrument. These individuals also commented on question clarity and content, including directions for the survey and its layout. These comments aided in improving the internal validity and the reliability of the non-demographic sections of the instrument. The reliability of the three component sections of the Likert-scale portion of the questionnaire was determined from the Cronbach's Alpha values obtained from data acquired from a pilot study.

Summary of Findings

Research Question 1

The first research question examined the effect that the substitution of a bench-top metal lathe would have on a student's ability to produce small-scale parts within a .005" tolerance range when compared to similar parts manufactured with the industrial metal lathe. Following a training session on the use of the metal lathe and a demonstration on the manufacture of the test bearing, shown in Figure 1 below, thirty-three student participants were asked to make one bushing each on the bench-top and industrial lathes. Following this, they were asked to record measurements for the outside diameter, step diameter, and step length. These measurements were also taken by the researcher. Summary statistics for the data are shown in Tables 2 through 4.

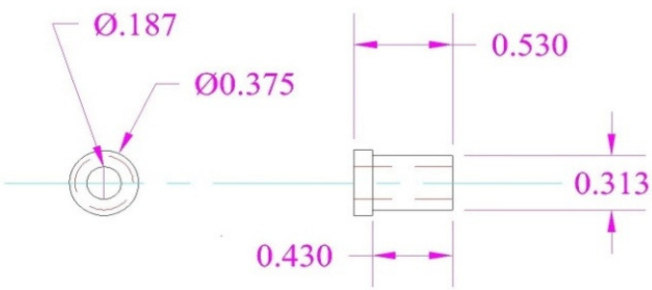

Figure 1. Test Bearing

Table 2. Summary Statistics Outside Diameter (n=33)

	Outside Diameter Industrial Lathe	Outside Diameter Bench Lathe
Count	33	33
Average	0.380	0.379
Standard Deviation	0.010	0.004
Minimum	0.365 inches	0.372 inches
Maximum	0.425 inches	0.388 inches
Range	0.060 inches	0.016 inches
Stnd. Skewness	9.385	0.456
Stnd. Kurtosis	24.480	0.013

Table 3. Summary Statistics Step Diameter (n=33)

	Step Diameter Industrial Lathe	Step Diameter Bench Lathe
Count	33	33
Average	0.312	0.311
Standard Deviation	0.003	0.003
Minimum	0.302 inches	0.302 inches
Maximum	0.315 inches	0.319 inches
Range	0.013 inches	0.017 inches
Stnd. Skewness	-4.059	-1.157
Stnd. Kurtosis	5.137	3.572

Examination of the data revealed that, in almost all instances, the data exhibited a departure from normality. The one exception to this was the outside diameter data from the bench-top lathe. Since the data set was found not to come from a normal distribution, it was not possible to run a standard t-test on this data. Instead, a Mann-Whitney Wilcoxon test was performed, as it does not require normal distributions. The results of the Whitney test showed that there was no statistically significant difference between the two medians at a 95% confidence level.

Not all data that is collected for analysis is normally distributed. In industry, this is a common problem. Generally, the cause for the non-normality should be determined and actions taken to address the problems. Common problems that lead to non-normally distributed data in industry can include extreme values that result in skewed distribution. Another common problem deals with the overlap of two processes. This commonly occurs when an operator changes positions or a shift change occurs. When this happens, two or more data sets that might alone be normally distributed are combined and two different frequent values may cause the data to look bimodal.

Table 4. Summary Statistics Step Length (n=33)

	Step Length Industrial Lathe	Step Length Bench Lathe
Count	33	33
Average	0.385	0.387
Standard Deviation	0.011	0.010
Minimum	0.362 inches	0.356 inches
Maximum	0.425 inches	0.413 inches
Range	0.63 inches	0.057 inches
Stnd. Skewness	2.058	-2.499
Stnd. Kurtosis	4.522	4.993

In the case of the above data, it is likely that similar situations did occur. With 33 students each performing a complete task, the fluctuation of the data is not surprising. Also, new, relatively inexperienced students performing introductory machining operations oftentimes make mistakes, which can explain the number of outliers that are present in the data sets. These outliers are easily seen in Figures 2 through 4.

Though it was not possible to perform a standard t-test on the data due to the normality of the distributions, it should be noted that the removal of the outliers resulted in normal distribution patterns. Consequently, a t-test comparing the means showed that there was no statistically significant difference between the different data sets at a 95% confidence level. While removing these outliers does allow the use of a standard t-test, it also results in the loss of data points on what is already a small sample. For this reason, it is not a recommended practice. However, the data were manipulated here to show the impact that these outliers have on the statistical analysis.

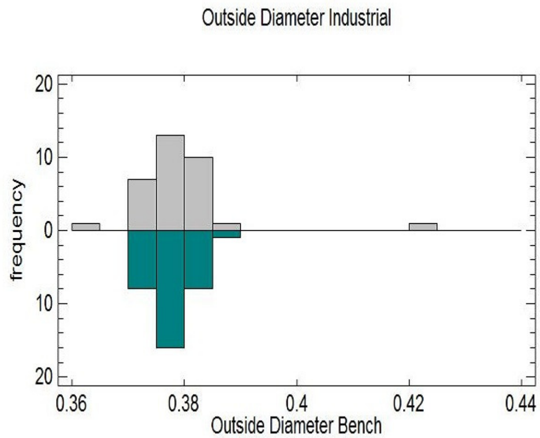

Figure 2. Outside Diameter Histogram for Bench-top and Industrial Lathes

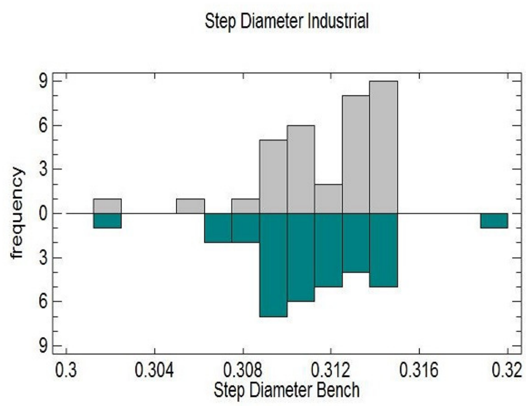

Figure 3. Step Diameter Histogram for Bench-top and Industrial Lathes

Pilot Study

In an earlier pilot study, two graduate students, who had some experience with metal lathe operation, performed the tests. Each graduate student fabricated 30 bushings on both the bench-top lathe as well as the industrial lathe used in this study. From each bushing produced, measurements were taken from the outside diameter, step diameter, and step length. Tables 5 and 6 show summary statistics for data collected from the outside diameter and also the step diameter. Analysis of standard skewness and standard kurtosis indicated that both sample sets were normally distributed. Following this, a t-test was run to compare the means, which showed that there was no significant difference at a 95% confidence level.

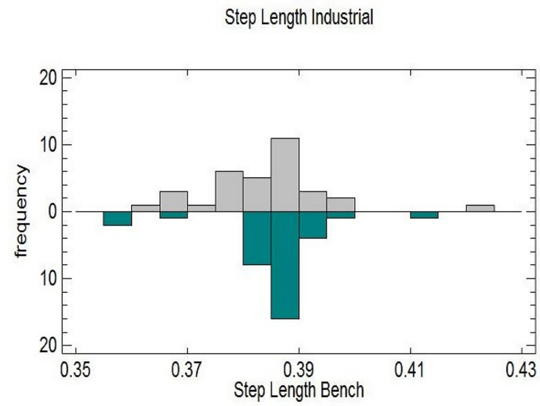

Figure 4. Step Length Histogram for Bench-top and Industrial Lathes

Table 5. Summary Statistics Outside Diameter (n=30)

	Outside Diameter Industrial Lathe	Outside Diameter Bench Lathe
Count	30	30
Average	0.351	0.350
Standard Deviation	0.003	0.002
Minimum	0.343 inches	0.347 inches
Maximum	0.355 inches	0.353 inches
Range	0.012 inches	0.006 inches
Stnd. Skewness	-1.934	-0.139
Stnd. Kurtosis	0.736	-1.148

Data collected from the step length measurements were found to have more variance. Summary statistics for the step lengths can be seen in Table 7. These data were found to show some departures from normality for both the bench-top and industrial lathes.

Since the data set was found not to come from a normal distribution, it was not possible to run a standard t-test on these data. Instead a Mann-Whitney Wilcoxon test was performed, as this does not require normal distributions. The results of the Whitney test showed that there was not a statistically significant difference between the two medians at a 95% confidence level.

Table 6. Summary Statistics Step Diameter (n=30)

	Step Diameter Industrial Lathe	Step Diameter Bench Lathe
Count	30	30
Average	0.313	0.313
Standard Deviation	0.002	0.002
Minimum	0.308 inches	0.308 inches
Maximum	0.318 inches	0.318 inches
Range	0.010 inches	0.010 inches
Stnd. Skewness	-0.059	-0.539
Stnd. Kurtosis	-0.385	0.112

Table 7. Summary Statistics Step Length (n=30)

	Step Length Industrial Lathe	Step Length Bench Lathe
Count	30	30
Average	0.237	0.239
Standard Deviation	0.010	0.008
Minimum	0.213 inches	0.208 inches
Maximum	0.253 inches	0.256 inches
Range	0.040 inches	0.048 inches
Stnd. Skewness	-2.065	-3.117
Stnd. Kurtosis	1.035	6.547

Research Question 2

The second research question asked "What will students perceive as the main advantage and/or disadvantage associated with using a bench-top metal lathe in an educational setting when compared to the larger industrial metal lathe?"

One question in the suitability to task section of the survey asks whether students felt that the bench-top lathe used in this experiment was capable of holding tolerances within a .005" range. Seventy-five percent of the students responded that they felt that the bench-top lathe was capable of holding tolerance within a .005" range. Some (21.9%) were neutral in regards to whether the bench-top lathe could hold this tolerance range, and a few (3.1%) disagreed that the lathe was capable of performing within this tolerance range.

A related question asked whether students felt that that the industrial lathe used in this study was capable of holding tolerances within the .005" range, and most (78.8%) felt that this was true, with the remaining (21.2%) being unsure about this issue. Other survey questions examined the controls used on both lathes. One question asked whether students felt that the controls used on the bench-top lathe were easy to use and most (78.2%) felt that they were, with a minority (18.8%) remaining neutral, and a small percentage (3.1%) feeling that they were not. A similar question was asked about the controls on the industrial lathe used in the study and a somewhat lower number (69.6%) of students felt that they were easy to use with others (27.3%) remaining neutral, and a small group (3%) feeling that they were not.

Comfort-Level Questions

Responses to one survey question indicated that the majority of students perceived that one advantage of using a bench-top metal lathe is that they felt it was a safer alternative (75.8%) and less intimidating (62.5%) to use than a full-size industrial lathe. Another survey question asked whether students felt that they learned more effectively when they are comfortable with their surroundings. The majority of the students (75.8%) felt that this was true, while some (21.2%) were unsure whether this was true or not. Only a small percentage (3%) of students felt that they learned more effectively in an uncomfortable environment.

One question on the survey instrument asked which lathe the students found less intimidating to work with. The majority of the students (62.5%) felt that the bench-top lathe was less intimidating to work with, while a much smaller group (15.6%) felt that the industrial late was less intimidating to use. Others (21.9%) felt that there was no difference in this regard between the two lathes. Another survey question explored whether students felt that there were any design issues that made the bench-top lathe inherently unsafe. Eleven students (34.4%) felt it did, while twenty-one students (65.6%) did not feel any design issues made the lathe unsafe.

Question 33 in the survey asked if students felt that the industrial lathe had any design issues that made it unsafe to operate. The response was nearly the same as for the previous question, with eleven students (33.3%) believing there were design issues that made the industrial lathe unsafe, and twenty-two students (66.7%) believing the design issues did not make it unsafe. Question 34 asked students which lathe they would feel safer working on. Six students (18.2%) felt safer using the industrial lathe, fifteen students (45.5%) felt safer using the bench-top lathe, and twelve students (36.4%) felt there was no difference.

Discussion

Analysis of the data revealed some interesting findings regarding the effect that substituting a bench-top metal lathe for an industrial metal lathe may have on a student's ability to produce small scale parts within a .005" tolerance range. Though in many cases students failed to achieve the required +/- .005" tolerance with one or both lathes, statistically there was no significant difference when comparing the two groups. In essence, both machines achieved similar results when used by the group of students in this study. Some students did produce more accurate bushings with one machine than they did with the other. However, a comparison of the number of non-conforming parts produced by students provided little evidence to suggest that one machine produced better results than the other with the exception of the measurements for step length, which is the length of the step diameter.

Of the three recorded measurements, achieving step lengths that were within the acceptable limits proved to be the greatest challenge for students using both lathes. The bench-top lathe produced a higher percentage of parts in which the step length measurements were within tolerance, but many of those parts were barely within tolerance. In contrast, many of the parts produced with the industrial lathe that were not within tolerance came very close to being within the acceptable range of +/-.005". An examination of the means for the bushings produced with each lathe—bench top and industrial—found that even though the measurements were dissimilar, the difference was not statistically significant.

The personal experience of the researcher determined that both lathes are capable of achieving tolerances considerably better than the +/- .005" target that was chosen for this study when either lathe is operated by experienced users. Both machines used in this study had factory test reports that showed them capable of producing work well within this tolerance range. Additional tests were also performed on both machines prior to the study to verify the factory tests. However, a study of this scope was needed in order to determine how both lathes would perform in an academic setting by students with limited experiences. While participants of this study were not expert in the use of the metal lathe, they were nonetheless representative of the skill level of students who would typically enroll in an introductory manufacturing processes class.

The results of this study demonstrated that while both lathes are capable of producing work within a given tolerance range, inexperienced users can produce accurate results using the smaller bench-top lathe. It is reasonable to conclude that if a piece of equipment appears to be intimidating to the user, then there is a greater likelihood that the learner may feel somewhat overwhelmed, resulting in a less than ideal learning environment. A similar conclusion can also be drawn about the perceived safety of a piece of equipment relative to its size. These perceptions were confirmed in student responses to questions related to comfort level and safety. Data obtained from responses to the study indicated that students overwhelmingly agreed that they learn more effectively when they are comfortable with the equipment in the learning environment. It can be argued, however, that students are perhaps not the best judges of the actual safety, equipment potential, and operating capabilities of equipment similar to those used in this study. However, the issue of comfort level is hard to ignore.

