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The TECHNOLOGY INTERFACE INTERNATIONAL JOURNAL (TIIJ) is an independent, not-for-profit publication, which aims to provide the engineering technology community with a resource and forum for scholarly expression and reflection. Articles appearing in TIIJ may represent research not requiring statistical analyses and which typically comes from educators wanting to discuss "best practices" activities in their classrooms, or from industry personnel wishing to publish innovative designs or novel applications from their businesses or organizations.

TIIJ is published twice annually (fall/winter and spring/summer) and includes peer-reviewed articles that contribute to our understanding of the issues, problems, and research associated with technology and related fields. The journal encourages the submission of manuscripts from private, public, and academic sectors. The views expressed are those of the authors and do not necessarily reflect the opinions of TIIJ or its editors.

EDITORIAL OFFICE:

Philip Weinsier, Ed.D.
Editor-in-Chief
Office: (419) 372-0628
Email: philipw@bgsu.edu
Department of Applied Sciences
Bowling Green State University-Firelands
One University Drive
Huron, OH 44839

THE TECHNOLOGY INTERFACE INTERNATIONAL JOURNAL EDITORS

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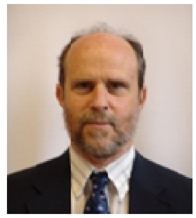
EDITOR'S NOTE: STEM EDUCATION AND PROBLEM-BASED LEARNING



Philip Weinsier, TIIJ Editor-in-Chief

It will come as no surprise to the average person entering school today that the traditional lecture is still widely used as the delivery method of choice. The fact that it favors the faculty in most cases likely will not be a surprise to, well, the faculty. In the preparation and delivery of lectures, faculty have almost dictatorial control over course content, when a topic is presented, and how much time is spent on it. Much of the reason why the lecture has endured for centuries likely is due in large part to the fact that it generally works for the masses.

Today we know that the lecture format is not the best choice for all students all the time; many—who are not able to adequately process auditory cues, are weak note takers, and/or feel stifled by the conformity of the process and do not ask questions—are able to survive only in spite of the process and not because of it. A multifaceted approach that includes lectures is now generally felt to be the best all-around choice and which is most likely to reach the greatest portion of students. Looking at the other side of the equation, at how much actual learning takes place for the teaching methods used, many researchers argue that problem-based learning (PBL) offers the best mix of presentation methods. In PBL, students take an active role in their own learning outcomes by being able to interact with both the instructor and the other students in whatever manner or format works best, and which may well be a combination of formats. Specifically, students tend to remember or "learn" a concept better if they are able to apply the knowledge or technique to a problem, while also being able to brainstorm and work through difficult stages of the problem with others.

Some of you are no doubt wondering if I've just come to this realization. No, PBL is said to have emerged around four decades ago at McMaster University Medical School. Or, if you prefer, back to Socrates and the question-and-answer dialectical method or argument for resolving a disagreement. Whatever your preferred timestamp, one has only to look back through our history to see that arguably the most efficient method for transferring skills and knowledge from one generation to the next came in the form of apprenticeships. These consisted of lectures (concepts being presented by the masters), discussions—arguments?—(to be sure that the idea was correctly transmitted to the apprentice), and then hands-on activities either alone or with a group that might also involve role assignments such as project leader, supervisor, or facilitator. Depending on whom you ask, apprenticeships go back hundreds of years and are generally believed to have come to the Americas from England and probably are a modern form of indentures. But, if I'm going to go back that far, why not argue that a similar format had to have been used as far back as spoken language?

But let's bring the discussion back to the present day as I really want to focus on STEM (science, technology, engineering and mathematics). STEM education is exemplified by curricula that integrate the rigor of all these areas with the goal of solving real-world problems. There is no shortage of organizations, associations, journals, government reports, and books enumerating myriad reasons why STEM education is crucial if our graduates are to successfully compete for jobs and for us as a nation to compete globally. Even the U.S. Department of Labor projects that most of the fastest growing occupations require significant science or mathematics training. So why, then, with all of the social and educational "pushing" and hype, are we not getting more students involved in STEM? Is there a perception problem or are our students simply no longer able to compete? I will leave the details of the argument to our authors and encourage you to read the two STEM-related articles in this issue.

Editorial Review Board Members

Listed here are the members of the IAJC International Review Board, who devoted countless hours to the review of the many manuscripts that were submitted for publication. Manuscript reviews require insight into the content, technical expertise related to the subject matter, and a professional background in statistical tools and measures. Furthermore, revised manuscripts typically are returned to the same reviewers for a second review, as they already have an intimate knowledge of the work. So I would like to take this opportunity to thank all of the members of the review board.

As we continually strive to improve upon our conferences, we are seeking dedicated individuals to join us on the planning committee for the next conference—tentatively scheduled for 2013. Please watch for updates on our website (**www.IAJC.org**) and contact us anytime with comments, concerns or suggestions.

Again, on behalf of the 2011 IAJC-ASEE conference committee and IAJC Board of Directors, we thank all of you who participated in this great conference and hope you will consider submitting papers in one or more areas of engineering and related technologies for future IAJC conferences.

If you are interested in becoming a member of the IAJC International Review Board, send me (Philip Weinsier, IAJC/IRB Chair, philipw@bgsu.edu) an email to that effect. Review Board members review manuscripts in their areas of expertise for all three of our IAJC journals—IJME (the International Journal of Modern Engineering), IJERI (the International Journal of Engineering Research and Innovation) and TIIJ (the Technology Interface International Journal)—as well as papers submitted to the IAJC conferences.

DEVELOPMENT OF A GENERAL ALTERNATIVE-ENERGY COURSE FOR A TECHNOLOGY PROGRAM

Faruk Yildiz, Sam Houston State University; Nedom C. Muns, Sam Houston State University;
Keith L. Coogler, Sam Houston State University

Abstract

Academic, business, and industrial fields have been seriously pursuing alternative energy systems advantageous to their needs. Students graduating from engineering and technology programs are involved in buying, managing and trading alternative energies during their careers as part of their job requirements. It is essential for engineering and technology students, at a minimum, to be familiar with alternative energy technologies and their applications and implementations. The proposed General Alternative Energy Course is composed of lectures, demonstrations, student inquiry, in-class problem solving, and hands-on projects. Class content includes photovoltaic systems, solar thermal systems, green buildings, fuel-cell systems, wind power, waste heat, biomass fuels, tidal power, active/passive human power, storage technologies (e.g., battery, supercapacitors), and hands-on laboratory projects. This course acquaints students with existing and potential ambient alternative energy sources, production capacities as well as energy harvesting, conversion, and storage techniques. The course concludes with a general review of how to integrate energy harvesting technologies into a system that provides a continuous and uninterrupted power stream. A detailed demonstration of course content, course materials, and hands-on course projects will be shared with academia.

Introduction

An increasing quantity of alternative energy resources presents much promise for our society. Due to this fact, the next generation of students will need more curricular support in this area, especially for those students engaged in engineering and technology programs. This is especially true as the issues of depletion of fossil fuel sources, climate change, global warming, increased electricity blackouts, and oil price variations continue to overwhelm people through the news media. So far, however, many schools from K-12 to community colleges do not have robust educational programs in these critical fields because of budget, laboratory and knowledge limitations. Alternative energy systems and sources are frequently discussed in the media and are continually in the thoughts of students from their daily life experiences and conversations. The public's general concern and interest about the environment has been increasing, and many attempts are being made to incorporate green technologies in school curricula. The number of alternative energy-related courses and programs is increasing due to the considerable demand for alternative energy sources. This demand will lead to greater competition between students in the future as they begin to seek career opportunities. Students earning engineering and technology degrees need a general knowledge of alternative energy systems, at least, to apply to their future fields.

Alternative energy-related courses are becoming an essential part of engineering and engineering/industrial technology curricula. Many schools are integrating renewable energy courses into their degree programs to support existing academic programs that expose students to energy systems and technologies [1-7]. The nature and content of renewable energy courses differ depending on the degree program of studies in various departments. For example, construction management and science programs usually adopt green building and geothermal-related classes and projects [8], engineering and technology programs adopt thermal systems, solar, wind, human power, energy-conversion systems, and biomass classes related to their curricula.

Usually, renewable energy courses provide an assessment of potential for various alternative and appropriate energy technologies to meet regional and global energy demand. They also explore conservation and end-use efficiency improvements that may allow civilization to exist in a more sustainable manner. Studies of modern energy resources, extraction techniques, conversion technologies, and end-use applications consistent with a conventional engineering and engineering/industrial technology curriculum are used as a baseline. Against this baseline, the courses introduce the physics, systems and methods of energy harvesting from non-conventional energy sources such as solar, geothermal, ocean-thermal, biomass, tidal-lunar, hydroelectric, wind, thermoelectric, human power, biomass and waves. Advantages and disadvantages of these alternative energy sources and the engineering challenges inherent in harnessing such forms of energy are covered. Evaluation and analysis of energy technology systems are taught in the context of achieving civilization's future economic and environmental goals [9-16].

The Energy Harvesting, Conversion, and Storage Systems of Alternative Energy Sources course is a general renewable energy course designed to enhance students' knowledge of renewable as well as traditional energy sources and their impacts on the environment and society. There is no prerequisite for this class so all on-campus students who have an interest in energy technologies may be reached. The basic concepts of electricity and power generation are covered at the beginning of the course to help students who do not have a background in electrical systems. Traditional energy sources include coal, hydro, nuclear, oil or natural gas; non-traditional sources include renewable energy such as wind, solar, geothermal, wave, hydrogen and bioenergy. Another goal of the course is to increase public awareness of renewable energy and renewable products through presentations, projects and discussions in the class environment. The course is the first level in a series of renewable energy-related classes that lead to an interdisciplinary minor in which students can apply their academic expertise to the area of energy and renewable energy.

Students are required to complete a series of exercises/projects and/or tests that reflect their knowledge of the stated objectives. Major points of the course are: a) understand the role of energy, energy sources and energy-use patterns in society; b) develop the basic ability to assess the relative merits and potential impacts of different energy sources; c) understand how energy conservation pertains to the management of efficient use of energy resources; d) develop basic knowledge to understand related issues of alternative energy products in the student's academic major/minor; e) develop a multidisciplinary background in alternative energy, energy conservation and efficiency, and self-sufficient products; and, f) develop an understanding of active/passive human power as an alternative energy source. The course will lead to the development of more renewable energy-related courses and eventually a degree program in the department.