Equipment is an important consideration in secondary and post-secondary technology education as tools to facilitate student learning and helping them acquire an understanding of basic manufacturing processes, including an understanding of how certain tools—mills, lathes, CNC machines, etc.—can be used to produce a manufactured product. Any equipment, however, is only as good as the people using it, and students must be properly trained in its use. Equipment, no matter its quality, may be a poor substitute for inadequate teaching. Competent educators utilize tools to enhance the learning experience while providing students with an understanding of relevant theories, thereby ensuring that students can apply the theories to a wide range of problems using selected tools. Ultimately, students need to acquire the knowledge and skills that they should have in order to be proficient in their chosen careers.

Conclusion

This study was designed to determine whether a bench-top lathe can handle tasks in an educational setting that is typically done with industrial lathes. Bench-top lathes, because of their size, have limitations and cannot complete many tasks that an industrial lathe can. For example, if instructors require that students make steam engines with six-inch bores, a bench-top lathe would not be an appropriate tool to use because the necessary parts would be too large. However, because of material costs, a project in an educational setting is more likely to be a small steam engine or similarly sized project that can be made using a bench-top lathe rather than a larger project that would exceed its ability and utilize larger quantities of expensive materials.

Engineering and manufacturing programs may need to be cost effective to survive, but cutting costs at the expense of the quality of programs does not seem to be an acceptable solution. The results of this study suggest that using bench-top lathes in educational settings may provide a more cost-effective alternative to industrial lathes without impacting the quality of programs. Using bench-top metal lathes will allow programs to provide hands-on experience with machine tools rather than utilizing virtual environments to teach machine-shop concepts, which may prevent students from acquiring the same skill sets as they would with traditional methods of instruction [6].

This study suggests that it is possible to use smaller, less expensive bench-top machine tools and still produce results similar to those produced with industrial lathes without the added safety, cost, space, and student/equipment ratio concerns outlined in the Ohio report [4]. And, the use of bench-top lathes as viable substitutes has the added benefit of providing hands-on experience that those in industry believe is important. The study also suggests that substituting bench-top lathes for industrial lathes may make it possible for educational institutions to provide students with the exposure to machine-tool processes that are necessary for manufacturing. Ultimately, individual programs must make choices that are most appropriate for their particular institutions and circumstances.

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Analyzing the Perceived Value of the NCIDQ Credential on Interior Design Professionals

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Abstract

While many professionals in the interior design profession seek certification, little information is known about the impact it will have on their careers. This study was intended to help these professionals make more informed decisions about what actual benefits they should expect when considering a National Council for Interior Design Qualification (NCIDQ) certificate. The primary research question addressed in this study was whether there were statistically significant differences in the perceived value of the NCIDQ certification between subgroups possessing the certification. The researchers sent a 35-question survey to 2,642 credential holders and received 606 (25%) completed surveys. The researchers utilized a one-way analysis of variance (ANOVA) to analyze eight dependent variables (increased recognition, opportunities for contributions, salary, promotion opportunities, job responsibilities, prestige among superiors, prestige among peers within the workplace, and prestige among peers outside the organization) based on six major groups of independent variables (years the credential has been held, reason why the respondent sought the credential, level of support received from the employer, location of practice, age group, and type of organization where the respondents are employed).

Of these six independent variable groups, three yielded statistically significant differences within and among their subgroups. Respondents holding the credential for 11-15 years perceived a higher increase in recognition than those holding it for 1-5 years (F=2.877, sig. 0.006). Respondents in the 50-59 age group perceived a higher increase in opportunities for contributions than those in the 40-49 age group (F=3.312, sig. 0.006). Finally, respondents working for firms other than interior design firms perceived a higher increase in promotion opportunities (F=6.898, sig. 0.009), job responsibilities (F=4.728, sig. 0.030), and prestige among individuals within their organization (F=5.788, sig. 0.016) than respondents working for interior design firms. It was hoped that the information garnered from this study will assist those in the profession in recognizing the value of the credential as well as encouraging those contemplating obtaining the credential.

Introduction

The role of architects and engineers in designing the buildings and infrastructure we use each day is generally understood by the public-at-large. Most people are likely to understand the need for these professionals to be licensed by the state in which they practice – much like they understand a doctor must be licensed to protect the health, safety, and well-being of the general public. Unfortunately, the role of an interior designer in creating our built environment is much less understood [1]. For over five decades, interior design professionals have tried to define and differentiate interior design as a unique and important profession [2].

Numerous articles have been written on the transition of interior design from practice to profession [3-6]. In one such article, Martin [7] identifies seven steps to professionalization in a scathing response to criticisms of the interior design industry by the Institute for Justice [8]. She argues that interior design, like architecture, fulfills the actions prescribed by the theory of professionalization including: 1) the establishment of professional organization membership; 2) a name change to achieve legislative restriction; 3) the creation of a code of ethics; 4) the establishment of educational requirements; 5) the establishment of a comprehensive examination; 6) the creation of legal recognition/regulation; and, 7) the requirement of continuing education for professional practice [7].

Unfortunately, the fractured nature of practice and/or titling laws across North America [9] has failed to resolve the confusion surrounding the professionalization of interior design. Currently, interior design credentialing laws have been enacted in 27 U.S. states, including the District of Columbia and Puerto Rico, and eight Canadian provinces [10]. Within these jurisdictions, the National Council for Interior Design Qualification (NCIDQ) certificate exam is the predominant methodology for individuals to satisfy mandated examination requirements. As such, completing the NCIDQ certificate exam is an important step to achieving recognition as an interior design professional.

However, this same logic is not as clear in areas of North America where interior design credentialing laws have not been enacted. While an individual who possesses the necessary background in education and experience may take and successfully obtain an NCIDQ certificate, the requirement to do so is not mandated. Currently, little information is available as to why an individual should consider the NCIDQ credential if it is not required to practice interior design. This study addresses this lack of data by surveying current NCIDQ certificate holders for their experience on the impact of obtaining the NCIDQ certificate. The authors' intent was to explore whether or not there is a statistically significant difference in the impact the NCIDQ credential has made across various demographic groups. The answer to this question will therefore help interior design professionals make more informed decisions about what actual benefits they should expect when considering an NCIDQ certificate, no matter their circumstances.

Review of the Literature

The National Council for Interior Design Qualification (NCIDQ) was originally conceived in the 1960s, but eventually was incorporated as an independent, nonprofit organization in 1974. More than 26,000 individuals have earned their NCIDQ certification since the first exam in April of 1974 [11], [12]. While the primary function of the NCIDQ is to develop and administer the NCIDQ certificate examination, the organization also conducts research, maintains resources for certificate holders to track their continuing education credits, and supports education and volunteer opportunities for active certificate holders [11].

The NCIDQ certificate exam is a two-day performance-based assessment that examines an individual's competence, mastery, and performance across the gamut of interior design knowledge areas including codes, building systems, construction standards, design applications, project coordination, and professional practice. The exam also includes an interior design practicum section [13], [14]. The NCIDQ certificate exam is regularly evaluated and modified by a collaboration of professionals, testing specialists, and consultants [13], [14]. Eligible candidates must possess at least six years of combined interior-design-specific education and experience [15]. Currently, three U.S. states require or allow alternatives to the NCIDQ certificate examination. These include the Interior Design Examination (IDEX) in California, the Council for Qualification of Residential Interior Designers (CQRID) in Illinois, and the Architect Registration Examination (ARE) in Indiana.

For interior designers, the debate over the importance of professional credentials is complicated by the countless licensing laws across the continent. However, interior design is not the only profession for which multiple types of professional credentialing exist. For architects and engineers, professional credentials for individuals can also be attained through both state licensure and/or specialty certification. The existence of both forms of credentials has historically been a source of contention and confusion for architects, engineers, and the general public [16], [17]. While the history of professional credentialing is beyond the scope of this study, it is important to investigate the distinction between both licensure and certification in order to ascertain the reason both types exist.

Licensure involves the granting of a license, usually by a governmental entity, to practice a certain profession. Most professions that include licensure requirements (e.g., medicine, law, architecture and engineering) do so because they are deemed to be a risk to the health, safety, and well-being of the general public [16]. While licenses may also be required for those whose occupations put them in contact with the public (e.g., barbers, massage therapists, chauffeurs), the qualification and requirements are much less stringent than those for the aforementioned classifications. As such, designers are uniquely aware of the significance that licensure plays in their professional career. Unfortunately, the purpose and value of the other type of professional credential, certification, is often much less understood. This gap in awareness between licensure and certification can be explained by the relative newness of certification, the vast array of certification options, and even the variations in the definition of the term itself [17]. Thus, it is necessary to further explore the definition of professional certification.

Bratton & Hildebrand [18], in their study of technology certification in education, define certification as "the process by which a professional organization or an independent external agency recognizes the competence of individual practitioners." Similarly, Summerfield [19] defines certification for health, leisure, and movement professionals as the process of proving qualifications through education, experience, and general examination components. The reasons why an individual may obtain professional certification are numerous. For some, it may be the prestige associated with a certain credential behind their name. For others, it may be a job requirement or a necessary step to achieving a higher salary [20]. Previous research efforts by the authors explored the benefits of credentialing in both the design professions and in other sectors – specifically nursing, information technology, automotive repair, teaching, and others [21-23]. Benefits include increased customer satisfaction, increased employee recruitment and retention, increased employer recognition, perceived distinction among peers, the possibility of providing expert testimony in court, mobility, advancement, job security, credibility, higher self-esteem, and consulting opportunities [24-28]. Despite these countless motivations, professional credentials typically offer a baseline for understanding an individual's level of knowledge [29].

Universities also recognize this positive trend. For instance, rather than following convention and naming their 20-hour Technical Sales program a specialization, Ohio University created a Technical Sales certificate [30]. Similarly, even though the concepts were covered in their existing curriculum, Drexel University started offering Six Sigma courses to working professionals [31]. Recognizing a demand for a lifelong credential, where professionals may prove a growing understanding of a field's body of knowledge, many credentialing bodies have begun offering multiple levels of certification. For instance, the American Institute of Constructors has an Associate Constructor credential and a Certified Professional Constructor credential [22], the U.S. Green Building Council has an LEED Green Associate credential and an LEED Accredited Professional credential [23], and the Society of Manufacturing Engineers, Association for Manufacturing Engineers, and Shingo Prize Consortium have bronze, silver, and gold certifications for lean certification [32]. Unfortunately, the myriad of "alphabet soup" certifications available today can sometimes call into question the true value of particular credentials.

While legislation and the push towards interior design registration/licensure may ultimately determine whether or not an individual seeks a professional credential, the NCIDQ certificate is, for the time being, an example of a path toward differentiation for interior designers across the continent. Unfortunately, the value of this professional credential has not been as well documented. Other industries, including healthcare, information technology, and automotive repair, may provide valuable insight on different ways individuals can associate value with a particular certification. Increased credibility, recognition/prestige, and improved customer satisfaction are just some of the observations in other industries that should be examined with respect to an NCIDQ certificate. Additionally, the link between professional certification and increased salary is another area of particular importance to some who are contemplating whether or not a credential's benefits outweigh its cost.

Methodology

As previously mentioned, only a few studies were found that addressed certification in the architectural and engineering (A/E) profession. Much of the literature found in this area has been completed by the authors of this current study. Thus, the authors modified a previously tested instrument titled *Perceptions of Certified Professional Constructors (CPC) Survey* developed by Bruce et al. [22] .The instrument was constructed using Survey Monkey and included a total of 35 questions about the respondents' perceived value of the certification and their demographic information. The researchers then forwarded the instrument to four educational experts for review. The population for this study included all NCIDQ certificate holders. At the time of this study, the NCIDQ advertised that over 26 000,interior designers had passed the exam since 1974. Of these, 2,487 allowed their e-mail addresses to appear publicly on the NCIDQ website at http://www.ncidq.org. Once the revisions to the survey instrument were complete, an electronic link to the survey was e-mailed to these certificate holders. Of the 2,487 original e-mails, 25 (1%) were returned to the researcher as undeliverable. Upon closing, 606 of the 2,462 successfully contacted the NCIDQ certificate holders (25%) had responded.

This study addressed one main substantive research question: are there statistically significant differences in the perceived value of the NCIDQ certification between subgroups possessing the certification? This question led the researchers to create six additional research questions asking if there were statistically significant differences in the perceived value based on six independent variables: 1) years the credential has been held, 2) reason why the respondent sought the credential, 3) level of support received from the employer, 4) location of practice, 5) age groups, and 6) type of organizations where the respondents are employed.

There were eight dependent variables concerning perceived value. Questions 4 a-h on the survey were used to measure the dependent variable. Table 1 below shows the questions. Respondents were asked to provide their level of agreement—from strongly agree to strongly disagree—to the eight statements. The researchers set the value of responses such that a response of strongly agree received a value of 5, agree 4, no difference 3, disagree 2, strongly disagree 1, and not applicable did not receive a value.

Results

Prior to presenting the results of the Analysis of Variance, it is worthwhile to note some general data. Figure 1 shows the frequency of the different organization types with Interior Designer as the most popular (58%). Table 1 addresses how the respondents felt about the impact the credential has had on their career in terms of recognition, professional opportunities, salary, opportunity for promotion, and job responsibilities.

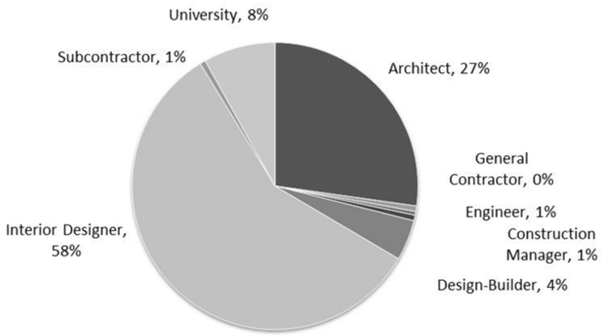

Figure 1. Organization Classification

Table 1. Survey Questions 4a-h Representing the Dependent Variable: Perceived Value

Survey Questions	**Agreed or Strongly Agreed**
Recognition: How has the NCIDQ certification impacted your career in terms of having others more fully recognize your abilities to perform your job?	72%
Contribution Opportunities: How has the NCIDQ certification impacted your career in terms of increasing your professional opportunities for contributions?	48%
Salary: How has the NCIDQ certification impacted your career in terms of increasing your salary?	41%
Promotion Opportunities: How has the NCIDQ certification impacted your career in terms of increasing your promotional opportunities?	50%
Job Responsibilities: How has the NCIDQ certification impacted your career in terms of increasing your job responsibilities?	42%
Prestige Among Superiors: How has the NCIDQ certification impacted your career in terms of increasing your prestige among superiors within your organization?	68%
Prestige Among Peers: How has the NCIDQ certification impacted your career in terms of increasing your prestige among individuals within your organization?	70%
Prestige Among Individuals Outside Organization: How has the NCIDQ certification impacted your career in terms of increasing your prestige among individuals outside your organization?	68%
	Yes
Do you feel more knowledgeable as a result of becoming certified?	69%
Do you feel more confident in your ability to do your work?	63%

With respect to the impact the credential has had on the respondents' careers and the means comparisons of the various sub-groups, 3 out of the 6 independent variables yielded statistically significant differences in at least one of the eight dependent variables. Tables 2 through 6 show the statistically significant differences among the various sub-groups.

Table 2 shows the mean responses for question 4a: How has the NCIDQ certification impacted your career in terms of having others more fully recognize your abilities to perform your job? The bolded means are those that were significantly higher at the 0.05 alpha level. The mean for respondents who have held the credential for 11-15 years was significantly higher than the mean for those who have held the credential for 1-5 years (F=2.877, sig. 0.006). Table 3 shows the results of Tukey's Honestly Significant Difference (HSD), which confirms the original significant difference.

Table 2. ANOVA Results for Increased Recognition by Years Certified

	<1	**1-5**	6-10	**11-15**	16-20	21-25	26-30	>30
Mean	3.77	**3.70**	3.93	**4.17**	4.08	3.98	4.05	4.04
n	57	206	111	64	48	51	21	25

F=2.877, Significance = .006

Table 3. Tukey's Honestly Significant Difference (HSD) Results for Increased Recognition by Years Certified

	(I) Years Cert	(J) Years Cert	Mean Diff (I-J)	Std. Err.	Sig.	95% Confidence Interval Low Bnd	95% Confidence Interval Upper Bnd
1	1-5	11-15	-0.468	0.13	0.008	-0.86	-0.07

Dependent Variable: 1. Impact

There were no significant differences between those that were required to seek the certification by the state and those that were required to seek the certification by their employer (independent variable 2) on any of the eight root questions associated with question 4a-h impact. Similarly, there were no significant differences in mean scores of professionals based on region where the respondent's office was located (independent variable 3).

Table 4 shows the mean responses for questions 4b (contributions) and 4d (promotions). For contributions, the mean for respondents in the 40-49 age group (mean=3.20) was significantly lower than the mean for those in the 50-59 age group (mean=3.65) (F=3.312, sig. 0.006). For promotions, the mean for respondents in the 20-29 age group (mean=3.60) was significantly higher than for those in the 60-69 age group (mean=3.00) (F=4.363, sig. 0.001) and 70-79 (mean=1.40) (F=4.363, sig. 0.001) age group. Table 5 shows the results of Tukey's Honestly Significant Difference (HSD), which confirms the original significant difference.

Table 4. ANOVA Results for Increased Contributions and Promotion Opportunities by Age

		Age Group	Age Group	F	Sig.
		40-49	50-59		
Contribution Opportunities	Mean	3.20	3.65	3.312	0.006
	n	129	141		
		20-29	60-69		
Promotion Opportunities	Mean	3.60	3.00	4.363	0.001
	n	82	60		
		20-29	70-79		
Promotion Opportunities	Mean	3.60	1.40	4.363	0.001
	n	82	5		

Table 5. Tukey's Honestly Significant Difference (HSD) Results for Opportunities for Contribution and Promotion by Age

	(I) Age Group	(J) Age Group	Mean Diff (I-J)	Std. Err.	Sig.	95% Confidence Interval Low Bnd	95% Confidence Interval Upper Bnd
1	40-49	50-59	-0.444	0.14	0.026	-0.86	-0.03
2	20-29	60-69	0.598	0.20	0.040	0.02	1.18
	20-29	70-79	2.198	0.55	0.001	0.62	3.78

Dependent Variables: 1. Contribution Opportunities, 2. Promotion Opportunities

Table 6 shows the mean responses for questions 4d through 4f: How has the NCIDQ certification impacted your career in terms of increasing your promotion opportunities, job responsibilities, and prestige among individuals within your organization? When interior designers were compared against all other organization classifications, the mean response for interior designers was significantly lower than all others for each of these three variables. Tukey's HSD could not be run since there were only two groups.

Table 6. ANOVA Results for Increased Promotion Opportunities, Job Responsibilities, and Prestige by Firm Type

		Interior Design Firms	All Other Firms	F	Sig.
Promotion Opportunities	Mean	3.17	3.44	6.898	0.009
	n	275	305		
Job Responsibilities	Mean	3.21	3.41	4.728	0.030
	n	276	305		
Prestige Among Individuals	Mean	3.53	3.77	5.788	0.016
	n	276	304		

Conclusions and Recommendations

The purpose of this research study was to determine whether there were statistically significant differences in the perceived value of the NCIDQ certification among subgroups possessing the certification. The researchers analyzed each respondent's answers to eight survey questions based on six independent variables. The eight survey questions involved the respondent's perception of the certification in increasing: A) recognition, B) contribution opportunities, C) salary, D) promotion opportunities, E) job responsibilities, F) prestige among superiors, G) prestige among peers within the workplace, and H) prestige among peers outside the office. The six major groups of independent variables were: 1) years the credential has been held, 2) reasons why the respondent sought the credential, 3) level of support received from employer, 4) location of practice, 5) age group, and 6) type of organizations where the respondent is employed. Of these six independent variable groups, three yielded statistically significant differences within and among their subgroups.

First, those that held the credential for 11-15 years valued the credential more than those that held the credential 1-5 years. This finding may help recent holders see that while they do not see value now, they may in the future. Also, for those thinking about obtaining the credential, this result may help them see that the results are more long-term than immediate. Second, there were no statistically significant differences between subgroups as to the reason why the credential was sought, the level of support received, and the location of practice. One might expect those required to obtain the credential would not value it as highly as those that sought it out on their own. Third, one might expect those that had no support from their employer to seek the credential might value it differently from those that received full support. Neither of these assumptions were supported. Fourth, there were no significant differences between any of the subgroups based on location of practice. Fifth, this study suggests that older professionals value this credential more than their younger peers when considering opportunities for contributions. However, in regard to promotional opportunities, the opposite was found to be the case. Those in the 20-29 age group felt more strongly that the credential has increased their opportunities for promotion than those in the 60-69 and 70-79 age groups. Does this mean that the latter two age groups are already retired? This question needed some clarification in the original survey. Perhaps a follow-up question could have been whether they are currently retired or are still working? Sixth, in regard to the types of organizations where the respondents were employed, one would expect that those working for interior design firms would value the credential more than those working for other types of firms. This was found not to be the case. In regard to feeling an increased opportunity for promotion, job responsibilities, and prestige among individuals within their organization, respondents working for interior design firms reported lower means than those working for all other organization types. Does this mean that within interior design firms, the credential is expected to be held? With all peers having the same credential, perhaps the impact is not as great.

Given the results discussed above, one could answer the research question in the affirmative. Yes, there are statistically significant differences in the perceived value of the NCIDQ certification between subgroups possessing the certification. The researchers hope this information will help those already holding the credential see that their perception of the credential could improve in the years to come and assist those contemplating whether to pursue it.

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SERVICE LEARNING: BRIDGING THE GAP BETWEEN CLASSROOM THEORY AND APPLICATION FOR TECHNOLOGY STUDENTS

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Abstract

Service learning provides an avenue where students are able to take what is learned in the classroom and provide a service to the community. Service-learning projects are typically organized to address a communal and/or societal need; however, students gain hands-on experience based on application of classroom theory. It is an academic approach that involves the instruction of students and/or participants on a prescribed objective. Often viewed as a progressive and sometimes constructivist practice, service learning is an effective strategy to help participants develop technical skills through abstract problem-solving simulations and activities.

This paper provides definition for and discussion of the application of service learning, and how technology is implemented in service-learning activities. In this study, the authors looked at how students in a Technology Education Master's Degree-level course learned fundamental concepts about instructional aides and adult learners, and created service-learning training to assist office personnel at a local agency. The class researched and identified a need for Microsoft Excel and Access proficiency for work for office personnel. While communicating with a non-profit organization in Mississippi, the Technology Education students discovered that their organization lacked some efficiency in record keeping due to deficiencies in Microsoft Excel and Access. Under the direction of the instructor of the Technology Education class, the students provided a service that was a fulfilling learning experience.

Introduction

Service learning is a process in which students take classroom applications and experiences to assist in fulfilling a societal need. The Virginia Office of Volunteerism and Community Services contends that service learning is an educational process by which students learn and develop through direct involvement in service that meets the needs of a community. It is coordinated between a school/ institution, community service program, and targeted community groups. This concept encourages the lifelong learning of participants and includes structured time for participants to reflect on the service experience [1]. Students may reflect by making hand-written or electronic journal entries with comments regarding experiences, thoughts, and views throughout the project. Since technology is such an integral part of lifelong learning and our ever-changing society, the union of service learning and technology will afford opportunities that will enable a progressive pedagogy for instructors. This will also allow participants to have autonomy in creative project development, and promote technological advancement throughout their community.

According to the International Technology and Engineering Educators Association (ITEEA), technology is defined as human innovation in action that includes the production of knowledge and progressions that will develop systems to solve problems and lengthen human competencies. Technology also involves advancements, transformations, or modification of the natural environment to satisfy professed requirements and needs [2]. With continuous advancements, transformations, and modifications, the community stands at the vanguard of a constant need for technological training and assistance. This renders a need for service [2], [3].

To assist in fulfilling this need, technology students may participate in service-learning activities to enhance their awareness of societal needs. In order for technology students at a post-secondary level to better assist, there must be research, assessment, and the evaluation of technological deficiencies in a community. This will aid the development of student comprehension on the pedagogy of technology integration. Students may identify a communal need such as computer literacy for which they may devise training sessions that will minimize computer illiteracy, as well as providing strategic methodologies and future recommendations. Once these objectives are satisfied, students will have more clarity of the theory and application acquired in the classroom, skills that they will use in the contemporary workforce.

Student Comprehension

Burr [4] suggested that today's progressive learning methods require a departure from emblematic, set and preconceived objectives because the learning will be student directed. Progressive education occurs as real-life applications are joined with a self-directed series of experiences that create unlimited possibilities. Burr further recommended that increased enthusiasm for learning could happen with the collaboration of progressive educational principles and service learning, resulting in progressive service learning.

In addition, great sums of persuasive confirmation attest to the benefits of service learning and experiential methods, thus revealing that teachers yet depend on the traditional practices of lecture and teacher-directed educational procedures—not appealing to all learning styles. Traditional practices should in no way be dismissed; however, they should include approaches where students are able to apply what has been learned in the classroom. Cohen and Brawer (as cited in Burr) stated the following:

> It is reasonable to assume that in an institution dedicated since its inception to "good teaching," new instructional forms will be tried. However, traditional methods of instruction still flourish. Visitors to a campus might be shown mathematics laboratories, the media production facilities, and computer-assisted instruction programs. But on the way to those installations, they will pass dozens of classrooms with instructors lecturing and conducting discussions just the way they and their predecessors have been doing for decades. (p. 155)

Service learning is an appropriate teaching and learning approach in which the workplace provides a practical setting for structured problem-based learning experiences. It has been indicated that technology can play a powerful role in project-based learning [5]. Technology contributes to student learning by enhancing interest, giving more access to information, providing active representation with the multimedia capabilities of technology, structuring the process to provide more tactical and strategic support, diagnosing and correcting errors more easily, managing complexity and aiding production, and providing potential for motivating students to carry out projects. During and after the service-learning project, it is essential that students have opportunities to reflect on what they have learned in the classroom, what they have experienced, and how they have positively impacted their community.

Service learning reflections

Service learning is an extension of classroom curriculum. It allows students to learn by performing services in their respective fields. It provides a great opportunity for students to receive hands-on training through application of classroom theory. Effective service-learning programs challenge students to reflect on their service experiences through such activities as group discussions and journaling. The need to introduce reflection and self-regulation into the learning experience is the most neglected component of service learning. However, it is a well-established fact that students learn through a combination of thought, theory, application, reflection, and civic engagement [6]. Effective learning can be achieved while discussing intellectual, civic, ethical, moral, cross-cultural, career, or personal goals [7]. According to Bradford [8], "students from middle schools are mastering academic content standards while immersed in hands-on, technology-integrated projects that provide learning experiences that are not usually possible within the confines of the traditional classroom". Integrating these various components greatly impacts learning experiences, especially when technology is present.

Technology Integration

Implementing technology into service learning is a major asset. Kurt [9] asserted that service learning can be a meaningful way to combine service with academic learning in a variety of technology courses. Technology-savvy students are eager to take on new roles in service learning. Service learning provides this change because students become more aware of their positive impact to the community while working on technical projects. "Integrating technology with service learning catches and holds the attention of students who have grown up in the digital age and rely on computers, video games, cell phones and digital music players for their information and entertainment" [9]. Students are given the opportunity to make advances in technology, especially when they assert that some technological applications are limited to their local community. With this in mind, students must have a strong technical skill set (e.g., computer application, electronics, manufacturing processes) and be able to develop a method of instruction that will appeal to those of various learning styles and abilities.

While technology is being integrated into every subject area, it is the instructor who decides what technology and how much of it will be used in his or her classroom. Instructors must stay abreast of the latest technologies and trends in order to prepare students for academic pursuits and the contemporary workforce. Since technology in the classroom can enhance instruction, it is very important that instructors develop effective ways to manage their classroom and the technology used in it. Along with managing the classroom and incorporating technology, instructors must not lose sight of activities involving critical-thinking skills, especially for graduate students.

Example of Graduate Student Involvement

At a research university in Mississippi, graduate students assisted a local non-profit agency in creating an electronic spreadsheet template that would allow the agency to better organize client information such as e-mail, phone, social network site data, and mailing addresses. The information was also to be placed in sub-groups that would categorize the clients. The original request was for a Microsoft (MS) Access 2007 database, but the participants were encouraged to utilize a Microsoft (MS) Excel 2007 program since the instructors were highly proficient. Based on the verbal communication from the Chief Administrative Officer (CAO) of the agency, the MS Excel 2007 spreadsheet would address their immediate needs. However, there were plans for the next service-learning project, which would convert the MS Excel 2007 spreadsheet into an MS Access 2007 database.