Goals

The main goal of the course is to help undergraduate students develop and apply a general understanding of renewable energy-related products and their associated markets. The course is designed to be a hands-on, interdisciplinary class with an emphasis on the study of the economic, social and environmental aspects of various renewable energy sources including bio-fuels, with hands-on experiments included to offer more insight into related products. Ultimately, the program strives to educate students to understand the technical, economic, social, political and environmental aspects of various sources of energy and to become more knowledgeable citizens. A summary of program objectives is given below:

- Learn and apply applications of photovoltaic energy systems, wind energy systems, passive solar air and water heating systems, active and passive human power, hydrogen fuel-cell systems.
- Learn the role of energy, energy sources and energy usage patterns in society.
- Develop basic knowledge to understand social, economic and environmental aspects of renewable energy.
- Develop a multidisciplinary background in renewable energy, energy conservation and efficiency, and self-sufficient products.
- Develop an appreciation of how renewable energy technology works and how it is currently being used in the U.S. and around the world.
- Gain knowledge and hands-on experience in renewable energy systems.
- Learn site surveying and load analysis for renewable energy customer needs.
- Develop skills to handle hybrid renewable energy technologies.

Description

This course is a comprehensive introduction to ambient energy sources and their applications. This course will acquaint students with existing and potential ambient alternative energy sources, production capacities and energy harvesting, conversion and storage techniques. By using traditional energy generation methods and by reviewing typical energy consumption patterns, key concepts, terminology, definitions and nomenclature common to all energy systems are introduced. Design Development, Industrial Technology, Construction Management, Industrial Management and Electronics majors/minors can take this course as an elective in the technology department. In addition, any majors and minors at the college should be eligible to take this class as an elective.

Methodology

Not all engineering and industrial technology departments will be able to offer a variety of renewable energy courses due to faculty, budget, laboratory and knowledge limitations. Unless a school decides to establish a renewable energy-related program or degree, it becomes difficult for faculty to teach renewable energy-related classes in addition to the classes in the core curriculum. Since tenure-track and tenured faculty are usually allowed to teach three classes a semester, it may become an issue to offer more classes if there are not enough faculty available. If this is the case, it would be better to have at least one or two general renewable energy classes to respond to all the needs of the programs/degrees in the department. In this way, students can be exposed to general renewable energy systems and may be given the opportunity to gain further information by enrolling in a general renewable energy course in the department. Since the spring 2009 semester, students have been involved in a renewable energy course and have accomplished several projects under the supervision of a faculty member who teaches and researches renewable energy systems.

Class projects were completed in the spring, summer, and fall, 2010, semesters, and students have requested access to a general renewable energy class before they graduate. There are several students registered in a renewable energy course to accomplish several projects during the spring, 2010, semester. In addition to these projects, a comprehensive renewable energy course was developed by several faculty members to extend knowledge to all students regardless of their major or minor. Faculty are currently teaching bio-fuel systems, construction technology, construction management and procedures, electronics, design and development and industrial safety classes; they also contributed to this curriculum by suggesting related subjects to be included in a revolving *IT 469 Special Topics* class. The course content was identified after several meetings to respond to students' needs and to extend their knowledge for future projects. There were also several presentations and meetings with interested student club members to discuss and discover potential renewable energy resources for energy harvesting. The Delphi Method was used to determine researchable alternative energy subjects [17]. It is an approach which consists of a survey conducted in two or more rounds; the participants in the second round were provided with the results of the first round so that they could alter the original assessments. Students from different majors/minors shared their ideas in group meetings and discussed the ideas presented by first-round participants. If an idea was not accepted by the participants, the students were instructed to bring supportive documents to the next meeting to explain their ideas in details. Students and faculty found this method quite enlightening to discover and learn different ambient energy resources. Table 1 summarizes the potential ambient -energy-source ideas discussed by students and faculty in the last meeting of the fall, 2010, semester.

The student participants were divided into five groups of six students. In Round One, the students were instructed to propose three innovative ideas, which, to the best of their knowledge, had not been developed or researched. The groups presented and described their concepts. Each topic/idea/concept was voted on by all of the participants to determine the most achievable concept/study by the class. Table 1 presents the list of ideas identified by the participants.

Table 1. Content for New Research Related to Renewable Energy Systems

Group	Ideas	Vote Count
1	1. Amplification of electromagnetic fields	2
	2. Photosynthetic electricity source	19
	3. Different ethanol processes and sources	1
2	1. New battery materials	0
	2. Geothermal cooling method	5
3	1. Flooring that stores kinetic energy	10
	2. Thermoelectric generators in walls as energy source	5
	3. Magnetic engine	4
4	1. Capture ocean and water currents as energy source	13
5	1. Ocean buoys to harvest electricity	X*
	2. Hemp as alternative organic for fuel production (ethanol)	0
	3. Harvest wind from exhaust fans and A/C units for energy source	20

*Group 5, Idea 1, was deemed to be the same as Group 4, Idea 1 and rejected.

Based on the counts, the top three subject ideas were selected. In Round Two, groups were reassembled to prioritize those three subject ideas according to which subject the students were most likely to pursue. The group results and consensus ranking are presented in Table 2.

Based on the results of the meeting using the Delphi Method, three ideas presented in Table 2 were considered and ranked for alternative energy research in the Industrial Technology program at Sam Houston State University. In future planning, the number of these meetings will be increased based on the interest and availability of students.

Content of the Course

Upon completion of this course, the student will able to:

- Locate and identify potential ambient alternative energy sources

Table 2. Top Three Energy Sources for Research Ranked by Meeting Groups

Subject Idea	Group					Rank
	1	2	3	4	5	
Photosynthetic electricity source	2	3	1	3	2	**3**
Capture ocean and water currents as energy source	1	2	2	2	3	**2**
Harvest wind from exhaust fans and A/C units for energy source	3	1	3	1	1	**1**

- Understand electric power generation, harvesting, conversion and storage systems
- Identify appropriate storage (e.g., battery, supercapacitors) technologies
- Learn about solar-energy systems using photovoltaic systems
- Learn to harvest energy from wind power
- Learn how to generate electrical power from biomass
- Understand hydroelectric power systems
- Learn the applications of hydrogen fuel cells
- Explore active/passive human-power sources
- Learn about geothermal energy and ground-source heat pumps
- Become knowledgeable about principles of renewable energy transportation systems
- Understand energy systems management and auditing
- Learn about energy utilization in our homes, businesses and schools
- Define relationships between renewable and non-renewable sources of energy
- Learn electric circuit design used in energy-harvesting systems
- Learn process and materials safety for alternative energy technology

Student Projects

Students are required to complete a series of projects in the class (Energy Harvesting Systems from Alternative Energy Sources) as part of the course requirements. Depending on the class size, groups are established to complete assigned projects in rotation. The instructor assigns a timeline for each group to finish their projects. If a group fails to finish the project according to the timeline, they receive partial credit for the incomplete project. Usually, a projected timeline to complete the project is sufficient for a group, because each group consists of at least three students. Students are allowed to work on their own during the weekends and under the supervision of an instructor or lab assistant during the weekdays. All of the information about the projects is provided to the other group members. Group leaders are in charge of updating the instructor about their projects; they are cautioned to ask for help if any issues arise. Groups are required to make a presentation on one of the projects they accomplish during the semester. The groups should start researching their projects in the third week of the class and finish them before finals week. A total of thirteen weeks are allowed to finish the projects. Table 3 is a sample project-assignment timeline with the list of projects.

Table 3. List of Projects Assigned to Groups

Projects & Project Timeline (2 weeks)	**Weeks/Groups**													
	3. week	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Skylight Installation	Group 1		Gr. 2		Gr. 3		Gr. 4		Gr. 5		Gr. 6		Gr. 7	
Passive Solar Air Heater Installation	Group 2		Gr. 3		Gr. 4		Gr. 5		Gr. 6		Gr. 7		Gr. 1	
Passive Solar Water Heater Installation	Group 3		Gr. 4		Gr. 5		Gr. 6		Gr. 7		Gr. 1		Gr. 2	
Wind Turbine System Installation	Group 4		Gr. 5		Gr. 6		Gr. 7		Gr. 1		Gr. 2		Gr. 3	
Photovoltaic System Installation	Group 5		Gr. 6		Gr. 7		Gr. 1		Gr. 2		Gr. 3		Gr. 4	
Hydrogen Fuel-Cell System Installation	Group 6		Gr. 7		Gr. 1		Gr. 2		Gr. 3		Gr. 4		Gr. 5	
Basic Geothermal System Installation	Group 7		Gr. 1		Gr. 2		Gr. 3		Gr. 4		Gr. 5		Gr. 6	

Laboratory Experiments

Establishing a renewable energy teaching and research laboratory involves undergraduate and graduate students, faculty, and community in learning about alternative energy and its impact in details. Hands-on renewable energy -related classes, labs, and projects promote alternative energy education at university campuses.

A fully functional laboratory delivers applied energy education workshops for local community colleges, secondary/high school science/technology teachers and students and for the general population, especially those not exposed to state-of-the-art renewable energy information. Information concerning solar, wind, passive solar water and air heating, fuel cells and human power can only be offered to small groups of students because of the limited laboratory space, current tools and components. Depending on tools and component availability, self-sufficient energy-efficient building design and construction, biomass, thermoelectric, and advance alternative energy systems may be offered at the campus. The current equipment for electronics, construction and production laboratories at Sam Houston State University are used for the renewable energy projects.

In addition, construction majors built a storage building to be used for the project as part of their class requirement. These small storage buildings are used as temporary laboratories. They are placed next to the construction laboratory and have a southern exposure for efficient sunlight. All the necessary parts for the projects were purchased with internal and external grant money and donations. No additional tools, equipment, or technological resources were necessary for students to complete the projects, since the university laboratories are well equipped and have these stock supplies. The following systems were used for the labs and hands-on projects of the course.

Skylight Installation

Tubular Skylights are energy-efficient high-performance lighting systems that are cylindrical in shape and are designed to light rooms with natural sunlight. A small, clear collector dome on the roof allows sunlight to enter into a highly reflective "light pipe" that extends from the roof level to the ceiling level. The light pipe is coated with a silver mirror-quality finish that allows the full spectrum of sunlight to be channeled and dispersed evenly into a room by means of a diffuser located in the ceiling. This project involved installation of four units of 13” tubular prismatic diffuser-type skylights on the roof of the storage building. Students learned to identify the best location on the roof to install skylights for efficient use and to increase illumination in the dark places in a house or building. They determined the length of the light pipe for installation. The picture of an installed skylight is shown in Figure 1.

Figure 1. Skylight Installation

Skylight System Components:

- 13” Tubular Skylight (Prismatic Diffuser and Pitched)
- Remote Controlled Dimmer, 13"
- Light Pipe Elbow and Extension

Passive Solar Air Heater Installation

Solar air heating systems are a supplement to regular heating systems and can dramatically reduce heating costs. Air in the building is circulated through a collector on the exterior wall, where it can gain up to thirty degrees before being vented back into the room. A 1500GS glazed secondary air heater (passive device resembling a large door) was mounted on a sunny, south-facing wall of the student-built storage buildings. A 270 CFM AC powered Combi Fan was used to circulate the air in the storage building for test purposes. The air circulation and quality of warm air were tested at different times during the day and under different weather conditions. Some of the following questions were assigned to students to learn air heating systems in detail. The passive solar heating system is shown in Figure 2.