The fall, 2010, academic semester was when this venture began. As a part of the professor's syllabus, the students were informed about the service-learning project. According to Hatcher & Bringle [10], courses with service-learning objectives should provide opportunity for student reflection, community partnerships, student supervision and assessment, and course assessment and research. Adhering to this philosophy, twenty-four technology education graduate students became oriented with service learning, its concepts, and how service learning reflected their course objectives. The professor provided the students with a general definition of service learning, and provided three technology education philosophical concepts: progressivism (change), constructivism (building on pre-existing knowledge), and pragmatism (practical approaches).

To better assist the students on their venture, the professor invited a representative from the University's Center for Community & Service Learning to provide an orientation and inform the students about a local Mississippi non-profit agency's need. The agency was inundated with client data in various forms (e.g., business cards, forms, email addresses). The agency needed a system to better organize and store client data, and to become more skilled in a modern technology application to handle this process.

Methodology

The class was broken into smaller groups (5 members per group) that focused on logistics, instructions, training materials, and spreadsheet template design and development. Each group had a designated captain who made progress reports to the professor and organized collaboration with other groups. All groups had to work collaboratively in order to progress with their designated responsibilities.

Thirty hours were collectively spent by these groups and the technical advisor to assess the agency's objectives, build the Excel template, create in-class and take-home learning materials, secure training equipment and facilities, as well as administrative duties and parking permits for the agency participants. Throughout the semester, the students posted their reflections on the discussion board section of Web-CT. This allowed the students to share their learning experiences and post questions to the professor as well as other students. After the students completed their assigned tasks, they invited the seven agency representatives to participate in two, two-hour courses. The purpose of the training course was to teach the agency representatives about the new features in MS Excel 2007 and short-cut techniques, as well as to have the students present the new template. In addition, the students provided training modules and a short-cut table. Nevertheless, the professor and students wanted to ensure that training and resource materials were helpful to the agency representatives.

Instrumentation

Merranko & Zeolla [11] stated that in any service-learning project one must reflect on whether the objectives were mastered. During this project, these reflections caused the students to ponder whether their plan of action would benefit the individuals they were serving. As a result, the students reflected on the following: How did the service-learning process link to the essential needs of the participants? Did the participants actually learn the concepts? How could execution of the project be improved for future implementation?

The agency's seven participants were taught how to properly use MS Excel 2007 and how to enter data into the new template—these were the learning objectives. The learning objectives for the agency's participants were to be mastered during two training sessions. After the completion of the first training session, a survey was administered to the participants to discover whether the participants' needs were met. In addition, the survey was used to analyze the quality of the instruction, resources employed, and training materials.

The survey was divided into two sections: instructional materials and instructional effectiveness. Participants were able to rank their responses based on a 5-point Likert Scale (where 1-poor; 2-fair; 3-indifferent; 4-good; 5-excellent). The results of the participant feedback survey were as follows:

Table 1. Instructional Material

Instructional Materials	Score	Attainment
Quality of the Training Materials	20	100%
Quality of the Electronic Materials Covered	20	100%
Quality of the Work Sample	20	100%
Usefulness of the Materials	20	100%
Quality of the Resources Employed	20	100%

Table 2. Instructional Effectiveness

Instructional Effectiveness	Score	Attainment
Innovation and Creativity in the Teaching Technique	18	90%
Verbal Communication of the Instructors	19	95%
Eye Contact and Interaction of the Instructors	20	100%
Ability to the Instructor to "Reach" Every Learner	19	95%
Confidence, Carriage, and Conviction on the Subject	20	100%

Overall, the participants indicated that they were satisfied with the instruction and the training materials. However, the students did make stronger efforts to improve verbal communicate and transition of the instructional delivery. The graduate students also modified pedagogical approaches to ensure that participants of all learning styles were being reached. This was accomplished through lectures, distribution of MS Excel condensed short-cut guides and interactive activities (e.g., spreadsheet data entries, calculations, mail-merge and pivot tables). The graduate students wanted the participants to be 100% satisfied with the instructional materials and effectiveness.

Methods to Improve Performance Measurement

Unfortunately, the participants did not share any comments on how the students could improve upon their performance as a class. The graduate students strived for improvement based on feedback from the peer evaluation on group members and self-evaluation to identify areas of improvement. Some areas of improvement included: proper and timelier communication among team members, submission of materials to meet project milestones, and better delegation of workload. To mitigate these concerns, the graduate students indicated that proper execution of the service-learning project may have been reflective of the participants' mastery of the objectives. In addition, the student feedback would be implemented in the following semester's course, in which they would continue service-learning projects.

However, the professor evaluated all training materials and student participation projections and made the following constructive comments: make transitions from one activity to the next smoother; make sure the participants remain engaged; and, provide activities where participants can demonstrate comprehension and mastery. The graduate students believed that it would have been prudent for the class to construct "take home" exercises after both sessions that required the participants to e-mail the instructors a document that proved mastery of the concepts taught. The graduate students also indicated that a take-home activity would have been a better measure of whether or not the information had been properly retained after the participants departed from the classes and returned to their respective offices to apply the knowledge. This was a part of the students' period of reflection.

Student Reflections

Billig [12] asserted that reflections in service learning should connect the experience, content, skill, and value. The graduate students posted comments on the discussion board using Web-CT. The graduate students indicated that the service-learning experience was fulfilling and it helped them to better understand the course content. Additional student comments revealed that the project increased their desire to work collaboratively and more effectively. The graduate students indicated that they obtained knowledge from the services that were provided, and they learned the culture of the community through providing instruction for the agency.

Furthermore, Billig contended that reflections should be on-going and used to evaluate the improvement of service for students. The professor provided information that provided foundational service-learning content and technology implementation (i.e., as an instructional aide or to remedy a technological application deficiency). In addition, the professor provided the following assignments and activities: service-learning article reviews, reflection comment postings on Web-CT, verbal reflections during class discussions, a service-learning research and reflection project paper, and a classroom presentation at the conclusion of the project. The professor found that the graduate students grasped the technology education course content and were able to apply classroom knowledge during the service-learning project. However, the professor found that the activities should be condensed to allow the students more time to fully execute additional service-learning concepts and reflect on service-learning experiences. The professor did know that there would be a limit on opportunities so students had to share their thoughts about the project and exchange ideas.

Limitations and Future Recommendations

When attempting to teach and implement course objectives, time is of the essences. This may cause the professor to condense some course materials, and it may cause students to rush to complete projects. The professor and students acknowledge that timing was a significant constraint in this project as several weeks were lost due to the participants' scheduling conflicts. In considering timing, it was recommended that the next project with the agency and future service-learning projects begin earlier in the semester

The distinctive element of service learning is that it enhances the community through the service provided, but it also has powerful learning consequences for the students or others participating in providing a service. According to Cherrington [13], service learning is a distinctively effective and satisfying method that develops the educative process for both students and communities [13]. In addition, service learning allows for the opportunity to deliberate on their experience, where students desire to achieve real objectives for the community and deepen understanding of all facets surrounding such a service.

Service learning combines experiential learning and community service opportunities. Service learning is distinguished in the following ways: curricular connections, student voice, reflection, community partnerships, authentic community needs, and assessment. Curricular connection is integrating learning into a service project, which is then coupled with student interactivity. Students have the opportunity to select, design, implement, and evaluate their service activity. Then, students' reflection of service-learning activities helps to establish dialogue and provide communication regarding the overall experience [14]. There should be balance of reflection and students should have the opportunity to develop a deeper comprehension of classroom applications. This may occur when the students are able to become active participants in the learning process, while taking the theory and utilizing it to solve problems.

Conclusion

There is a demand for technology literacy in lower social economic areas. Some people tend to avoid technology and computer utilization for numerous reasons: 1) they have never been properly introduced and instructed on computer technology utilization, 2) they have never been informed of the benefits of using computer technology for professional or personal development, and 3) they are unaware of entertainment components. However, completion of proper training will minimize the computer illiteracy issue. Since this is an area in which students may provide assistance to minimize or alleviate this and other societal issues, it gives them the opportunity to apply acquired classroom knowledge.

Technology students should participate in service-learning activities to enhance their awareness of societal needs. They may assist in efforts in fulfilling those needs and other demands by utilizing classroom knowledge to fulfill the demands of the community in such areas as technology. Such efforts enable technology to serve as a means that continues improving the quality of life for all. Service learning motivates students and it also motivates learning. Moreover, service learning can help students develop leadership skills, teach them how to be involved citizens, and give them practice in working with others.

Genuine community needs are when local community members or service recipients are involved in determining the significance and depth of the service activities involved. Well-structured assessment instruments with constructive feedback through reflection provide valuable information regarding the positive, reciprocal learning and service outcomes for sustainability and replication. Service learning is one of the most prominent school-based approaches to involving students in their community. At its best, community service learning integrates school or community-based service projects with academic skills and content, and provides opportunities for structured reflection on the service experience [15-17]. Since service learning allows students the opportunity to learn through experiences, students may develop competencies that will prepare them for the contemporary workforce. Participating in a service-learning project not only helped employees of the non-profit organization learn valuable computer applications (MS Excel and MS Access), it created a positive connection between learning and the community for the technology education graduate students.

Since technology is ever-changing, some community entities may find it challenging to stay abreast of current trends. According to Wang [15], students who participate in high-quality service-learning programs demonstrate an increased sense of personal and social responsibility, and this was reflected in the students' project [18]. At the same time, these students showed an inspiration to learn. This translates into higher attendance rates and increased academic performance. Service learning has a positive effect on interpersonal development, student comprehension, and teamwork [19]. Students see themselves as positive contributors to their community, thus feeling they can impact the world around them. These were sentiments expressed by the technology education graduate students.

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KEEPING APPLIED CONSTRUCTION TEACHERS IN THE SECONDARY SCHOOL SYSTEM

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Abstract

The purpose of this study was to investigate the reasons why applied construction teachers in the Career and Technology Education (CTE) field are leaving the teaching profession in their first five years of service or, if they stayed, what were the dominant factors that caused them to consider leaving the profession and what were the factors that were causing them to remain in the CTE field in one Midwestern state. This was done through the triangulation of 44 mixed-design surveys with open-ended questions and six semi-structured interviews.

The data revealed there was a significant difference in the retention rates of four-year teachers with teaching degrees and alternatively certified teachers. The four-year teachers with teaching degrees and a Bachelor of Science degree in Education had a higher retention rate than those teaching with construction experience and alternative certifications. The data also revealed that the only significant difference in why four-year teachers with teaching degrees and alternatively certified teachers had considered leaving the profession was that the alternatively certified teachers were considering leaving because of limited opportunities for professional advancement.

The main reason teachers who had been teaching more than three years thought that teachers were leaving their profession was due to low pay; however, the teachers who had left stated that salary was not at all important in their decision to leave the CTE teaching profession and they stated that their main concerns were student discipline problems, dealing with special-needs students that were not interested in the program, poor student motivation, and lack of influence over school policies. Considerations of why teachers were thinking about leaving the profession included low salary, inadequate support from administration, and student issues, especially discipline and poor motivation.

The data showed, overwhelming, the reasons why teachers were staying in the profession. Over 75% of the responses dealt with enjoyment of working with the students and seeing student success in their field, followed by teacher benefits and a strong teacher retirement program.

Introduction

The educational community understands that there is a shortage of quality teachers in classrooms across America. The National Commission on Teaching and America's Future [1] announced that teacher retention was a national crisis, and Bartell [2] agreed when he stated "the need for well-qualified, highly competent teachers has never been greater". The CTE field has not been immune to the teacher-shortage problem. A study done by Heath-Camp & Camp [3] reported that 15% of newly hired vocational education teachers leave after their first year, and an astonishing 48% of trade and industrial arts teachers leave before their third year has ended. Teachers going into education and not staying in the field long enough to become an established, viable asset to the program is one of the problems facing CTE programs today [4], [5].

Many students benefit greatly from these hands-on learning environments by attaining skills that will help them get a job and provide earnings both before and after graduation. These hands-on experiences will also provide the benefits of increasing student engagement, retention, persistence, and directing them to postsecondary education and the pursuit of lifelong learning [6]. However, research done by Gray & Walter [7] reveals there is a general shortage of CTE teachers, and "in some programs, such as technology education, the shortage is so severe that it threatens the program of study's very existence".

Therefore, using quantitative and qualitative data, this current study examined the reasons construction teachers in the CTE field left the teaching profession in a Midwestern state in their first five years of service or, if they stayed, what were the dominant factors that caused them to consider leaving the profession and what were the factors that caused them to remain in the CTE field. In addition, ideas for local industry to support and help retain current CTE teachers were considered.

Design

The research questions for this study were designed to reveal descriptive, quantitative comparison data regarding any difference in the retention rates of four-year teachers with Bachelor of Science degrees in Education from CTE programs compared with alternatively certified teachers. In this Midwestern state, to be alternatively certified to teach at a CTC, the individual needed 6,000 hours of approved occupational experience within the past 10 years, would have to agree to have a mentor teacher assigned for two years, and agree to take a minimum of two courses a year, six semester hours, for three years for a total of six classes. The classes include information in basic foundations of education, curriculum development, methods of teaching, and assessment. The study also looked at differences in the reasons four-year degree CTE teachers have considered leaving compared to alternatively certified teachers, and the dominant reasons CTE teachers are leaving the profession during their critical first five years. In addition, phenomenological qualitative data based on participants' answers to open-ended questions and personal interviews were used to validate and expand on the dominant reasons construction CTE teachers have left the profession, factors causing existing teachers to consider leaving, and factors causing them to stay in the teaching profession.

The quantitative data were obtained from a survey consisting of closed and open-ended questions, and was administered to the population of construction CTE teachers in a Midwestern state's secondary school system during the school years of 2003-2007. By using information from the Department of Education, 109 individuals were qualified as teachers giving instruction in construction processes during the years in question. The comprehensive high schools employing a construction CTE teacher were called and the contact information was verified for each teacher at each of these institutions. Area Career and Technology Centers (CTC) were also contacted. CTCs are strategically located vocational/technical schools that service several area high schools with vocational programs that are too expensive to be offered at each individual school. Students are bused to these locations and every CTC with a construction teacher was also contacted. Each participant was emailed, informing them of the research taking place and asking for their assistance in the survey.

Participants were asked on the survey if they would be interested in taking part in a personal interview to collect more descriptive information that would "directly reflect the purpose of this study and guide in the identification of information rich cases" [8]. From these responses, a purposeful and convenient sampling was made in the form of follow-up interviews with both teachers who have stayed in the teaching profession and have been teaching for three or more consecutive years, and those who have left the teaching profession and changed vocations before having three years of teaching experience. These interviews were intended to provide the researcher with additional insight into retention and attrition of construction CTE teachers.

The researcher identified five construction CTE teachers who left before their third year of teaching. There were 12 more teachers that had less than three years of teaching experience, therefore their data were not used for the purposes of this study. Two of those who left the profession could not be found by the researcher; however, two of the remaining three filled out the survey and were interviewed. There were 92 potential candidates who had been teaching for three or more years; 18 were located in the comprehensive high school setting and the remainder were located in area CTCs. Of those 92 surveys that were sent out for participation in this study, 42 were returned, yielding a return rate of 45.7%. The teachers who began teaching after the 2006 school year and were still teaching at the beginning of the 2008-09 school year did not have three years of experience, and therefore their data were not used for the purposes of this study.

Semi-structured, follow-up interviews were then conducted by the researcher. The researcher interviewed both of the teachers who had left the profession and four of the teachers who had been in the profession more than three years, both in the comprehensive high school and CTC settings. The selected individuals included both four-year degree CTE teachers and alternatively certified teachers. The interview served as a probe of the questionnaire responses and provided a purposeful sampling of participants with the opportunity to extend their open-ended written answers and further consider related issues of retention and attrition of construction CTE teachers.

Findings

Demographics

All of the respondents were male. The average age of the respondents was 48 with an average of 13 years of teaching experience. It should also be noted that 25% of the teachers answering the survey were at least 55 years old and several stated they would be retiring in the next three years. Seventy-seven percent of the respondents were teaching at a CTC and 73% were teaching with their alternative certification. Four of the alternatively certified teachers had a four-year Bachelor of Science degree. The four degreed teachers who were certified had degrees in Construction Management, Elementary Education, Forestry, and Environmental Design.

Retention Rates

There was a significant difference in the retention rate of four-year teachers with teaching degrees compared to their alternatively certified counterparts. These four-year teachers with teaching degrees had a higher retention rate. This is in agreement with other research that has been done on a national level; alternatively certified teachers have a lower retention rate compared to the four-year teachers with teaching degrees [9-11].

Differences in Reasons Four-year and Alternatively Certified Teachers Have Considered Leaving

Forty-two participants rated 13 possible reasons for leaving the profession on a scale of 1 (Not at all Important) to 5 (Extremely Important). An independent-samples t-test was conducted to compare the means of each answer between the two groups of teachers; the significance level was .05. Analysis revealed one significant difference between the possible reasons the four-year construction CTE educators considered leaving the profession from those teachers having an alternative certification. Alternatively certified teachers (M = 3.07, SD = 1.22) rated "Poor opportunities for professional advancement" significantly more important compared to their four-year colleagues with teaching degrees (M = 2.08, SD = 1.12). Therefore, it can be concluded from the data that "Poor opportunities for professional advancement" is less important to four-year teaching degreed teacher, t (42) = 2.50, p = .02, and consequently may believe they are in a better position for advancement than their alternatively certified counterparts (Table 1).

Reasons Teachers Have Left the Profession

Current construction CTE teachers believed salary was the number one issue in teachers' decisions to leave the profession. However, those leaving the profession contributing to this study revealed that salary issues were not important in their decision to change positions. They understood the salary issues when they took the position. What they were unprepared for were the discipline problems. Those leaving ranked student discipline problems as their highest concern. One teacher stated that new teachers "do not realize the student discipline problem would be such an issue" and one remarked that the "frustration with the lack of discipline of students is a major concern." One teacher who left the profession stated, "If the counselors had to spend a week in my

Table 1. Reasons Teachers Have Considered Leaving the Teaching Profession

Reason	Four-year Teaching Degree	Alternative Certification				
	M	*SD*	*M*	*SD*	*t*	*p*
Poor salary	3.85	0.99	3.69	1.07	0.49	0.66
Inadequate support from administration	3.69	1.44	3.24	1.21	1.05	0.30
Student discipline problems	3.54	1.13	3.21	1.24	0.83	0.41
Lack of influence over school policies	3.00	1.08	3.07	1.36	0.16	0.87
Lack of control over own classroom	2.31	1.65	2.52	1.57	0.39	0.70
Challenges caused by special needs students	2.85	1.46	2.76	1.24	0.20	0.84
Not given enough time	2.62	1.12	2.48	1.21	0.34	0.74
Poor student motivation to learn	3.31	1.38	3.45	1.18	0.34	0.74
Inadequate mentoring	2.38	0.96	2.69	1.34	0.84	0.41
Poor opportunities for advancement	2.08	1.12	3.07	1.22	2.50	0.02
Class size too large	2.92	1.32	2.55	1.43	0.80	0.43
Sometimes do not feel suited for teaching	1.77	1.17	1.90	1.26	0.31	0.76
Preparation for teaching inadequate	2.23	1.54	2.00	1.20	0.53	0.60

Means, Standard Deviations, t Statistics and for Career and Technology Education (CTE) Teachers with a Four-year Teaching Degree vs. Construction Experience with Alternative Certification
Note: N=42

class, that would change everything. I tried to tell them, if you would be afraid to leave this kid alone that you've assigned to my class with a power tool or a blow torch or a framing hammer for five minutes, if you're afraid to leave them alone, don't put them in my class."

Challenges caused by special-needs students and poor student motivation ranked a close second and third, respectively. Teachers who had been in the profession more than three years also noted student issues and poor support from administration as major concerns for those leaving the profession.

Reasons Teachers Have Considered Leaving the Profession

The main reasons current construction CTE teachers have considered leaving the teaching profession, ranked in order of importance, were poor salary, inadequate support from administration, poor student motivation to learn, student discipline problems, and lack of influence over school policies. Several of the teachers commented that industry is not involved at all in their CTE programs. All of these issues were in agreement with other research studies. Therefore, this study suggests that even though strides have been made in teacher retention, there are still concerns that should be considered to help retain CTE teachers.

Reasons Why Teachers Are Staying in the Profession

There were two dominant reasons why current construction CTE teachers were staying in the profession. The overwhelming response given by 76 % of the teachers who had been in the teaching profession more than three years was their enjoyment of working with the students who wanted to learn and seeing students learn and become skillful in the construction craft. One wrote, "I enjoy having my students being able to learn something they were having a hard time wrapping their minds around", and another commented they had a "belief in the need for students to know a skill that will/can provide a living for them". One stated there is "the reward of how it feels when I make a connection with students that have traditionally been cast off as worthless by academic teachers, and then they excel in my program."

The other prevailing reason given by 33% of the teachers were the benefits and retirement that went with the job. Several teachers indicated they would have left the profession if it were not for the secure and excellent retirement package. Therefore, these positive factors should be addressed more frequently to help promote an optimistic school climate and encourage current CTE teachers.

Conclusion

The study's findings have direct implications for administrators, counselors, school boards, state departments of education, post-secondary institutions, and the construction industry. Since 73% of the teachers responding had their alternative teaching certificate, it appears that alternative certification will continue to play a significant role in the near future. Therefore, state departments of education should continue to strive to give these individuals the very best training possible in the shortest period of time to prepare them for their first-year teaching experience. Since the review of literature and this study both indicate higher attrition rates for alternatively certified teachers, it is imperative the educational system do everything it can to ensure the success of these individuals.

This training should emphasize classroom management, student discipline preparation, and grounding in the areas of handling special-needs students. These beginning teachers need to be prepared for students' lack of motivation and lack of respect. One teacher said he thought teachers were leaving because the "instructors were thrown to the wolves by administration." The school counselors can also play an important role in making sure the students enrolling in the CTE programs are interested in the area into which they are being placed and that the program is not used as a "dumping ground" for problem students. Many students are placed in CTE programs by the counselor simply because they do not know what else to do with them; it can become a detriment to the entire program. As one teacher pointed out, "[I am] frustrated over a single student occupying the majority of my time." Therefore, the counselors should be educated in the construction CTE program and what basic skills are necessary to make a successful student in that program so they can be placed accordingly.

In addition, because student discipline is such a major factor in the retention of construction CTE teachers, administrators need to take an active role in classroom and student discipline and support the teacher so they do not believe they are fighting the discipline battle alone. The educational community should also encourage CTE teachers who have a good understanding of CTE protocol to further their education and become administrators as they will have empathy for the discipline issue. Administrators can show tremendous support by taking the appropriate action with problem students and actively reinforce the concept that the teacher is not in this profession alone.

Administrators, school boards, the surrounding community, and industry can also bolster the retention of construction CTE teachers by giving them positive reinforcement at every opportunity. Many of these teachers have left prominent, high-paying jobs because they wanted to become teachers. The data suggest that many of these alternatively certified teachers are thinking about leaving because of the pay, and there is no opportunity for advancement in their field. Inman and Marlow [12] stated that the teacher most likely to leave the profession is the male teaching in the high school setting who has not been teaching very long. These teachers have communicated that the professional prestige of the profession is not as good as they originally perceived it would be. Therefore, these teachers need to be encouraged at every opportunity and shown they are needed and supplying a valuable service to the student, the school, and the community.

Local industry needs to become actively involved with CTE programs and educators. Some of the survey suggestions included "help students job shadow", "help subsidize pay and give teacher bonuses or incentives to stay in the teaching field", "partner with classes and provide opportunities for teachers to remain abreast of new technology", and "create a unified certification process for students and then make it a priority to hire those students." Additional suggestions included educational support on new advances in technology and equipment and financial support for newer and more advanced equipment to the program. These teachers need to be encouraged at every opportunity so that they become a positive driving force in the lives of their students and in the future workforce.

In addition, since the data indicated the number one reason teachers were staying in the field was their enjoyment of seeing students learn and seeing the students becoming successful and skillful in their field, it would be advantageous for the educational community to convey these success stories to the CTE teaching profession. Therefore, it would be an asset to the CTE teaching community if a newsletter or website could be established, where teachers could communicate their accomplishments, projects, and students' success stories to help strengthen and encourage other CTE teachers across the region.

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Preparation of Engineering and Technology Graduates for Manufacturing Careers

Phillip S. Waldrop, Georgia Southern University; Hugh Jack, Grand Valley State University

Abstract

Faculty in programs other than manufacturing engineering need to teach manufacturing content in order to enhance student success in their careers. Whether designing special machines, solutions for transportation, agriculture, structures, energy, or consumer products, employers require that the designs go beyond function and style to consider economic manufacturability in a globally competitive environment. Regarding the need for manufacturing-oriented education, an argument was made for the need for manufacturing content in all technical degrees, including Mechanical Engineering. Examples of manufacturing considerations in design are presented here.

Introduction and History

Education is an inexact process. The design and delivery of content is a careful balance of objectives, constraints, and limited resources. Teachers strive to prepare graduates who will have successful careers and contribute to society. This process would be easier if the curriculum could be tailored to the students and their careers. In practice, though, the curriculum must try to stretch resources to serve the most students in the best way possible. After graduation, students enter the workforce or sometimes return for more education. Where and how the graduates are employed varies widely; however, there is no question that a majority will be directly or indirectly working in the manufacturing fields. Consider the following statement from a Department of Labor report [1];

> About 36 percent of engineering jobs were found in manufacturing industries, and another 30 percent were in the professional, scientific, and technical services industries, primarily in architectural, engineering, and related services. Many engineers also worked in the construction, telecommunications, and wholesale trade industries. Federal, State, and local governments employed about 12 percent of engineers in 2008. About 6 percent were in the Federal Government, mainly in the U.S. Departments of Defense, Transportation, Agriculture, Interior, and Energy, and in the National Aeronautics and Space Administration. Many engineers in State and local government agencies worked in highway and public works departments. In 2008, about 3 percent of engineers were self-employed, many as consultants. (5-6)

The most common engineering titles in industry are Design Engineer and Manufacturing Engineer. Ironically, the number of graduates with manufacturing degrees is very small compared to the number of employees with the title Manufacturing Engineer and there are no Design Engineering degrees. Many mechanical engineers are hired to work as manufacturing engineers without having had so much as a manufacturing processes course. Likewise, many designers are hired without any knowledge of how their designs will be produced. The simple fact is that if any engineering program is to effectively serve its graduates, it must include manufacturing content. Some of the gaps between the higher education outcome and industry needs have been identified in the Manufacturing Education Plan (MEP) from the Society of Manufacturing Engineers Education Foundation (SMEEF) [2].

General Competency Gaps:

- Business Knowledge Skills
- Project Management, International Perspective
- Written and Oral Communication
- Problem Solving
- Teamwork
- Personal Attributes

Manufacturing Competency Gaps:

- Supply Chain Management
- Materials
- Manufacturing Process Control
- Product/Process Design
- Quality
- Specific Manufacturing Processes
- Manufacturing Systems
- Engineering Fundamentals

Manufacturing-specific programs have been making progress in addressing these needs [3], to the shared benefit of graduates and industry alike. Other disciplines, such as Mechanical Engineering, are making progress on the general gaps but there are some excellent opportunities to address the manufacturing gaps. The extent of these curricular modifications and redesigns varies in scope and the addition of manufacturing curricula can occur many ways. Consider a

Mechanical Engineering program or instructor who chooses to address more manufacturing content. A very-low-impact approach is to add a few manufacturing-oriented problems and examples to an existing course by adopting a textbook in machine design that includes manufacturing considerations [4]. Another positive change might be the addition of manufacturing design techniques to a machine design or similar course. A subsequent section of this paper outlines the Design For Manufacturing (DFM) technique that can be applied to many design courses in many disciplines. More elaborate efforts include the addition of new electives or new emphasis areas in a program.

The Manufacturing Body of Knowledge

Manufacturing is a very old discipline that was exclusively housed in non-manufacturing-titled technical programs until 1955 when Hartford State Technical College (now Capital Community College) accredited their Manufacturing Engineering Technology Associate degree program. Since then the count of manufacturing-named programs in the U.S. has increased to over one hundred. Regardless, manufacturing education remains a vital part of many other technical degrees. How these other programs define manufacturing knowledge is a function of the program type and focus. For example, a mechanical program would tend to focus on machines, while an electrical program might put more focus on assembly.

Industry widely recognizes the need for reeducating new employees for manufacturing careers. Larger companies such as Caterpillar [5] develop and offer academic courses to cover the education gaps of new employees. When possible, companies try to use external educational sources including private training and relationships with local schools [6]. A vivid example is the recent corporate focus on Lean Manufacturing that has resulted in tremendous investments in continuing education and training. Even a minimal understanding of Lean Manufacturing gives new graduates a tremendous advantage in job seeking.