- Does a solar air heater work at night?
- Can I mount the air collector upside down?
- What happens during the summer?
- Can I mount it horizontally?
- How long does the installation usually take?
- Where are the units manufactured?
- Will it produce heat on cloudy days?
- Is it better to use a 2 pack (solarsheat 1500G and 1500GS) or two stand alone units (2- 1500G units)?
- Do air heaters need to face true south and at a tilt angle 90 degrees to the sun?

Figure 2. Passive Solar Air Heating System

Passive Solar Air Heating System Components:

- 4", 5" 6" Combi Fan 270 CFM AC Powered
- Roof Flashing Aluminum for Shingled Roofs
- 1500GS Glazed Secondary Solar Air Heater (passive device)
- Collector Flush Mount -Tall Pads Style

Passive Solar Water Heater System Installation

Students involved in this project learn to distinguish both solar electric and solar thermal heating and have an understanding of the uses of both; they also develop a good understanding of how to identify a proper site for a solar thermal system and have resources to explore local installation options. Initially, a wheeled cart was designed using computer-design-and-drafting software tools. All major components were shown in the design. After the design of the complete system (with real dimensions), the wheeled cart was built to test the passive solar heater system in different locations. The passive solar water heating system is shown in Figure 3.

Figure 3. Passive Solar Water Heating System

Passive Solar Water Heating System Components:

- 2'X3' Sample Collector
- Standard Mount Kit for AE Series
- 100 PSI Pressure Gauge 1/4" MPT
- D5/710B PV Circulating Pump- threaded
- 35-250F Thermometer
- 10 Gal. SS DB Tank w/ Heat Exchanger
- 3/4" Cast Iron Flanges
- Taco 1/40 HP Bronze Pump, 0-6 GPM
- Eagle 2 Differential Temperature Control w/t Display
- Air Vent, 150 PSI, 1/4" MPT
- "MAXI-FLOW" Spring Check Valve, 3/4" SWT
- 3/4" 2-WAY Sweat Ball Valve
- Kyocera KS10 10W 12V Solar Panel
- AET PV Mount
- Whirlpool 15G Tank w/ Electric Element
- TACO 1/25 HP Cast Iron Pump, 0-14 GPM
- Eagle II Data Port Adapter
- 3/4" Boiler Drain
- GPM Flow Meter
- Gal Expansion Tank
- 150 PSI Pressure Relief Valve

Wind and Photovoltaic Systems Installation

Five wind turbine units (12V 200W) and fifteen solar module units (12V 65W) were purchased for student projects. All of the related parts to build a complete wind and photovoltaic energy system were also purchased to supplement the student projects. Students built a wind/solar hybrid system to control and record data to investigate the reliability of both systems. A data acquisition system was implemented to record and analyze temperature changes, solar irradiation, wind speed, power generation and consumption with load changes. The hybrid alternative energy system (solar and wind) is shown in Figure 4.

Photovoltaic and Wind System Components

Photovoltaic System:

- KC65T 65W 12V Solar Panel with J-Box
- Ground/Roof Fixed Tilt Legs
- 10-12 10A, 12V Light Controller
- BabyBox 4 Slot AC or DC Breaker Panel
- 6 Amp Din Rail Mount Breaker
- 20 Amp Din Rail Mount Breaker
- 8G24 12V, 73 AH (20HR) Sealed Gel Cell Battery
- 125W XP 125-12 12V Inverter

- 110A Fuse & Holder W/Set Screw Lug
- Vivid PAR 20 Floodlight (36 LEDs), AC/DC
- Assistant Software (PV Only)
- Solar Pathfinder™ with Case & Tripod
- LA302 DC Lightning Arrestor
- Voltage/Current DC Sensors Dual Irradiation Sensor
- Temperature Sensor

Wind Energy System:

- Anemometer (Wind Meter)
- Air Breeze Wind Turbine Land 200W 12V
- 2-Position Stop Switch for Air Turbines
- LA302 DC Lightning Arrestor
- Analog Amp Meter Kit
- BabyBox 4 Slot AC or DC Breaker Panel
- 50 Amp Din Rail Mount Breaker
- 63 Amp Din Rail Mount Breaker
- 27FT Tilt-up Tower Kit for Air Turbines
- Galvanized Augers for 27' Tower
- CB50 50A Circuit Breaker
- CBBOOT for 30A/50A Circuit Breaker
- 12V 135AH (20HR) Sealed AGM Battery
- SureSine Inverter SI-300-115
- 110A Fuse & Holder W/Set Screw Lug

Figure 4. Hybrid Solar and Wind Energy System

Hydrogen Fuel-Cell System

The solar module converts radiant energy into electrical energy to power the electrolyzer, which breaks water into its basic constituents of hydrogen and oxygen. These gases are stored in the graduated cylinders. When electrical power is required, the PEM fuel cell recombines the stored gases to form water and release heat and electricity. Students are familiarized with fundamental principles of fuel cells through solar-hydrogen fuel-cell technology. The module provided is a training unit and students are involved in a variety of laboratory experiments provided by the manufacturer. In this project, students engage in twenty to twenty five hands-on experiments for introductory and advanced environmental science, as well as demonstrate the sustainable benefits of fuel cells and hydrogen technology. Figure 5 shows a hydrogen fuel-cell training unit with a data-acquisition system.

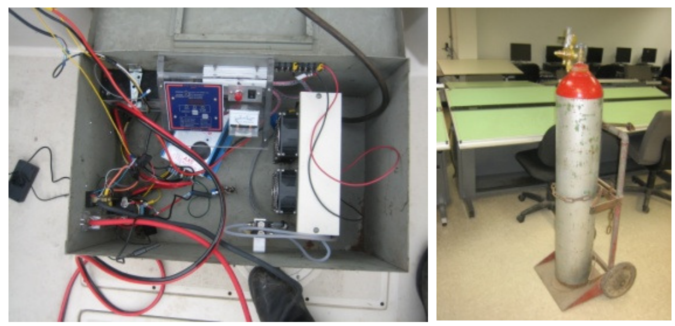


Figure 5. Hydrogen Fuel-Cell System

Human-Power Generating System

In this project, students were familiarized with the conversion of mechanical energy (through human kinetic energy) to electrical energy. Students studied low-rpm permanent-magnet DC generators, generator types, mechanical torque, human-power applications, charge controllers, battery types, measuring voltage and current, voltage rectification and power output changes with mechanical force. The instructor provided exercises to be accomplished by students and submitted for their project grade. The Human-Power Trainer is shown in Figure 6.

Human Power Generator System Components:

- Bike Power Generator
- Electromate 400, 12V Power Pack
- Power Monitor
- 10FT Connecting Cable – Diode Protected with Power Pack Connector
- Low RPM Permanent Magnet DC Generator

- 35A Power-Up Reverse Current Rectifier Bridge Assembly
- Power-Up Reverse Current Diode Assembly

Figure 6. Human Power Trainers

Solar Pathfinder

Students were divided into three groups and were provided three Solar Pathfinders, assistive software and laptops with software. A short description of the equipment, summary of the experiment and questions were provided in the experiment. A sun-path calculator was used to view the solar window for a particular location for assessing shading. Other means can be used to evaluate shading, but sun-path calculators are usually the quickest and easiest to use. The Solar Pathfinder is a popular type of sun-path calculator that consists of a latitude-specific sun-path diagram covered by a transparent dome. The dome reflects the entire sky and horizon on its surface, indicating the position and extent of shading obstructions. The sun-path diagram can be seen through the dome, illustrating the solar window. The solar window is compared to the obstruction reflections to determine the dates and times when shading occurs at the site. When a sun position is overlapped by an obstruction, the sun would appear behind the obstruction and the location would be shaded. The pictures of the solar path calculator are shown in Figure 7.

To use the Solar Pathfinder the unit was located at the proposed array site. It was leveled and oriented to true south with the built-in compass and bubble level. Looking straight down from above, the user observes reflections from the sky superimposed on the sun-path diagram and traces the outlines of any obstructions onto the diagram. Students draw shading areas in different locations and identify obstructions around the solar modules. Students are required to submit a detailed report and suggestions for the given experiment.

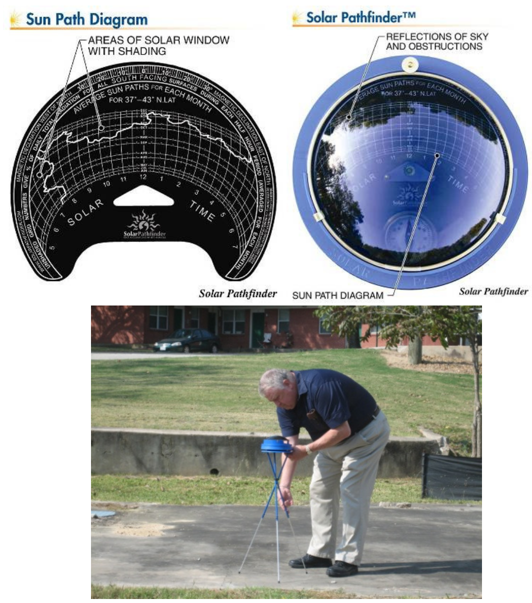


Figure 7. Solar Path Calculator System

Class Survey

To evaluate the effectiveness of the class and test the content knowledge of the students, each student was asked to complete a survey after completing the class. The outcomes are presented in this paper. Thirty-six students participated in the renewable energy class since the spring semester of 2010. The authors believe the data gathered from the student-participation questionnaire indicate that this experimental class promotes alternative energy systems. The results indicate that the class is promising and should be introduced to more students, regardless of major. Survey results are summarized in Figure 8. Fifteen multiple-choice (select 1-5 type) and four questions for additional comments comprised the survey and are summarized in Appendix A.