An academic degree indicates, at minimum, exposure to and, oftentimes, mastery of a certain body of knowledge. Given that few professional job applicants have degrees in design engineering or manufacturing engineering, employers must use a résumé to determine qualifications. In the absence of an appropriate degree, many manufacturers use certification as an alternative qualification. From an employee perspective, certification proves that their knowledge meets certain standards. Unlike degrees, certifications come in many forms, often endorsed by a professional group. At the entry level, these can include skills such as safety. At the upper professional level, these can include advanced design and manufacturing skills such as Lean Manufacturing or systems design management.

One of many groups involved in manufacturing education and certification is the Society of Manufacturing Engineers (SME). Of interest to this discussion are the Certified Manufacturing Technologist (CfMT) and the Certified Manufacturing Engineer (CfME) certifications. These certifications have a number of requirements including years of service and standardized tests. The standardized tests are based on a formal Body of Knowledge that is parallel to many undergraduate programs [7]. The major categories are summarized with content percentages used for certification testing. The exhaustive SME body-of-knowledge document breaks these headings out into finer details such as liability, algebra, communications, and tool design.

1. Mathematics, Applied and Eng. Sciences (10-12%)
2. Product/Process Design and Development (10-12%)
3. Manufact. Process Applications and Operation (14-15%)
4. Prod. Systems and Equip. Design/Develop. (20-21%)
5. Automated Systems and Control (7-9%)
6. Quality and Continuous Improvement (10-13%)
7. Manufacturing Management (14-15%)
8. Personal Effectiveness (8-10%)

A step above certification is accreditation. Accredited programs have been reviewed against formal standards and are endorsed with some legal standing. For manufacturing programs, there are two main accrediting groups, ATMAE and ABET. Technology programs from two-year, four-year, and graduate levels are accredited by ATMAE (Association for Technology, Management, and Applied Engineering), formerly known as NAIT. ABET, Inc. (Accreditation Board for Engineering and Technology) has historically focused on four-year, entry-level degrees in Engineering and Technology. The criteria for ABET manufacturing programs are provided below. These accreditation criteria have been developed by volunteer groups in SME.

ABET-TAC Manufacturing Engineering Technology
2012-13 [8]

Objective: An accreditable baccalaureate degree program in manufacturing engineering technology will prepare graduates with technical and leadership skills necessary to enter careers in process and systems design, manufacturing operations, maintenance, technical sales or service functions in a manufacturing enterprise. Graduates of associate degree programs typically have strengths in manufacturing operations, maintenance and service functions.

Outcomes: Programs must demonstrate that graduates are prepared for careers centered on the manufacture of goods. In this context, 'manufacturing' is a process or procedure through which plans, materials, personnel, and equipment are transformed in some way that adds value. Graduates must demonstrate the ability to apply the technologies of materials, manufacturing processes, tooling, automation, production operations, maintenance, quality, industrial organization and management, and statistics to the solution of manufacturing problems. Graduates must demonstrate the ability to successfully complete a comprehensive design project related to the field of manufacturing.

ABET-EAC Manufacturing Engineering 2012-13 [8]

Content: The program must prepare graduates to have proficiency in (a) materials and manufacturing processes: ability to design manufacturing processes that result in products that meet specific material and other requirements; (b) process, assembly and product engineering: ability to design products and the equipment, tooling, and environment necessary for their manufacture; (c) manufacturing competitiveness: ability to create competitive advantage through manufacturing planning, strategy, quality, and control; (d) manufacturing systems design: ability to analyze, synthesize, and control manufacturing operations using statistical methods; and (e) manufacturing laboratory or facility experience: ability to measure manufacturing process variables and develop technical inferences about the process.

A parallel set of standards is offered by ATMAE. However, ATMAE has a much broader mission than SME and ABET including accreditation and certification of both technical and technical management programs. Despite the different approaches of these groups, they are complementary and are coupled by overlapping membership, interests, and objectives. As an illustration of the similarities, the ATMAE Certified Manufacturing Specialist (CMS) Certifications are listed here [9]. Although stated differently, they are parallel to the expectations of SME and ABET.

1. Manufacturing Joining Processes
2. Manufacturing Forming Processes
3. Manufacturing Casting Processes
4. Nontraditional Machining
5. Machining
6. Manufacturing Philosophies
7. Polymers
8. Industrial Materials
9. Computer Integrated Manufacturing
10. Quality
11. Production Planning
12. Wood Technology
13. Metrology
14. Supervision/Management
15. Technical Drafting
16. Electronics

Another partner is the U.S. Department of Labor (DOL), which has a mission "To foster, promote, and develop the welfare of the wage earners, job seekers, and retirees of the United States; improve working conditions; advance opportunities for profitable employment; and assure work-related benefits and rights." The DOL plays a major role in defining and supporting manufacturing, including Engineering and Technology professions. In terms of standards, they define various career paths in manufacturing and provide education and training support. One ongoing and relevant development is the DOL Skills Pyramid model [10] shown in Figure 1. The certification and accreditation models discussed previously focus heavily on knowledge, while the DOL model focuses on skills and competencies.

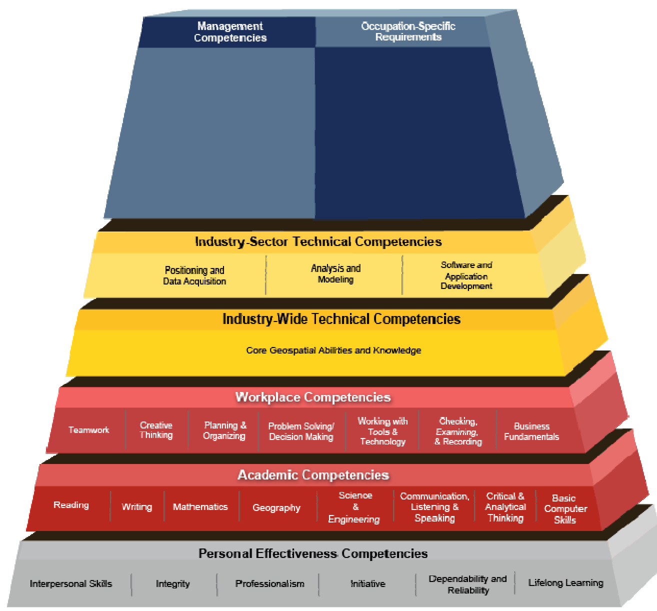

Figure 1. The DOL Skills Pyramid

The Four Pillars of Manufacturing Engineering

In 2010, a discussion arose between academics and professionals with an interest in better defining Manufacturing Engineering. Similar efforts had been undertaken previously [11-13] but changes in technology, competition, globalism, and methods required an update. After numerous rounds of discussion, the Four Pillars of Manufacturing Engineering model emerged, as shown in Figure 2 [14]. The model was meant to be descriptive (not prescriptive) and integrate the various models discussed in the previous section including ABET, ATMAE, DOL, and SME standards. An extensive description and application examples for this are available in the Curricula 2015 Report [3].

The model is based on the four fundamental pillars of i) Materials and Manufacturing Processes, ii) Product, Tooling and Assembly Engineering, iii) Manufacturing Systems and Operations, and iv) Manufacturing Competitiveness. The divisions for the pillars are aligned with the ABET manufacturing program criteria. Each of the pillar areas can be broken into sub-topics such as Metrology, under Quality and Continuous Improvement, under Manufacturing Competitiveness. The sub-topics in the pillars are drawn from various Body of Knowledge documents. These divisions of

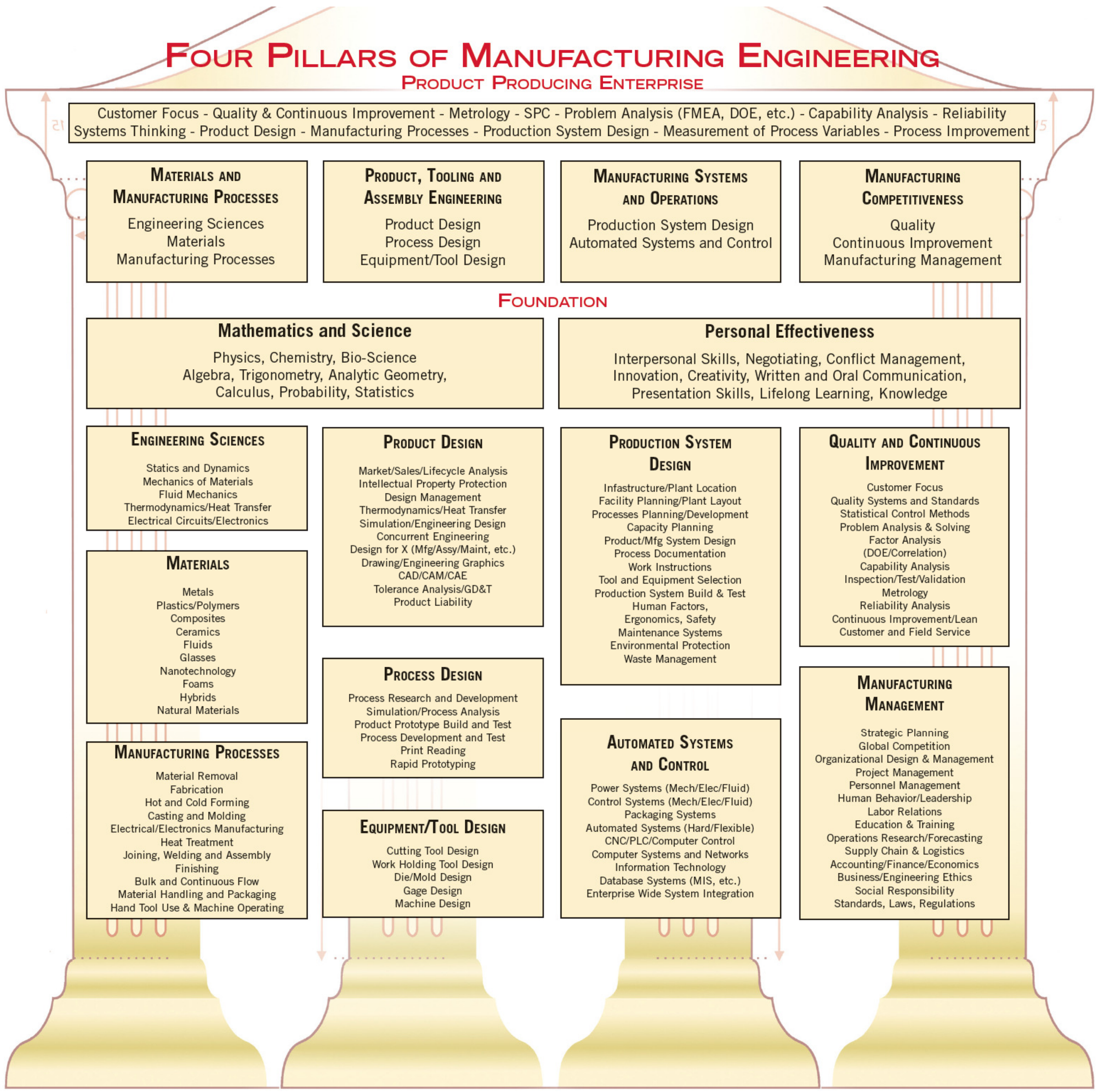

Figure 2. The Four Pillars of Manufacturing Engineering

the pillars and topic areas were based on current standards and practices with no intent to redefine. Beneath the four pillars are the foundations of i) Mathematics and Sciences and ii) Personal Effectiveness. The roof of the structure includes those professional skills recognized by multiple sources including the SME competency gaps, the DOL pyramid, and all accreditation standards.

With respect to a curriculum, a manufacturing-titled program will contain extensive coverage of all four of the pillars. On the other hand, non-manufacturing-titled programs, like Mechanical Engineering, will cover some of the four-pillar subjects such as Materials but may exclude others such as Manufacturing Management. It is worth noting that a topic like Materials can be taught multiple ways, including some that do not include the manufacturing aspects of materials. While this may ”check a box” in a column, it does not benefit the manufacturing body of knowledge. It is understood that the clean boxes in the columns will not always align with particular courses and curriculum threads, but the whole of the curriculum is what defines a manufacturing engineer.

The model is still being refined and reviewed, but it has been receiving wide acceptance and it could be used in the accreditation process to illustrate program coverage and emphasis. For programs with other emphases, like Mechanical Engineering, the four-pillars diagram can be used as a visual tool for assessing manufacturing coverage and opportunities in the curriculum. The Four Pillars can also be used as a medium when discussing program focus with companies and advisory boards so as to set a common language for discussion. At present, the model is not as well suited for describing associate and graduate degree programs but can certainly set a context for selecting content and courses. The content of the Four Pillars will continue to evolve with the field of manufacturing and with contributions from topic experts. Examples of topics that may see greater individual prominence include energy, the environment, product lifecycle, sustainability, agility, and simulation.

Design for Manufacturability and Assembly: A Classroom Application Example for Mechanical Engineering Faculty

As stated earlier, the critical nature of product design activities must go far beyond ensuring functional performance and durability. Commercial products of all types and volumes must be designed so that they will be economically successful in the face of global competition. It is estimated that as much as 80% of the cost of a product’s development and manufacture is determined by the various decisions made in the initial design stages [15]. Students must be made to realize that a critical cost element is time. Reiterations of a design through review and rework sessions—so that the product can be produced and sold—is not only costly in terms of money and engineering resources, but especially time in the sense that the end product is delayed in becoming available to potential customers. New products that come on the market earlier than others typically earn a greater portion of sales volume and revenue.

After an initial design is adopted and produced, product engineering often evolves to include re-engineering effort addressing changes to style, next-generation materials, increased demand, performance or cost reduction goals, or governmental regulations. Creative, effective problem solving demands a broad awareness of potential material/ process solutions and related issues. The process of designing a product, whether a single component or a complex final assembly, requires a professional knowledge set that involves aspects from each of the four pillars of Manufacturing. With rare exceptions, product designers must be future-oriented. Therefore, it is essential for design professionals to not only have a foundation in existing technologies and methods of utilizing them, but to also maintain and grow their knowledge by proactively pursuing opportunities to learn about new and emerging materials, processes, advances in equipment and tooling, automation, and aspects that improve waste-reduction and competitiveness. Curricula must evolve to keep pace with associated technologies.

Engineering faculty must, in course content and delivery, include the above factual content issues, but also emphasize concepts, facts, and examples of what are commonly referred to as producibility or manufacturability considerations and solutions in product design. There are many directly related print and electronic reference materials available under the heading of DMFA (Design for Manufacturing and Assembly) or Product Life Cycle Design, which looks beyond production to include factors such as serviceability and “cradle to grave” environmental impact [16].

- One key concern is designing within the scope of the processes and limitations used by the manufacturer’s own factory, and/or their suppliers. An example is the case of a major U.S. aerospace firm’s engineering project manager trying to keep proposal costs down by excluding a producibility engineer from the initial design team. After six months of costly design work on a titanium substructure, a manufacturing producibility engineer was allowed to review the design. He informed the designers that while the design solution was elegant, there was only one forging press in the world capable of producing the large critical central forging, and it was in Russia.

- Another concern is the reduction of processing and assembly costs. A case example is found in the redesign of the blower housing (air-cooling engine shroud) assembly of a small gasoline engine. Converting from a metal design to plastic eliminated metal drawing and stamping, VOC solvent cleaning and painting, while greatly reducing the number of parts and thus the related production floor space, equipment, materials, and assembly labor. In this case, the combined cost savings more than offset the fact that the now integrated assembly would need to be purchased from a supplier since the parent firm was not in the business of molding plastics. Further benefits involved end-product weight and noise reduction.
- A classic case involving Product Life Cycle Design is the instance of an office copy machine manufacturer focusing on the reduction of assembly costs through desirable features such as using snap-fit rather than screws or other fasteners. The product was a success in terms of selling price, but a failure because the component most often needing service replacement was buried within the machine. Users were faced with major service-call costs because of the time required to get at the component and then reassemble the machine.

Importantly today, DFMA and Product Life Cycle Design, as umbrella terms, must include Lean concepts and requirements in addition to the traditional focuses illustrated above. Lean methods involve identification and elimination or minimization of eight categories of waste. For example, parts and assemblies may need to be designed in consideration of the Group Technology approach so that they fit into product families that are used to define the workflow and capabilities of work cells in the modern focused factory.

Mini case studies such as those described above can be effective tools when briefly included in materials science, engineering economy, or design classes. One goal of the SME Manufacturing & Research Community is to develop and disseminate such case studies to engineering faculty. Beyond this sprinkling of producibility content, faculty members may find it difficult to include ever greater amounts of additional content within the lecture time allotted to existing courses; and adding a dedicated new manufacturing course within the constraints of the undergraduate curriculum simply may not be possible. It should be noted, however, that processes and producibility-focused and/or Lean methods courses could be value-adding components of graduate program offerings, serving to fill the manufacturing knowledge gap that is typical of recent graduates of B.S. degree programs and of significant concern to industry.

An excellent way to convey an understanding of the issues and importance of manufacturability knowledge is to provide the students with real-world case studies in the form of study assignments outside of class. Case studies may involve good, effective examples of producibility in design, as well as examples of real-world failures and successful redesign solutions. The literature contains a great amount of related supporting information, and real-world case examples may also be contributed through interviews with local companies, submissions from academic program industry advisory board members, or external sources such as SME. These cases can be very motivating to the students when assigned as small-group analysis projects, and today's online research and communications capabilities make these much more practical than in the past.

One example of design for manufacturing would be a case involving the transition from initial prototyping and small-volume production to higher volumes as a product gains popularity. For plastics parts, a distinct advantage of rotational molding is that there is no pressure involved, thus the equipment and tooling can be fairly low cost. But to produce similar hollow components in the high volume required by a major automotive firm, a faster, more automated/less labor-intensive method is needed, so the product might transition to injection blow molding. A meaningful assignment for students might be to be exposed to the basics of rotational molding, then be challenged to research and propose alternatives for mid- or high-volume production.

Modern design and production steps and procedures are intimately linked through the practice of Computer Integrated Manufacturing (CIM). The 3D CAD database created by the product designer is passed along, to be utilized in various simulations for form, fit, function, and processing. The data may be used to produce a rapid-prototype model, to simulate the cutter path for CNC machining of a mold and/or the component, for programming of automated inspection procedures, or for assessment of accessibility for product final assembly and maintenance. The designer must have insight into how the product can be/will be created, including processes, tooling and equipment.

A simple example of a student exercise in redesign for cost reduction is shown in Figure 3. A simple metal plate must have an attachment point for a tension spring. Based on students being exposed to basic process lab experiences, their initial solution might be to drill and tap a hole so that a threaded pin could be installed. The pin might be custom made by machining, but could be a purchased part in the form of a machine screw. Research might lead them to discover that a projection resistance-welded pin would eliminate all the drilling and threading operations. They might eventually realize that the separate pin could be eliminated by simply punching, shearing and bending a small tab on the edge of the plate as it is stamped, all in one quick step (bottom). A greater depth of study could be pursued by designing the process tooling for the press.

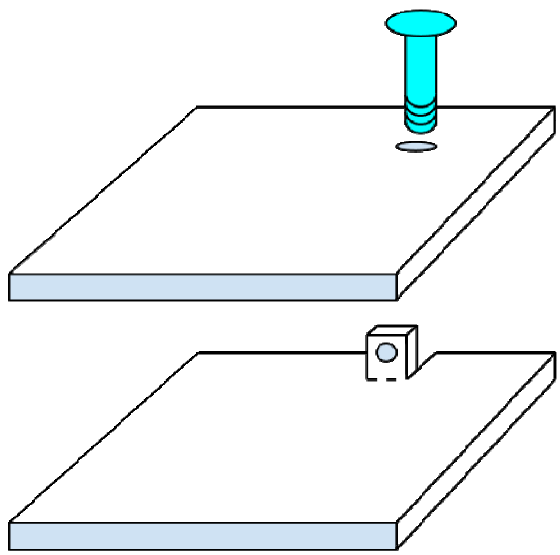

Figure 3. Simple DFMA Exercise Example

The merits of such a simple, basic exercise may be considered in relation to several of the competencies and content elements described in Figures 1 and 2. Among others, from the DOL model (Figure 1) these would include Critical and Analytical Thinking, Creative Thinking, Teamwork, Problem Solving/Decision Making. From the four-pillars model (Figure 2), students could delve into, and gain insights into the interdependence of a wide range of subtopics from within at least three of the key pillars: Materials and Manufacturing Processes, Product, Tooling and Assembly Engineering, and Manufacturing Competitiveness.

Conclusions and Recommendations

Given that manufacturing is critical to the viability of any national economy and the largest identifiable employer for engineering and technology graduates, educators have an obligation to prepare their students for these careers. The present financial situation in higher education may dictate that, while perhaps ideal, it is not feasible to add courses or to establish a new curriculum. However, modifying the delivery of traditional content within existing courses can do much to support all of the educational prerequisites, while imparting valuable career knowledge. Faculty members in a non-manufacturing-named program may consider some of the following strategies:

- Use the models of manufacturing education, including the Four Pillars, to identify curriculum opportunities.
- Identify courses where manufacturing problems and examples could enhance current content[17]
- Identify courses where manufacturing could replace less-relevant topics. The DFMA section illustrates one approach while others include prototyping [18] and bevel gear design [19].
- Consider offering a manufacturing-engineering-focused elective or emphasis.
- Allow students to take a manufacturing elective from another program.
- Enhance a graduate program by offering a course that is tailored to address the aforementioned gaps typical of undergraduate programs.
- Approach local manufacturers to find examples of applications of theory.

Manufacturing program faculty can help by promoting and supporting manufacturing education in other programs, acting as emissaries and support resources for those teaching faculty who have an interest in manufacturing.

- Approach faculty in other disciplines teaching traditional topics such as Machine Design, Computer Aided Design, Thermo-Fluids, Electronics Design, etc.
- Offer to help support new materials, identify textbooks that include manufacturing examples, help develop laboratory experiences and projects, etc. DFMA is an excellent bridge between other disciplines and manufacturing.
- Introduce other faculty to manufacturing techniques such as Six Sigma [20].
- Consider developing elective courses that introduce product design and manufacturing to other technical disciplines.
- Help other faculty engage local industry.
- Help other faculty apply for grants and resources from internal and external resources.

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ENHANCING ELECTRICAL ENGINEERING EDUCATION USING ONSITE, VIRTUAL AND REMOTE LABORATORIES

Akram Abu-aisheh and Tom Eppes, University of Hartford

Abstract

Limited financial resources for the acquisition of new laboratory hardware continue to marginalize the quality of electrical engineering education. However, the complementary use of onsite, remote, and virtual laboratories can be used to help overcome this trend. There is a variety of ways to integrate these three types of lab experiences into the curriculum. For fulltime, on-campus students, remote and virtual labs can be used as supplemental work to the onsite labs. Virtual and remote labs are especially useful for "predict and measure" experiments that focus on analytical learning. Onsite labs can continue to dwell on design and troubleshooting-oriented exercises. Remote labs can also be used to increase access to one-of-a-kind equipment among a group of students. This is especially true in upper-term courses where the quantity of advanced test equipment restricts availability. There are also opportunities to form collaborative arrangements with other institutions in which remote labs can be shared.

Introduction

The use of software-based test and measurement tools in engineering education has increased substantially, in part due to the rapid development of low-cost, high-speed computers. The acquisition and ongoing costs of modeling and simulation tools is much less than that of hardware and yet can provide a valuable learning experience. Consequently, universities with science and engineering programs are incorporating more software-based tools in both teaching and research laboratories. Science and engineering courses typically involve students performing practical experiments and assignments in laboratories as part of their knowledge and skills development. This is essential in reinforcing the theories learned in lectures and in providing a means to foster independent thinking. Knowledge and skills development also bring the course theory alive so students can see how unexpected events and natural phenomena affect real-world measurements and control algorithms.

Equipping a traditional electrical engineering laboratory is a major expense, and maintenance (both break-fix and calibration) is an ongoing expense. Qualified instructors are needed to manage the laboratory, oversee students, and grade their work. The laboratories are available only when equipment and instructors are both available. These resource limitations are an impediment to achieving more efficient use of the space and equipment. Limited financial resources to support traditional hardware-oriented laboratories continue to marginalize the quality of engineering education. in this paper, the authors discuss the use of onsite, remote, and virtual laboratories as complementary tools to reduce cost, increase access, and, thereby, promote learning.

Combining the onsite laboratory experience with remote and virtual work allows educators to enhance the quality of engineering education. The approach is not to replace the onsite laboratory experience, but rather to supplement it with a system that provides greater access to many of the same experiments. The focus should be on integrating a constellation of onsite, remote, and virtual laboratory resources so that students receive good, hands-on experience. The National Instruments (NI) ELVIS (Electronics Laboratory Virtual Instrumentation Suite) platform, along with its various plug-in modules, can support experimentation across a wide variety of science and engineering topics. The authors have successfully implemented this approach for a combination of all three types of labs [1].

Onsite Lab Experience

The NI-ELVIS platform provides an economical solution to equip electronic laboratories for onsite courses. It allows users to run experiments nearly identical to the ones that they now perform with hardware-based equipment. It is less expensive to outfit multiple lab stations with this platform than with traditional dedicated test and measurement equipment. Such tools as variable DC power supplies, digital multimeters, oscilloscopes, and waveform generators appear as virtual instruments displayed on a computer screen with knobs, readouts, and controls similar to their hardware counterparts. Each lab station then consists of a personal computer, an NI-ELVIS base unit and at least one plug-in board to support a specific set of experiments. The most often-used NI-ELVIS built-in instruments are: function generator, digital multimeter (DMM), oscilloscope, and variable DC power supply. The NI ELVIS platform is flexible enough to teach analog and digital circuit fundamentals, instrumentation, control systems, and wired/wireless communications techniques.

The authors have evolved the electrical laboratory to be a blend of traditional measurement equipment and virtual instruments. Dedicated test and measurement equipment are primarily used in the 1st and 2nd year of the four-year program; however, in the 3rd and 4th years, several courses in communications and instrumentation now employ the virtual instruments within the NI-ELVIS platform. After several semesters, the authors' experience with integrating NI-ELVIS into their lab sections has been positive. Students are first introduced to the platform with two introductory experiments that give them exposure to the virtual instrument panel. Initially, the oscilloscope and waveform generator configurations are employed to make measurements on hardware devices under test (DUT). Later, other virtual instruments are introduced so that students get experience on them as well. Placing jumpers and cables on the plug-in board is a convenient and easy way to set up a DUT. Each experiment contains a connection diagram that illustrates how this should be done. Data is collected from the virtual readouts in much the same way as with traditional instruments.

The student experience with the NI ELVIS setup was measured using a survey in a third-year RF communications class [2]. The results showed that students were highly supportive and described it as a positive process. A number of elements contributed to the positive, hands-on experience of our students. For example, they were able to quickly create a wide range of test configurations with minimal time required to wire and troubleshoot the DUT. The Help resource for the virtual instruments is well-written and enables students to understand how to modify settings and obtain accurate data. Furthermore, the detachable breadboard allows project work to be carried out independent of the base unit itself. NI-ELVIS, coupled with other tools such as Multisim and LabVIEW™, provides an inexpensive yet powerful teaching platform.

Virtual Lab Experience

NI's Multisim circuit simulation environment shown in Figure 1 can also be used as a virtual lab to supplement its onsite counterpart. Multisim offers a user-friendly experience, especially for students who are new to circuit simulation software. New users do not need to work with SPICE (Simulation Program with Integrated Circuit Emphasis) syntax and commands, while advanced users have access to all SPICE details. Multisim has a wide range of components and models to teach analog, digital, and microcontroller concepts. It also provides special components known as interactive parts, which can be modified while a simulation is running. Interactive parts such as switches and potentiometers will immediately and accurately affect the results of the simulation. This is useful to explore 'what-if' scenarios and to observe how a change in a circuit can affect its behavior.