Conclusion

In this paper, the *IT 469 Energy Harvesting Systems from Alternative Energy Sources* course taught in the Industrial Technology Program at Sam Houston State University is summarized. Student feedback was very

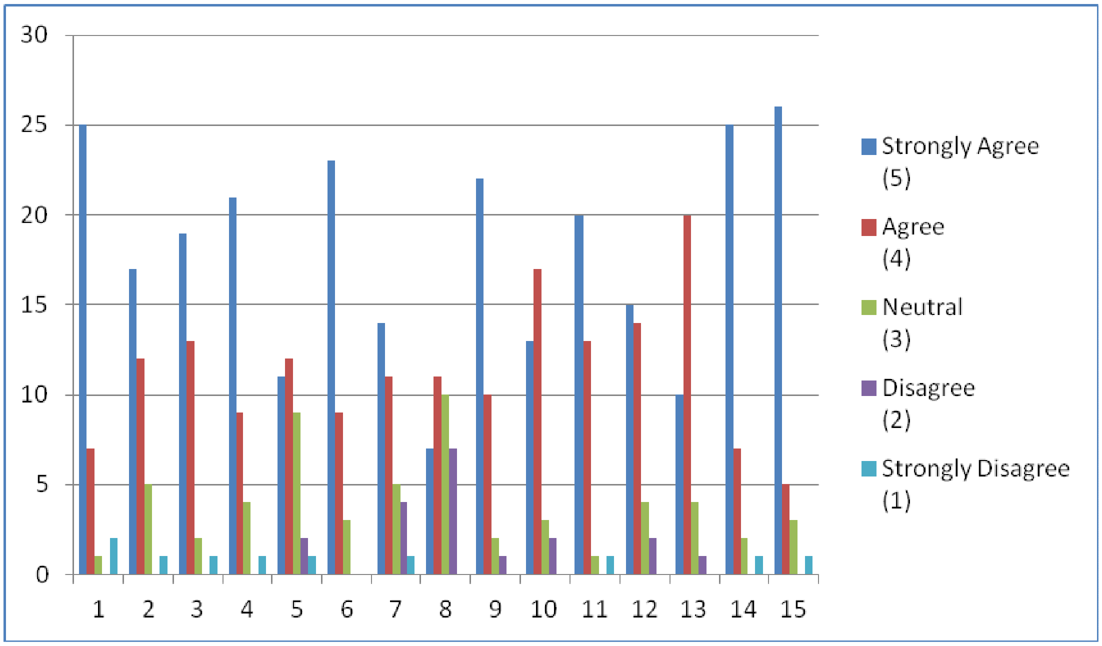


Figure 8. Student Survey Results

positive and critical comments were made to improve the class.

Most of the students suggested there be several field trips, when time permits to see industrial working systems. The main themes covered in the course are the needs, concepts, operation principles, modeling issues and simulations of solar, wind, passive solar air/water heating, human power, geothermal, hydrogen fuel-cell systems and their techniques. This class did not cover all potential energy sources due to time and equipment limitations. Students showing an interest, and who wanted to accomplish energy projects, are encouraged to enroll in a directed (independent) study course. This class is offered as an elective course and is not in the current catalog, but was already a full class by the end of the first day of class registration. Several students attempted to register for this class but were not allowed to because of equipment and laboratory limitations. Several faculty members who are currently on the curriculum development committee desire to increase the number of energy-related courses.

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Biographies

FARUK YILDIZ is currently an Assistant Professor of Industrial Technology at Sam Houston State University. His primary teaching area is Electronics, Computer Aided Design, and Alternative Energy Technologies. Research interests include: low power energy harvesting, renewable energy technologies.

KEITH L. COOGLER is an instructor of Industrial Technology at Sam Houston State University. He holds a in B.S. Industrial Education and is pursuing an Ed.D. in Higher Education from Texas A&M University – Commerce. His primary teaching area is Construction Management. Research interests include: automation, alternative energy, and “green” construction.

NEDOM C. MUNS is a Professor of Industrial Technology at Sam Houston state University. His primary teaching area is Construction Management, Vocational Teacher Education, and Design & Development.

Appendix A. Survey Questions

<table>
<tr><td colspan="3">Note: This survey is prepared to measure effectiveness of the training unit (mini-lab) in the hands-on learning process of Photovoltaic and Wind Systems. Please place a “X” to corresponding and preferred section.
Questions</td></tr>
<tr><td>1. Have you found the course useful to improve your knowledge on renewable energy applications?</td><td>2. Have you found the course and term project useful to improve your knowledge on energy efficiency and efforts on reduction of carbon foot print (CO_2)?</td><td>3. Do you think solar and wind power applications will help you as a student to understand renewable energy systems better?</td></tr>
<tr><td>4. Do you think renewable energy would be a good tool to promote science and technology majors in college?</td><td>5. Would you be interested in enrolling in a Technology curriculum course entitled Applied Renewable Energy promoting Math, Science, and Engineering?</td><td>6. Overall quality of instruction was appropriate and useful for this class.</td></tr>
<tr><td>7. I am interested in future classes, workshops, and summer research activities in these or similar subject courses at SHSU.</td><td>8. Before undertaking the Photovoltaic and Wind Power System Experiments, I felt comfortable with the concepts related to photovoltaic power.</td><td>9. The Introduction to the Photovoltaic and Wind Power System Experiments given by the instructor was useful in understanding the operation of photovoltaic and wind power systems.</td></tr>
<tr><td>10. The Laboratory Description document was useful in understanding the experimental procedure and data reduction.</td><td>11. After completing the Photovoltaic and Wind Power System Experiments and Lab Reports, I have a better understanding of the operation of photovoltaic and wind power systems.</td><td>12. After completing the Photovoltaic and Wind Power System Experiments and Lab Reports, I have a better understanding of the performance (power output and efficiency) of static and tracking photovoltaic and wind power systems.</td></tr>
<tr><td>13. The PV and Wind Power System Experiments increased my interest in photovoltaic and wind power systems.</td><td>14. I believe that alternative or renewable energy is important for the future.</td><td>15. This course has increased my understanding of alternative or renewable energy sources.</td></tr>
<tr><td colspan="3">Comments: “How could the PV and Wind Power System Experiments and Course be further improved to enhance the learning experience?”</td></tr>
<tr><td colspan="3">Question: If you are given a chance to find a unique (undiscovered) renewable energy source what would be a first, a second, and a third source you would like to implement? For example, energy generation from an AC condenser outside of a building (Cost and application is not considered just list a source to generate electricity).</td></tr>
</table>

International Opportunities in Engineering Technology – An Entrepreneurial Approach

Jeremy B. Ross, East Tennessee State University; Keith V. Johnson, East Tennessee State University;
Kevin W. Varney, East Tennessee State University

Abstract

The East Tennessee State University Department of Engineering Technology recognizes the crucial importance of international exposure and learning opportunities for our students; however, ETSU does not have an overseas campus or a permanent study abroad program center outside of the United States. Considering the fact that most of our students are from the East Tennessee and Southwest Virginia area, this need is critical in providing a comprehensive, broad-based education. Like most schools, our greatest challenge is funding. This challenge has led us to create an entrepreneurial approach to funding and delivery of international opportunities for Engineering Technology students. In short, the school has established a program that has attracted private funding and created mentorships and job opportunities for students along with a consistent study abroad program for ETSU students.

This entrepreneurial approach has three components: funding, delivery and student recruitment. Overwhelmingly, donors provided partial sponsorships for all 13 students in the first class. Various cultivation, solicitation and stewardship processes were employed as well. The ETSU at Rome Program has been underway for approximately two years. This entrepreneurial approach has provided additional private funds for students, mentorships with community leaders, international opportunities for students and additional revenue to the university through added tuition dollars.

Vision

The ETSU at Rome Program has been a life-changing experience for many students. The initial idea for the program came about in late 2007. The vision for the program was to provide an international experience for Engineering Technology students. This program is currently the only study abroad program in the Technology Department. The vision for the program has evolved since its inception which is to create a permanent presence abroad, to change the local culture's views on study abroad, and to create more courses that will be added into the technology curricula, as opposed to being only electives.

Creating the first technology program abroad at ETSU, financing the operation, and dealing with the local mentality regarding study abroad programs are all major hurdles that have presented themselves throughout the course of the program. Most ETSU students are from the East Tennessee and Southwest Virginia regions. It has been found that many of the local students are of the mindset that study abroad is out of their reach. Most students have never traveled abroad, and some have never even flown. To these students, traveling to another continent seems too big, too incomprehensible, for them to accomplish. Overcoming these hurdles requires an entrepreneurial approach. This paper describes how these obstacles were addressed with the creation of a successful program in Rome, Italy. The following topics will be discussed:

- Funding
- Curriculum
- Mentorship Program
- Growth/ Future Plans

Funding

Using this entrepreneurial approach to funding was considered as a way to change student culture. Raising funds to defray costs, it was believed, would help change students' outlook about the expense of traveling abroad. Student funding to study abroad is the greatest obstacle for Engineering Technology students and most students at ETSU. The approximate costs for a student to study for three weeks in Rome for a three-hour course are:

Table 1. Approximate Costs per Student

$2,475	Program costs (housing, side trips, etc.)
$1,000	Airfare
$795	Tuition
$500	Food
$300	Books, passport, entry fees, other
$5,070	TOTAL

For students at ETSU, these program costs presented a challenge for most, in spite of there being some scholarships at ETSU to assist in these expenses. Every student at ETSU pays a $10 fee per semester for foreign travel. This money is made available in the form of scholarships to students desiring to travel abroad. For the ETSU at Rome Program, students can apply for up to $1,500 ($500 per week) if they have a 2.75 grade point average, possess financial need, and the course will directly meet their degree requirements. Most students have been getting the full amount, and this brings the cost down to $3,570, which is still prohibitive for most.

Funding is usually the biggest challenge many students face when considering studying abroad [1]. Considering the financial challenges, an entrepreneurial approach to attaining private funding was necessary. With effort and determination, students and universities can discover money to assist in studying abroad [2]. The first step was to research potential funding sources, using an approach designed by the University of Indiana School of Philanthropy [3]. This approach scores and ranks potential giving prospects in three categories: 1) linkage, 2) ability and 3) interest. Linkage is the relationship one has with ETSU. For example, are they an ETSU Foundation member, a staff member or a member of the alumni? Ability refers to one's resources. Do they have significant personal wealth or influence over corporate giving? Finally, interest simply refers to one's interest. Are they an engineer, architect, contractor or just an individual who has traveled abroad and knows the importance of such an experience? All prospects were rated on a scale of 1 (being the lowest) to 3 (being the highest) in all three categories. A total score was given for each prospect and the scores of 9 were focused on first, then 8 and so forth. This allowed fundraising members to prioritize and identify the best prospects.

Table 2: Potential Donor Evaluation Chart

Prospect	Linkage	Ability	Interest	Score
Loyal Donor & General Contractor	3	2	3	8
Tennessee Bank of Money	2	3	1	6
Federal Reserve	0	3	0	3

During the planning stages in 2008, the most beneficial and entrepreneurial idea in identifying prospects was to target architects, engineers and contractors who had been contracted for work on campus in the last five years. All of these individuals and organizations had the maximum ratings in linkage, ability and interest. Also, the school already had relationships with them, and some cultivation had already taken place. Essentially, organizations that had received contracts from ETSU were asked to consider providing a $1,000 sponsorship for a student in their field to study abroad. This approach was highly successful, and all 13 students for the 2009 summer course received a sponsorship, and most received the ETSU International Scholarship. In all, $27,560 in sponsorships and scholarships were provided for the 2009 class.