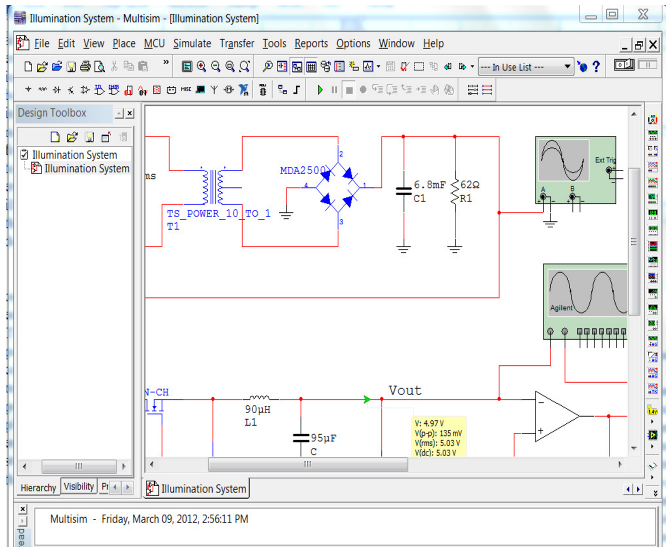

Figure 1. Multisim Circuit Environment

When the need arises for more advanced analysis, Multisim delivers over fifteen sophisticated analyses. Some examples include sinusoidal steady-state, transient, and frequency spectrum analyses. In addition to traditional SPICE analyses, Multisim allows users to intuitively connect virtual instruments to schematics. These virtual measurement instruments can be used to interactively measure the response of circuits that behave like their real-world equivalents as the user sets, changes, and reads the outputs.

Virtual instrumentation can be used to help institutions overcome the resource limitations of onsite laboratory space and hardware. One of the approaches in this study was to allow students to connect to onsite equipment and pre-staged experiments remotely over the Internet. In cases where space and facilities are limited, access was expanded.

Remote Lab Experience

Remote laboratories are a way to allow laboratory equipment to be accessed by students from a distance using the Internet. Some exciting applications can be easily done using NI-ELVIS. Experiments can be made available 24 hours a day, 7 days a week, and students can perform experiments from their campus residence or home. This approach also enables research teams to make expensive equipment available to others, enabling institutions to get more use from its current equipment base and to meet demand without necessarily purchasing more.

A significant hurdle lies in providing a requisite substitute for the traditional onsite experience. Early work on remote delivery of experiments appeared in 1998 with Esche & Chassapis [3]. It was followed in 2000 with a report by Gurocak [4]. A distance platform that supplements the hands-on experience was developed and pilot tested at the University of Hartford in 2004 [5], [6]. The system allows users to control test and measurement equipment remotely and, thereby, run the same experiments normally performed by coming to the lab.

Sharing a remote laboratory platform between students in different courses, sections, and perhaps across institutions, requires detailed planning across several fronts. Two types of management approaches are possible; however, both require a high degree of pre-planning with minimal change during the semester. As shown in Table 1, the first approach is called ‘synchronous’ in which all students perform the same set of experiments on the same weekly schedule. The advantage is that the set-up and take-down for each experiment need only be done once. The main issue is ensuring sufficient access for a given population of users and time period to get the work done. The second approach, called ‘asynchronous’, is the most flexible; however, it requires weekly coordination to ensure that the relevant experiments are made ready. This approach works only if an onsite technician with sufficient time to focus on DUT set-up and take-down is available.

Table 1. Approaches to Course Collaboration

Approach	Advantage	Disadvantage
Synchronous	Minimal setup and take down required	Experiments and timing must overlap
Asynchronous	Experiments and timing are flexible	Help needed for frequent DUT change

For a truly effective remote lab, there is no commercially available solution that offers a comprehensive suite of management and learning tools, e.g., video conferencing/ chatting, remote hardware configuration, simulation software, and downloadable lecture/lab materials. There is a need to develop a more complete and fully integrated distance learning environment that offers sharing and collaboration options between and among institutions [7]. An Integrated Virtual Learning Platform (IVLP) was developed and reported in 2010 to address this need [8]. An interesting advantage of IVLP is that it employs a simple architecture based solely on LabVIEW™.

LabVIEW™ can be used to programmatically control hardware in the base unit, enabling, for instance, automated signal acquisition and generation. NI-ELVIS instruments can be opened inside the Multisim environment to analyze both simulated and real signals. Students can compare expected results using simulations with actual values from physical devices promoting an understanding of the difference between theory and practice.

The NI-ELVIS workstation can be reconfigured for various electronic laboratories by choosing different plug-in modules. Plug-in modules are available for controls, communications, electronics, fiber optics, digital logic, and other topics. The eTCB (electronics Training Circuit Board) is one example from Delmar Cengage Learning. This unit supports DC and AC circuit analysis for design and analysis topics. For advanced courses, Emona Instruments has developed the DATEx and FOTEx boards as plug-ins. Figure 2 is a picture of the Emona DATEx-ELVIS setup used in radio frequency (RF) and data communications. Figure 3 shows the Emona FOTEx-ELVIS used for fiber-optic communications.

Figure 2. DATEx-ELVIS Setup

Remote Lab Experiment

This experiment demonstrates the use of the Emona FOTEx board to transmit two discrete message signals along an optical fiber in the same direction using WDM. At the receiver end there is filtering in order to recover just one of the messages. Figure 4 presents a block diagram for the

WDM experiment, while figure 5 presents the actual connections on the FOTEx board [9].

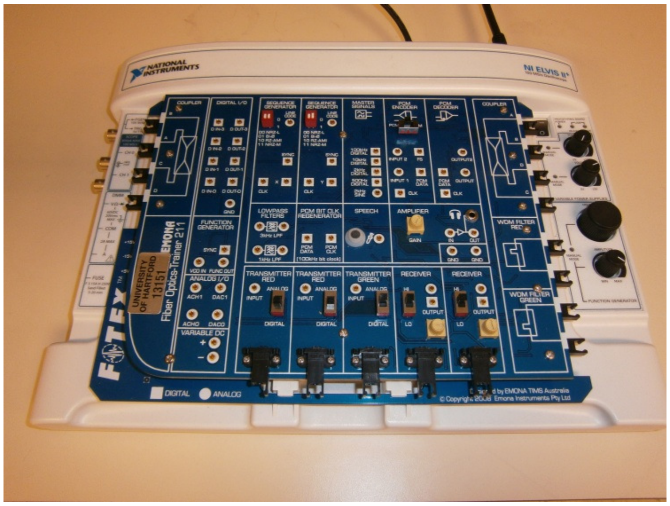

Figure 3. FOTEx-ELVIS Setup

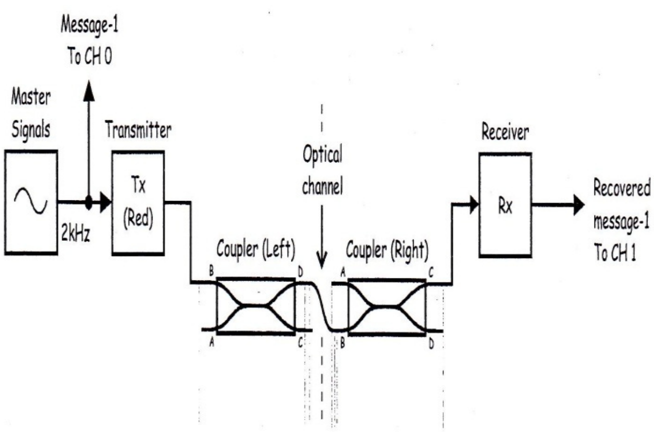

Figure 4. WDM Experiment Block Diagram

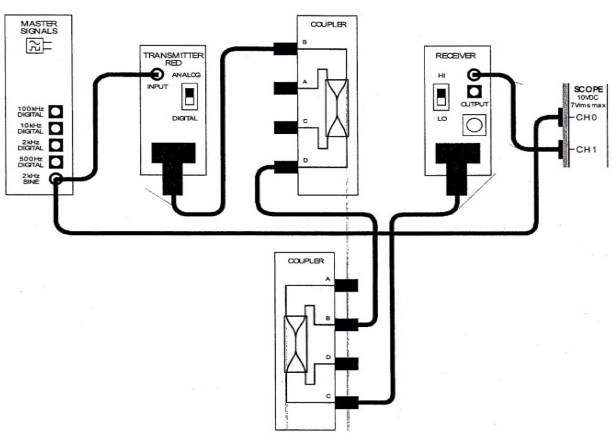

Figure 5. WDM Experiment Setup

The setup is a single-channel transmission system. The master signal module's 2kHz sine output is used to model an analog message. Coupler modules are used to facilitate the remainder of the experiment remotely. Then set the NI ELVIS II oscilloscope VI as follow:

- Timebase control is 100us/div.
- Channel 1 is activated. Recovered message observed is given in Figure 6.

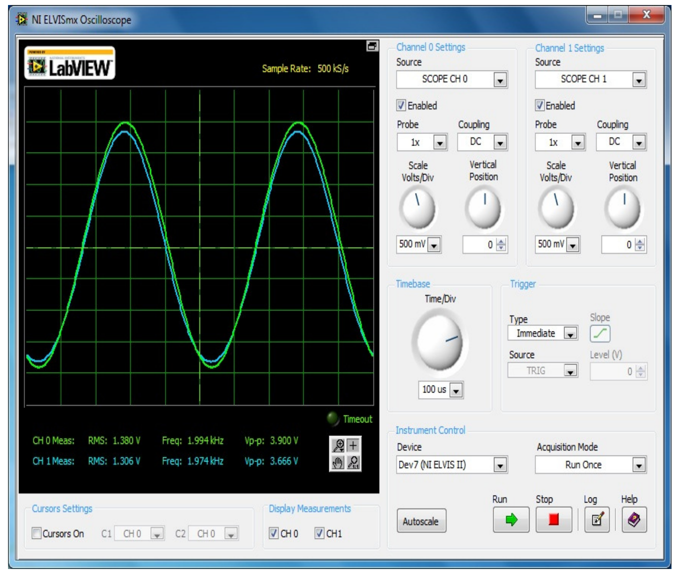

Figure 6. WDM Experiment Set-up

Then, send the two signals over the channel – an analog and a digital message (modeled by the master signal module's 10kHz Digital Output). The result of the WDM operation can be observed on the oscilloscope virtual instrument, as given in Figure 7. The set-up used for this experiment enabled students to use LABVIEW capabilities for data calculations.

Students Experience Using Remotely Controlled Test Environment

Two surveys were conducted to get student feedback about the use of the FOTEx communication trainer set-ups in the lab. The following questions about their experience in using the FOTEx-ELVIS II setup in a Fiber-Optic Communications course were used for the survey:

1- Do you feel comfortable using this setup?
2- Were the setup experiments clearly written?
3- Were the experimental procedures easy to follow?
4- Did the use of the setup increase your interest in the labs?

5- Did you have difficulties in configuring the FOTEx -ELVIS setup software?
6- Did you have difficulties in configuring the FOTEx -ELVIS setup hardware?
7- Did you experience difficulties in performing any Fiber -Optic Communications experiment?
8- Was the lab setup very valuable in terms of learning?
9- Overall, do you support the use of the FOTEx -ELVIS setup in this course?

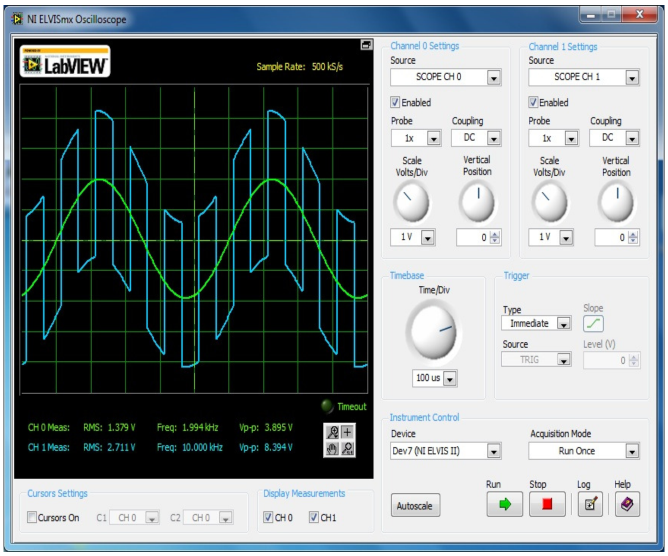

Figure 7. WDM Output

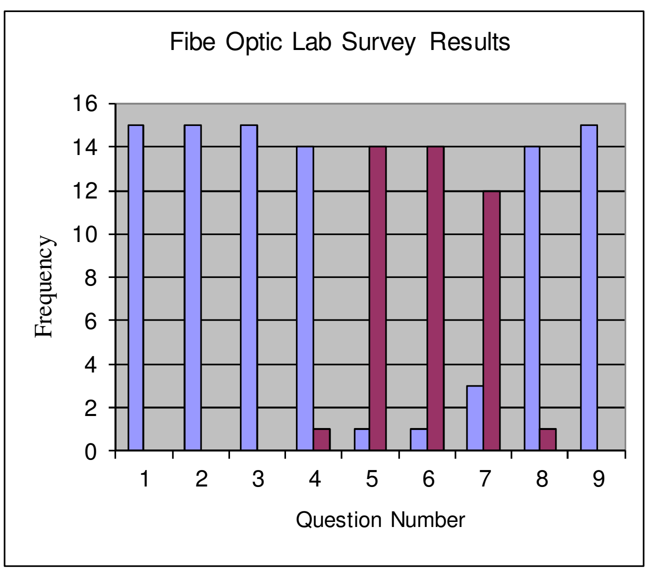

Figure 8. Fiber Optic Communications Survey Results

The survey included 15 students enrolled in a graduate fiber-optic communications engineering course, and the results of the survey are illustrated in Figure 8, where the blue (light) bar represents a YES answer and the red (dark) bar represent a NO answer. The X-axis represents the question number, and the Y-axis represents the frequency of each answer. As given in the graph, there is a total agreement among all students that they feel comfortable using the FOTEx-ELVIS setup and that FOTEx -ELVIS setup experiments were clearly written. Also, all students surveyed support the use of the FOTEx -ELVIS setup. The results of this survey also show that this setup is user friendly and has a fast learning curve. The next step is to implement the use of this set-up with an optical switch matrix and use the set-up in a collaborative distance learning environment.

Conclusion

Institutions that offer science and engineering programs continue to be under pressure to do more with less. Limited resources for equipment and instructors make a blended architecture of virtual and remote labs an attractive way of supplementing onsite labs. Remote access to experimental setups expands the window of equipment availability and opens the possibility of collaboration across other campuses and schools. To date, there is no commercially available management system that meets the needs for remote lab operation. A course management system integrated with LabVIEW™ would appear to be the most effective. Otherwise, institutions will continue to rely on proprietary or other work-around solutions.

On the positive side, the combination of LabVIEW™, Multisim, and NI-ELVIS is a useful way to mesh theory and practice. Students develop a firm grasp of the principles of electronic devices, circuits, and systems using a blend of onsite, virtual, and remote labs.

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Biographies

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