Fundraising for the 2010 program implemented new strategies. With further deterioration in the economy and particular challenges in the construction industry, many of our 2009 sponsors were not in a position to provide additional funds. Therefore, individuals who had strong ties to the university, an interest in study abroad, and a previous history of support to the College of Business and Technology were targeted. News coverage of the 2009 program, word-of-mouth about the program, and strong university leadership helped attract new donors and provided good stewardship to the donors in place. For the 2010 class, 16 donors provided scholarships, and numerous ETSU scholarships were granted. Funding provided to the students for 2010 totaled approximately $38,000.

Fundraising for the 2011 program is in the initial stages, and many of the same funding strategies for the previous years will continue. However, an effort to create larger gifts and an endowment will be added to the efforts. Currently, a $24,000 endowment has been initiated to help fund the program. Also, a solicitation has been made to one of the current major donors, and a proposal for a $25,000 - $50,000 endowment is under consideration. Another goal is to create major gifts and endowments to provide financial stability for future growth and efforts.

Other key factors to attaining funding for the ETSU at Rome Program have been partnerships and participation among university leaders. The President of ETSU, the Dean of the ETSU College of Business and Technology, and the instructors for the courses have personally sponsored students and made direct requests and appeals for funding. Additionally, other university staff members, including the provost, have taken a direct interest in the program and offered support to help all eligible students attain any available public funding.

Finally, there has been a concentrated effort to initiate and maintain a stewardship program. All students contact their sponsor with thank-you cards and letters before departure. While in Rome, Italy, donors receive a postcard from their student and a short video, via email, thanking them for such an amazing experience. After returning to campus, a reception is held in the President's Conference Room with the donors, and a presentation is given by the students to share their experience. Each student personally thanks their sponsor and gives the donor a personalized gift. For 2010, each student picked out a handmade Italian wine stop. Additionally, donors are recognized in local newspapers, campus publications and other marketing materials. Another stewardship opportunity—from the planning stages in 2011—came in the form of a donor trip. All sponsors, donors and a few new prospects will be offered the opportunity to visit the ETSU at Rome Study Center and personally meet the student they are sponsoring. Other special experiences and excursions have been designed for them during their visit. Each donor who enrolls in the program will be asked to make a minimum $1,000 donation to sponsor one student as part of their enrollment fee.

The funding efforts to date have provided over $100,000 to support the ETSU at Rome Program. Cultivation, solicitation, partnerships, stewardship and strong support by university leaders have been essential to the success to date. Many, if not most, of the students who have participated in the program have never traveled abroad or even flown on an airplane. Their stories have been told, and they have touched the hearts of the donors. One girl related that she planned to withdraw from the program because of a lack of funding. She was working two jobs but still lacked the resources necessary for the course. She was able to thank her donor during the President's Reception, and she told him that because of his sponsorship and her family selling four cows, she was able to participate in the program. Other personal circumstances and her sincerity had an emotional impact on many. The story of this student and many other touching stories are shared with the donors as much as possible. This has resulted in the donors feeling good about their investment and feeling special to their student and ETSU. It is our hope that continual personal involvement by the donors will result in new, creative opportunities for students.

Marketing/Recruitment

The marketing and recruitment process is an aspect that requires much time and effort because without students this program cannot exist. It is important that students feel comfortable with their professors, be well informed, and clearly communicate expectations for their experience to be successful. Much time and consideration is spent to make this take place for the students. Numerous ways to spread the word regarding the ETSU at Rome Program have been established. Posters have been created and placed on bulletin boards across campus in academic buildings, dormitories and student centers. Going class-to-class presenting the program has proved to be a beneficial way to increase student enrollment. A Facebook group has also been created as a hub for discussion and information. The site is used for students to view pictures from Rome, new details regarding the trip and pre-departure meetings, and discussion aspects with current and former classmates. With each new class traveling to Rome, the word will spread around campus. Numerous students have enrolled who were referred by a friend who attended a previous course in Rome.

Due to the efforts of one instructor and two students, a website for the ETSU at Rome Program, www.etsurome.co, was launched. This website incorporates photo galleries, program details, donor recognition, various forms, and previous work (i.e., sketches, projects, writings, etc.). It also serves as a focal point of information for anyone interested in the program. The best recruitment technique is felt to be the personal attention focused on each student throughout the entire process. Creating a comfortable environment for students is vital to the success of the program. The more comfortable each student is with the entire concept of studying abroad, before and during the trip, the better everyone's experience abroad will be. The key to a successful program is making it all about the students. This "all about the student" approach has helped students feel more comfortable with pre-departure aspects as well as what to expect once they arrive abroad. Program leaders personally meet with every potential student interested in studying in Rome for roughly 30 minutes. Listening to every student's concerns, and addressing these needs, provides a better overall experience for everyone involved.

Hardly any students are familiar with all of the details involved in preparing for a study abroad experience. Thus, the students are helped to complete everything involved in receiving their visas and informing them of what to expect once they arrive. About three or four group meetings are held prior to departure. The first meeting is a get-together, usually at a restaurant during the middle of the fall semester. This meeting is mainly for students to get to know one another, though scholarships, visas and passports are also discussed. These are things that should be completed prior to the spring semester.

During the other pre-departure meetings, housing arrangements, flight information, emergency contact information, money exchange, and all other important details that should be examined prior to departure are discussed. Preparation is vital to the success of recruitment and the overall experience students have while studying abroad. It is important for students to be comfortable with one another as they will be a virtual family while together abroad.

Curriculum

It is hoped that students will gain knowledge, experience the culture, and grow as individuals during their stay abroad. Studies in recent years have shown a significant impact of internationalization on university curricula across the country [4]. Since the ETSU current course offerings last only three weeks during the Pre-Summer Session, the curriculum was designed so that students will be able to gain as much as possible from their study abroad experience. A typical school day in Rome consists of a short lecture prior to a walking tour to complement the discussions. Generally, a one-hour lecture takes place in the classroom in the morning to discuss details of the sites to be visited afterward. The walking tour is usually 3-4 hours visiting sites throughout Rome.

Side trips have also been incorporated into the course. These excursions are not only learning experiences for students but a get-away from the bustling streets of a large city. Each year students visit Pompeii and Tivoli, both of which can be easily completed as a day trip. ETSU has partnered with a professor of archeology to accompany the students around the historic city of Pompeii. While in Tivoli, a visit to Villa d'Este is included in order to study its Renaissance architecture, gardens, fountains, and to spend a day outside the bustling city of Rome.

For the required coursework, students are divided into small groups and are assigned a time period. These groups, typically 3-4 students each, are assigned Antiquity, Medieval, Renaissance or Baroque. Each group is required to complete an introduction to the time period, a profile of a key figure, and six case studies. For the case studies, students depict information from lectures, observations and field studies of a building or site from their assigned time period. Along with this project, students are also required to complete a sketch/photo journal. All of the students' work is compiled into a large project detailing time periods, key figures and sites throughout historic Rome, and an on-campus presentation is made documenting the effort upon returning to the United States.

Mentorship

Another entrepreneurial aspect of the program is the relationship that can be created with the student and his or her sponsor. Sponsors are asked to mentor a student as a part of the ETSU at Rome Program and numerous opportunities for interaction are created. Students are encouraged to continue their relationship with their sponsor throughout their professional career as well. After the students' experience in Rome, a non-formal gathering is scheduled for the students to meet their sponsors. This meeting provides an opportunity for the students to express their appreciation and to share their experiences. The first year's gathering was so successful that many sponsors expressed interest that day in contributing funds for the following year. Also, several students have attained employment and other benefits as a result of this arrangement.

When most donors contribute to a university, they are unable to witness the direct impact that they are making on students' lives. Typically when a donation is made to a university, a check is written, a receipt is provided, and a name is printed in a donation listing. However, the ETSU at Rome Program is different. Donors are considered as sponsors, and they are much more involved in the process because of the one-on-one communication with their student recipient.

Students are encouraged to write a thank-you card prior to the trip, send a postcard while in Vatican City, and present a gift at the post-trip gathering. A short video clip is also emailed to the sponsor of their student expressing gratitude while standing in front of a famous sculpture or building. Attending the post-trip gathering also allows sponsors the opportunity to witness the excitement and joy on the faces of their students. To many students, their Rome experience is life-changing, and the opportunity to express this to their sponsor is highly anticipated. This type of interaction between the donors and students has reinforced the strength of all contributors' investments.

Growth/Future Plans

The plan for the ETSU at Rome Program is for students to be able to complete an entire semester's worth of classes during the summer. It is hoped that in the near future courses can be offered not only that are part of the students' curricula, but also certain other general education courses such as speech and language. Offering general education courses will help to expand the range of students to include more disciplines.

A technology endowment was started by an individual for use specifically in the Technology Department. This endowment was created with an initial gift of $10,000 and, through contributors, has grown to $24,000 since the start of the ETSU at Rome Program. Without funding, this program would not be where it is today. Plans to expand the program cannot happen without additional funding and scholarships. Thus, involvement from specific individuals throughout the community and university for financial support Is being sought. Enrollment has reached 25 students for the 2011 session, and a waiting list for this session has also been created. Currently, progress is being made to allow students the opportunity to earn a certificate while studying in Rome. For the 2012 summer session, another professor in the College of Business and Technology is planning to offer a course to 12 MBA students. Additionally, the director of the Roan Scholars Program, a leadership program at ETSU, is working to establish a permanent course offering for four students every year in Rome.

Conclusion

It is a challenge to create permanent study abroad courses at a regional university. The obstacle of cost and the common feeling among students that living and studying abroad is more of a dream than a reality can cause many good intentions to fail. The ETSU at Rome Program provides a good case study on overcoming common challenges. In short, the key to success starts with funding, and that is the most unique part of this program. Students receive significant scholarships from student fee money and sponsorships from donors in their field. Targeting companies and individuals with ties to the department, interest in the field of study and the ability to access resources is paramount in attaining funding. The donors also feel good about this program. They are afforded the opportunity to meet their students and learn first-hand how they improved their learning experience. This is unique, and one should not underestimate the value of involving donors and clearly demonstrating how they have made a positive difference. Finally, long-lasting partnerships between the students, community leaders and the university are strengthened.

Certainly there are numerous organizations that regional universities can partner with to create opportunities abroad for their students. However, much more can be gained from having a permanent study center abroad. Students, professors, community leaders and others will attain far more success when each is personally invested in a program that is their own. Many of the students who have completed a course with ETSU in Rome have been helped financially to live abroad, been exposed to new learning opportunities, established many new relationships, worked with mentors, attained employment and many other unique benefits. The challenges to creating a permanent study abroad program are many, but the rewards are great. Be assured that a well-thought-out plan and a passion from department and university leaders will allow most institutions to achieve success.

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Biographies

JEREMY B. ROSS received the Bachelor's degree in Architecture from the University of Tennessee, Knoxville, TN, in 1996, and the M.S. degree in Engineering Technology from East Tennessee State University, Johnson City, Tennessee, 2007, respectively. Currently, he is an Assistant Professor in the Engineering Technology Program and an Associate Vice President at East Tennessee State University. Professor Ross may be reached at rossjb@etsu.edu

DR. KEITH V. JOHNSON received the B.S. and M.S. degrees in Technology from North Carolina A&T, Greensboro, NC, the M.S. degree in Technology from North Carolina A&T, Greensboro, NC, and the Ph.D. degree in Technology from the Ohio State University, Columbus, OH, respectively. Currently, He at is Chairman and a full professor in the Department of Engineering Technology, Surveying and Digital Media at East Tennessee State University. Dr. Johnson may be reached at johnsonk@etsu.edu

KEVIN W. VARNEY received the B.S. degree in Engineering Technology from East Tennessee State University, Johnson City, Tennessee, in 2009, and the M.S. degree in Engineering Technology from East Tennessee State University, Johnson City, Tennessee, 2011, respectively. Currently, he serves as an assistant instructor for the *ETSU at Rome Program* at East Tennessee State University. Mr. Varney may be reached at zkwv2@goldmail.etsu.edu

INCREASING THE STEM PIPELINE THROUGH PROBLEM-BASED LEARNING

Michele Dischino, Central Connecticut State University; James A. DeLaura, Central Connecticut State University;
Judith Donnelly, Three Rivers Community College; Nicholas M. Massa, Springfield Technical Community College;
Fenna Hanes, New England Board of Higher Education

Abstract

Problem-based learning (PBL) is an instructional approach whereby students learn content by actively and collaboratively solving authentic, real-world problems. Used extensively in medical education since the 1970's, PBL has emerged as an exciting and effective alternative to traditional lecture-based instruction in science, technology, engineering and math (STEM) education. Research shows that PBL improves student learning and retention, critical thinking and problem-solving skills, teamwork, and the ability to apply knowledge in new situations – skills deemed critical for success in the 21st-century workplace.

In "Problem Based Learning for Sustainable Technologies: Increasing the STEM Pipeline" (STEM PBL), the principles of PBL are being used to develop innovative, standards-based curricula with the aim of increasing students' interest and preparedness in pursuing STEM-related careers. STEM PBL is a project of the New England Board of Higher Education and is funded by the National Science Foundation. Currently, the project PIs are working with industry collaborators breaking new ground in "green" technologies to create a comprehensive series of online multimedia PBL resources focused on sustainability. Referred to as STEM PBL challenges, these instructional materials are designed to engage secondary and post-secondary students in real-world problem-solving. In addition to providing professional development in both on-site and online formats to in-service teachers, the STEM PBL project will also create a model course in PBL methodology for pre-service middle and secondary school teachers.

Introduction

Need for STEM Talent in the U.S. and National Statistics

Long-term growth in the number of positions in science and engineering has far exceeded that of the general workforce, with more than four times the annual growth rate of all occupations since 1980 [1]. The most recent occupational projections from the Bureau of Labor Statistics [2] forecast that total employment in fields that the National Science Foundation classifies as science and engineering will increase at nearly double the overall growth rate for all occupations by 2014, growing by 26% from 2004 to 2014, while employment in all occupations is projected to grow 13% over the same period [3].

In spite of such promising job prospects, recruitment for science and engineering programs is a real challenge for most universities nationwide. Unfortunately, math and science are not the subjects of first choice for the majority of American high school students. According to the recent report, Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future, in South Korea, 38% of all undergraduates receive their degrees in natural science or engineering. In France, the figure is 47%, in China, 50%, and in Singapore, 67%. In the United States, the corresponding figure is only 15% [4].

If the U.S. is to maintain its competitive edge in the global economy, the pipeline of interested and qualified students prepared to enter STEM careers must be increased. Yet recent results from a survey by the American Society for Quality (ASQ) revealed that more than 85% of students today are not considering careers in engineering and that more parents encourage their daughters to become actresses than engineers. Forty-four percent of survey respondents cited a lack of knowledge around engineering as the top reason they would not pursue such jobs. Another 30% listed the "geek" perception as their top reason, indicating that "engineering would be a boring career," according to the ASQ [5]. This is one of the most serious issues our nation will face over the next decade, as the current science and technology workforce retires without a pipeline of workers to replace them.

Equally alarming, international comparisons of student mathematics and science performance indicate that U.S. students scored below average among industrialized countries [3]. U.S. 15-year-olds ranked 27th out of the 39 countries participating in the 2003 Program for International Student Assessment (PISA) examination, designed to assess students' abilities to apply scientific and mathematical concepts to real-world problems [6]. Furthermore, the retention rate for engineering students is one of the lowest among all majors; one-third of all U.S. students intending to pursue engineering change majors before graduating [4]. Thus, improving the preparation of STEM teachers in the United States and the number of effective teaching tools available to them is critical if American students are going to keep pace with their counterparts internationally. Furthermore, the characteristics of instruction that best serve diverse student populations is a research area of particular need [7].

Problem-Based Learning

Overwhelming evidence exists that students from all backgrounds have the capacity to become proficient in math and science, and that children of all ages can and do engage in complex reasoning about the world [8], [9]. The National Academies, in its recent publication Taking Science to School: Learning and Teaching Science in Grades K-8, made the following statement [8]:

> Comparisons of science standards and curricula in the U.S. with that of countries that perform well on international science tests reveal overly broad and superficial coverage of science topics in U.S. classrooms … an overemphasis on recipes for data collection procedures—whether experimental, observational, or archival—may strengthen the misconceptions that some students hold about the so-called scientific method—the image that scientific discoveries emerge unproblematically if one just faithfully follows the steps outlined in the science text. (p.342)

One of the reasons for declining enrollment in many STEM programs is that students are often turned off by the way these subjects are typically taught, with traditional classroom lectures followed by "cook-book" type laboratory experiences that provide little opportunity to actively engage in creative, real-world problem solving. In 2008, the National Academy of Engineering [10] identified "Advance personalized learning" as one of the Grand Challenges for Engineering in the 21st Century, and made the following point:

> Throughout the educational system, teaching has traditionally followed a one-size-fits-all approach to learning, with a single set of instructions provided identically to everybody in a given class, regardless of differences in aptitude or interest. … In recent years, a growing appreciation of individual preferences and aptitudes has led toward more 'personalized learning,' in which instruction is tailored to a student's individual needs. [10]

Engineers and scientists are problem solvers— individuals who skillfully apply their knowledge to tackle real-world problems by designing experiments, building and troubleshooting prototypes, analyzing and interpreting data, and presenting experimental results to peers, supervisors and customers. It follows that to attract more students into STEM careers, students must be provided with more meaningful learning experiences in order to motivate and excite them—learning experiences that relate directly to the world in which they live. They want and need active hands-on learning experiences that challenge them to explore new and emerging technologies that provide opportunities to think outside the box and apply their knowledge, skills and creativity in solving authentic real-world problems [11-14]. Problem-Based Learning (PBL) is capable of providing this type of learning experience.

PBL is an instructional method that challenges students to "learn how to learn" by collaboratively solving ill-defined, real-world problems. It is based on the constructivist model of learning and consists of four key components: 1) ill-structured problems that are likely to generate multiple hypotheses about their cause and multiple approaches to their solution, 2) student-centered learning, where students determine what it is they need to learn and find appropriate resources for information, 3) teachers acting as facilitators or tutors, and 4) authentic, real-world problems [15].

In PBL, students actively participate in their own learning by solving real-world problems in which the parameters are ill-defined and ambiguous. Unlike traditional instruction in which students attend lectures and solve well-defined end-of-chapter homework problems, PBL is open-ended and contextualized, and student learning is driven by the problem itself. With PBL, students learn the process of learning in addition to course content by engaging in a systematic and iterative process that begins with problem analysis, carefully and methodically dissecting a problem by reflecting on prior knowledge to identify knowledge gaps, situational constraints, and other pertinent problem features required to formulate a solution. Once the problem has been properly framed, students engage in self-directed learning to acquire the knowledge and skills needed to solve the problem. This is followed by brainstorming possible solutions with peers, and finally solution testing, where students develop viable strategies to test and validate their solutions.

PBL has been used extensively in medical education since the early 1970's and research has shown that PBL improves student understanding and retention of ideas, critical thinking and problem-solving skills, motivation and learning engagement, and the ability to adapt their learning to new situations [16-19]. While PBL has been adopted in other fields of higher education including business and law, it is only beginning to emerge as an alternative to more traditional approaches in K-12 STEM education. Though not abundant, results from studies of PBL in K-12 STEM education are also promising. In a recent review article published in the Journal of Engineering Education, Litzinger et al. state “it is clear that [engineering] students would benefit from a greater number of opportunities to address authentic problems” and recommend PBL as an instructional approach that can be used to achieve this goal [20].

Some research even suggests an increased likelihood that at-risk students will succeed academically when provided with alternative learning environments such as PBL. A study of girls at risk of failing middle school math or science showed that all study participants had positive reactions to PBL, as evidenced by improvements in students’ learning processes and self-efficacy [21]. A separate study compared the effectiveness of PBL and traditional instructional approaches in developing high school students’ macroeconomics knowledge and found PBL to be more effective overall [22]. Interestingly, the results from this study also showed that PBL was particularly effective with students of average verbal ability and below, students who were more interested in learning economics and students who were most and least confident in their ability to solve problems.

While there is substantial evidence to suggest that PBL can be a valuable supplement to traditional, lecture-based instruction, its effectiveness depends on a variety of factors including variations in the implementation of PBL methodology and assessment of learning outcomes, as well as teachers’ knowledge skills and attitudes towards PBL [23], [24]. A recent case study described the outcomes of one high school science teacher’s exploration of PBL methods in her classroom [25].

> For many teachers who have not experienced new methodologies as teachers or as learners, trying a new approach can be intimidating. If PBL is to become more prevalent in K-12 contexts, assuming this is a desirable goal, then teachers will need support and encouragement to try it. Deidre, who should be praised for her willingness to try something new in support of her students' learning, was uncomfortable with letting go of the control offered by her usual methods of instruction. She overcame this barrier, but completed the project still questioning the efficacy of PBL. Many teachers are driven to cover the curriculum, and adopting this more time-consuming approach is not consistent with coverage. (p.280)

Additional research into the factors affecting teachers’ adoption of PBL may prove valuable in promoting more widespread use of this promising pedagogical approach.

Previous Work

To improve the readiness of teachers, including in-service and pre-service K-12 STEM educators, to incorporate PBL into their instructional methodologies, the STEM PBL project will build upon the successes of PHOTON PBL, a project of the New England Board of Higher Education (NEBHE) that was launched in 2006. Funded by the National Science Foundation (NSF), the PHOTON PBL project led to the development of eight multimedia PBL “challenges” which were created in partnership with the photonics industry and university partners and field-tested by more than 50 STEM educators from secondary and post-secondary institutions across the U.S. The PHOTON PBL challenges are self-contained multimedia instructional modules designed to develop students’ problem-solving abilities and understanding of photonics concepts and applications. The eight PHOTON PBL challenges are listed below and are currently available at NEBHE’s PBL website (http://pblprojects.org), along with an Implementation Guide for Teachers and several related conference publications and resources which provide a complete description of this prior work.

The PHOTON PBL challenges:

- Stripping with light, fantastic! – PhotoMachining Inc. in Pelham, NH, needs to develop a laser-based process for stripping the coating from 50-micron wire.
- DNA Microarray Fabrication – Boston University graduate students need to determine the best starting exposure time for a DNA microarray fabricator.
- High-Power Laser Burn-In Test – IPG Photonics in Oxford, MA, needs a way to run 100-hour unattended burn-in tests on a 2-kilowatt laser.
- Shining Light on Infant Jaundice – Partners Photodigm, Drexel and SMU ask, "Can technology provide a safe and effective portable home treatment for newborn jaundice?"
- Watt's my light? – The package on an energy-saving light bulb says the 26-watt fluorescent has the same light output as a 100-watt incandescent. Can Cal Poly Pomona students verify this statement?
- Of mice and Penn – UPenn McKay Orthopedic Research Lab graduate students study the healing of tendon injuries using mouse tendons. Can optics provide a non-contact method for measuring mouse tendon properties?

- Hiking 911 – Two boys are lost in deep woods in rough terrain. Penn State Electro Optics Center (EOC) needs to recommend the best technology to locate them.
- Blinded by the Light – A man is arrested for blinding a pilot with a laser pointer. Is he innocent or guilty? Make your case.

Results of pilot tests revealed that with increased experience with the PBL challenges, students' conceptual knowledge and problem-solving abilities improved markedly. While pre-post measures of student content knowledge were not available for the study, instructor observations and comparisons of student performance in aggregate using traditional measures (homework, quizzes, and exams) for PBL students with performance of non-PBL students in the past showed that PBL students performed at least as well as non-PBL students. Results also revealed statistically significant increases in intrinsic motivation, self-efficacy and metacognitive self-regulation. Finally, results showed a statistically significant increase in metacognitive self-regulation—a key factor linked to students' ability to transfer knowledge and skills to new situations [26].

The STEM PBL Project

Building on the success of PHOTON PBL, the STEM PBL project will develop six additional PBL challenges focusing on sustainable technologies to bring real-world problem-solving experiences into an even broader range of STEM classrooms in an effort to develop students' critical thinking and problem-solving skills and to expose them to the exciting career possibilities in sustainable technologies. Professional development opportunities for in-service and pre-service STEM educators will develop teachers' capacity for incorporating PBL instructional methods in their classrooms.

The STEM PBL project has four primary goals:

1. Develop six multimedia STEM PBL challenges focused on sustainable technologies in collaboration with industry and university partners designed to appeal to secondary and post-secondary STEM students.
2. Create and implement a web-based professional development course for in-service STEM educators in PBL methodology and the implementation of the PBL challenges in the classroom.
3. Develop a model one-semester classroom course in PBL instructional methods using the STEM PBL challenges for use in pre-service technology and engineering teacher education programs.
4. Conduct research to support future development of PBL instructional materials and courses.

Four of the six STEM PBL challenges have been completed and are listed below. The remaining two are still in development.

Completed STEM PBL challenges:

- FloDesign – Students need to design a new way to extract electrical energy from a wind turbine.
- RSL Fiber Systems is designing an ergonomic and energy-efficient lighting system for submarines.
- Cape Cod Cranberry Growers Association – Can technology be used to make a cranberry bog more energy efficient?
- TTF Watershed Partnership – Can the problem of urban stormwater be addressed by local communities without investing in huge infrastructure projects?

The Anatomy of a PBL Challenge

Each PBL challenge contains five main sections, as can be seen in Figure 1: 1) Introduction – An overview of the particular topic to be explored; 2) Company/University Overview – An overview of the organization that solved the problem to set the context of the problem; 3) Problem Statement – A reenactment of an authentic real-world photonics problem as originally presented to the organization's technical team; 4) Problem-Discussion – A reenactment of the brainstorming session engaged in by the organization's technical team; and 5) Problem Solution – A detailed description of the organization's solution to the problem. The Problem Discussion and Problem Solution sections are password-protected allowing instructors to control the flow of information and pace of instruction. Each of the five main sections contains additional information and resources (e.g., scripts, websites, spec sheets, etc.) intended to guide the student through the problem-solving process.

Figure 1. Multimedia PBL Challenge Interface

Designed to be implemented using three levels of structure ranging from Structured (instructor led), to Guided (instructor guided), to Open-ended (instructor as consultant), the PBL challenges provide the necessary scaffolding to assist students in the development of their problem-solving skills through a developmental continuum. By allowing students to gradually progress through the PBL challenges along a developmental continuum, students can develop the knowledge, skills and confidence to take responsibility for their own learning. Likewise, providing instructors with control over the learning process and user-friendly technical and pedagogical resources makes it easy to implement PBL in their classrooms.

Another unique feature of the PBL challenges is the Problem-Solvers Toolbox. The Problem Solvers Toolbox is a resource designed to help students develop a systematic approach to problem solving through a four-stage recursive process, as illustrated in Figure 2.

Figure 2. Problem-Solving Toolbox with Icons Representing Problem Analysis, Independent Research, Brainstorming and Solution Testing

- Problem Analysis – Identifying what is known, what is unknown and needs to be learned, and identifying any problem constraints to properly frame the problem.
- Independent Research – Setting specific learning goals, identifying necessary resources, and developing a timeline and strategy for achieving those goals.
- Brainstorming – Productively engaging in collaborative learning to identify the best course of action for solving the task at hand.
- Solution Testing – Developing a viable test plan to validate your potential solution based on specific performance criteria.

For each of the four processes, students click on an icon that reveals a "Whiteboard" graphic designed to emulate an actual classroom whiteboard. The whiteboards, shown in Figure 3, provide a systematic method for students to capture their thoughts, ideas and learning strategies during each stage of the problem-solving process. Students may cycle through the whiteboards several times for a given problem, revising their problem solution each time until they converge on an optimal solution. For instructional purposes, the whiteboards can either be printed or projected/copied onto an actual classroom whiteboard. (see Figure 4).

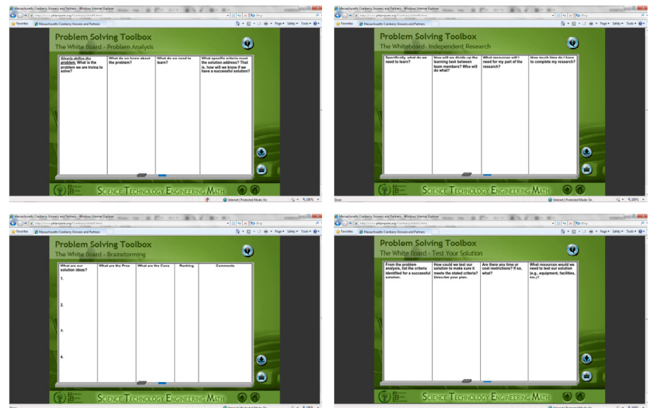

Figure 3. The STEM PBL Whiteboards for (clockwise from upper left) Problem Analysis, Independent Research, Brainstorming and Solution Testing

Figure 4. Students using the Problem Analysis Whiteboard

For instructors, a comprehensive Teacher Resource section is included (see Figure 5) that provides technical background on the main concepts introduced, assessment strategies, implementation stories detailing how other instructors at different educational levels have implemented the PBL challenge, a guide for standards alignment and a PBL How-To Video illustrating the use of the PBL challenges in the classroom.

Figure 5. Teacher Resources

Assessing student learning in PBL often presents a unique challenge for educators accustomed to traditional assessment methods used in lecture-based instruction. The method used to assess student learning in the PBL challenges is based on a three-pronged adaptive expertise model adapted from the Vanderbilt-Northwestern-Texas-Harvard-MIT (VaNTH) Research Center for Bioengineering Educational Technologies [27], which involves three measures: content knowledge, conceptual knowledge and problem-solving ability (see Figure 6). A weighted average calculated for the three measures results in a final composite score. Specific weights may be assigned by the instructor depending on the specific course format.

Figure 6. Student assessment strategies.

To assess content knowledge, the PBL challenges include a test bank consisting of multiple-choice questions, closed-ended problems and higher-level thought provoking questions centered on specific technical content associated with the particular problem. Conceptual knowledge refers to a student's understanding of and the relationship between key concepts underlying a particular domain of knowledge. To assess conceptual knowledge, the PBL challenges include a list of main concepts related to the topic being explored, a reference or expert concept map for instructors, detailed instructions for students on how to construct a concept map, and a concept map scoring rubric. Assessing problem-solving ability involves both formative and summative assessments. Formative or in-process assessment is accomplished via the whiteboards. As students collaboratively engage a problem by completing the four whiteboards, they reflect upon and elucidate their current state of understanding, their thought processes and problem-solving strategies. Research shows that verbalizing the thought process while engaging in problem solving improves metacognition, which is essential for effective problem solving [28]. Summative or post-process assessment is accomplished through a Final Challenge Report. The Final Challenge Report is a reflective journal that requires students to provide a detailed summary and critical analysis of the problem-solving process employed in solving the PBL challenge. Researchers maintain that this final reflective exercise is essential in the development of effective problem-solving skills [29]. A scoring rubric is provided to grade the Final Challenge Report.

Web-Based Professional Development for In-Service Educators

Over the 2009-2010 academic year, thirty secondary, community college, four-year college and university in-service STEM educators were recruited nationwide to take part in a 15-week online course. The online course was conducted in three 5-week sessions in fall 2010, winter 2011 and spring 2011, for a total of 90 hours of coursework, with a break of 6-8 weeks between sessions. Experience gleaned from prior online course delivery [30] revealed that participants perform better in short-term sessions with time in between to reflect on the experience and begin to plan implementation of the course material in their own classrooms.

Experienced PBL instructors from the PHOTON PBL project have also enrolled in the course as mentors who monitor discussions and provide guidance to new faculty. Course participants work in small teams of 3-4 teachers to model the dynamics of how the PBL challenges will be used in their classrooms. Using Blackboard Vista® as a course delivery platform, participants work to solve three STEM PBL challenges, beginning with a Structured format (Session I), then a Guided format (Session II), and finally an Open-ended format (Session III) through threaded discussions and online chats. From session to session, the participants are given greater autonomy as more responsibility is placed on them to self-direct their own learning. The course structure, from highly structured to open-ended will emulate the way instructors will use the challenges with their own students. Between online class sessions, participants will collaborate with each other, PHOTON PBL mentors and the STEM PBL project team to explore how best to incorporate the PBL challenges into their own classroom and curricula.

Prior to the online course, a two-day introductory workshop was held in early fall 2010 at a central location to acquaint participants with the online learning environment and the PBL challenges, and to create a learning community to foster online collaboration. All participants were added to the PBL listserv, an email listserv managed by the New England Board of Higher Education (NEBHE) and composed of a nationwide network of PBL educators, educational researchers and industry mentors. Employees of partner industries and research universities also participate in the listserv to provide ongoing technical support to educators.

A Model Classroom Course for Pre-Service Technology and Engineering Educators

In addition to providing professional development to in-service teachers, the STEM PBL project will also create a model course in PBL methodology using the STEM PBL challenges for technology and engineering education (TEE) majors (pre-service middle and high-school teachers). To accomplish this goal, an existing required classroom course in instructional methods at Central Connecticut State University (CCSU) is being adapted to include PBL theory and applications. The course, TE 399, is currently offered once per year and the new PBL-based version will be delivered for the first time in spring 2011. TE 399 is required of all TEE undergraduates at CCSU and students must have taken at least one practicum course in the program and achieved junior status prior to enrolling. A course description follows:

TE 399: Development of knowledge and skills needed by an individual to function as a professional technology education teacher. Preparation, presentation and evaluation of student-developed lessons and methods of student assessment, unique to technology education laboratories, will be emphasized.

Similar to the online course, students will work to solve three STEM PBL challenges, first as a Structured problem, then as Guided and Open-ended. As a capstone project for the course, students will use the pedagogical strategies and technical skills they acquire throughout the semester to develop an original multimedia PBL challenge on a STEM topic of their choosing. As a result, a collection of STEM-related PBL learning tools will evolve and will be disseminated through the NEBHE PBL website.

Research Methods

As demonstrated by the literature cited previously, there is a great deal of evidence to suggest that there are multiple benefits to be realized by using PBL. The research also shows, however, that PBL requires time and effort in gaining acceptance and that more work is necessary to improve teachers' skills in facilitation and attitudes toward self-directed learning. To address this need, the STEM PBL project is currently conducting quantitative and qualitative research into teachers' knowledge, skills and attitudes concerning PBL and their self-efficacy with regard to its implementation. The project will also examine the extent to which specific online professional development activities contribute to changes in teaching practices (i.e., transfer of training) among participating in-service teachers and compare these results with the outcomes of the pre-service course.

To accomplish this, the Motivated Strategies for Learning Questionnaire (MSLQ) will be administered to the in- and pre-service teachers at the beginning and end of their respective courses. The MSLQ is an online survey consisting of 81 statements regarding motivation for learning and learning strategies to which students are asked to respond using a 7-point scale, from 1 ("Not true of me at all") to 7 ("Very true of me") [31]. The questionnaire, which takes approximately 20 minutes to complete, will be customized in order to specifically assess teachers' perceptions of PBL. The results from the MSLQ surveys will be triangulated with data from pre- and post-tests on PBL content knowledge as well as samples of course work and comments from focus groups. Informed consent will be required of all participants.

Conclusion

In this paper, the STEM PBL project was presented, a three-year NSF-funded project aimed at increasing the STEM pipeline through PBL focused on sustainable technologies. Also discussed was how the STEM PBL project team, building on their prior work on the NSF-funded PHOTON PBL project, is now working with industry and research universities breaking new ground in sustainable and green technologies to create a comprehensive series of multimedia PBL challenges designed to engage students in real-world problem solving. A detailed summary of the PBL challenge model was presented as well as a description of the online professional development course offered over the

2010-2011 academic year for in-service teachers in PBL instructional methods using the STEM PBL challenges. Also described was the development of a new course in PBL instructional methods for pre-service TEE teachers Finally, a discussion on the research activities scheduled to take place to evaluate the efficacy of the new STEM PBL challenges with regard to the learning outcomes and transfer of training among participating faculty was presented.

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Biographies

MICHELE DISCHINO is an assistant professor in the Technology & Engineering Education Department at Central Connecticut State University. Dr. Dischino received her Ph.D. in Bioengineering from the University of Pennsylvania in 2006 and her B.S. in Mechanical Engineering from Manhattan College in 1992. Dr. Dischino may be reached at dischinomic@ccsu.edu

JAMES DELAURA is a full professor and chair of the Technology & Engineering Education Department at Central Connecticut State University, where he is reshaping and revitalizing the curriculum to include the latest methods of technology instruction. He holds an Ed.D. from the University of Northern Colorado and is a Certified Manufacturing Engineer. Dr. DeLaura may be reached at delaura@ccsu.edu

JUDITH DONNELLY is a full professor in the Photonics Engineering Technology Department at Three Rivers Community College. She holds a B.S. degree in Chemical Physics from Tufts University and an M.S. degree in Bioengineering from the University of Connecticut. Ms. Donnelly may be reached at jdonnelly@lasertechonline.org

NICHOLAS MASSA is a professor in the Laser Electro-Optics Technology Department at Springfield Technical Community College in Springfield, MA. He holds B.S. and M.S. degrees in Electrical Engineering from Western New England College and a Ph.D. in Educational Leadership/ Adult Learning from the University of Connecticut. Dr. Massa may be reached at massa@stcc.edu

FENNA HANES is Senior Director of Professional & Resource Development for the New England Board of Higher Education in Boston. She holds a B.S. degree in Liberal Arts/Business Administration from Northeastern University and an M.S. degree in Public Affairs from the University of Massachusetts. Ms. Hanes may be reached at fhanes@nebhe.org

CAN USING A FORMAL SYSTEM FOR TRACING COMPUTER PROGRAMS HELP STUDENTS LEARN INTRODUCTORY COMPUTER SCIENCE?

Tom M. Warms, Pennsylvania State University Abington College; Qiang Duan, Pennsylvania State University Abington College; Kavon Farvardin, Pennsylvania State University

Abstract

Teachers of computer science have known that the ability to trace a computer program is in some sense a necessary condition for being able to write original programs. The concept of tracing has not been given much specificity in the literature. In the research reported upon here, a formal concept of tracing is used to present material to an introductory computer science class and, in a computer software representation, is made available to the students as a resource. Neither the tracing method nor the software is made available to a control section. The results of the research suggest that programming students feel that the tracing technique and software are useful tools, and inexperienced students respond more positively to the method and the software than experienced students.

Introduction

Tracing a computer program is an imprecise term that is used to describe the activity of following the statements of the program, step-by-step, and predicting the results of executing the statements. The literature describes experiments that relate the ability of a student to trace programs or program segments accurately to the student's ability to write original programs. One study [1] examined behaviors of students as they tried to solve programming problems, and found that students who accurately formed certain kinds of traces had a high probability of getting the correct answer to a variety of programming-related questions. Conversely, the study found that students who did poorly on tracing had a fragile grasp of basic programming principles, and suggested that an early emphasis on tracing and program comprehension might liberate the student to concentrate on the more creative aspects of programming. Another study [2] suggested that "the combination of tracing and explaining questions, more so than each skill independently correlates highly to code writing skills, supporting the ... notion of a hierarchical development of skills in learning to program."

In the present study, a formal method for tracing the execution of computer programs [3], [4] is introduced by the instructor to an experimental section; a computerization [5] of the system is used for lecturing and is made available to the students in that section as a resource. The study seeks to determine whether or not the student's overall performance in the course is enhanced by this availability.

Method

The experiment was conducted in two sections of the CMPSC 121 course in the Fall 2010 semester at a campus of Pennsylvania State University. CMPSC 121 introduces the fundamental concepts of computer programming and teaches students basic skills for designing and implementing structured programs. This course uses C++ as the programming language and employs the procedural paradigm almost exclusively. This is the first course in a three-course programming sequence for computer science and computer engineering majors at Penn State. There is no computer programming prerequisite for the course. Topics covered in this course include data types, mathematical expressions and calculations, basic I/O and files, control structures, looping structures, user-defined functions, arrays, simple searching and sorting algorithms, and the mechanisms of running, testing, and debugging a program.

There were two sections of CMPSC 121 taught by the same instructor in Fall 2010. The experimental section in which the tracing method was taught and for which the tracing software was made available had 16 students. The control section had 7 students who were not exposed to the tracing method. Students enrolled in the two sections included computer science and computer engineering majors as well as students in a variety of engineering and other majors.

Before taking this course, some students learned programming either by taking courses in high school or college or by teaching themselves. For other students, this was their first programming experience. In the experimental section, the instructor introduced the tracing method at the beginning of the third week of the semester. At that time the tracing software was provided to students by posting it on the class bulletin board for download.

From the time of introduction, the instructor used the tracing software as a tool to explain new concepts. Typically, the instructor used the software to trace through example programs to demonstrate how those programs are executed. By doing that, the instructor also demonstrated how to use the tracing software. Example programs for the following subjects were analyzed by using the tracing software: basic mathematical expressions and calculations, if and if-else statements, while, do while, and for loops, user-defined function calls and returns using both call-by-value and call-by-reference, arrays, and linear search. Students in the experimental section had opportunities to use the tracing method and the software both in class and after class. The instructor also demonstrated how to use the tracing method manually without running the software, and asked students to practice it in a homework assignment.

The same set of topics was taught in both sections. Students in the control section were not exposed to either the tracing method or the tracing software. In order to compare the student performances in the two sections, identical homework, test questions and programming activities were assigned to both sections.

```
// This program prompts the user for three integers
// and calculates and prints the largest and smallest
#include <iostream>
using namespace std;
void getExtremes(int, int, int, int &, int &);
int main()
{
      int x1, x2, x3, large, small;
      cout << "Enter three integers: ";
      cin >> x1 >> x2 >> x3;
      getExtremes(x1, x2, x3, large, small);
      cout << "The largest integer is  " << large << endl
            << "The smallest integer is " << small << endl;
      return 0;
}
void getExtremes(int x, int y, int z, int &lge, int &sml)
{
      lge = x;
      sml = x;
      if (y > lge)
            lge = y;
      else if (y < sml)
            sml = y;
      if (z > lge)
            lge = z;
      else if (z < sml)
            sml = z;
}
```

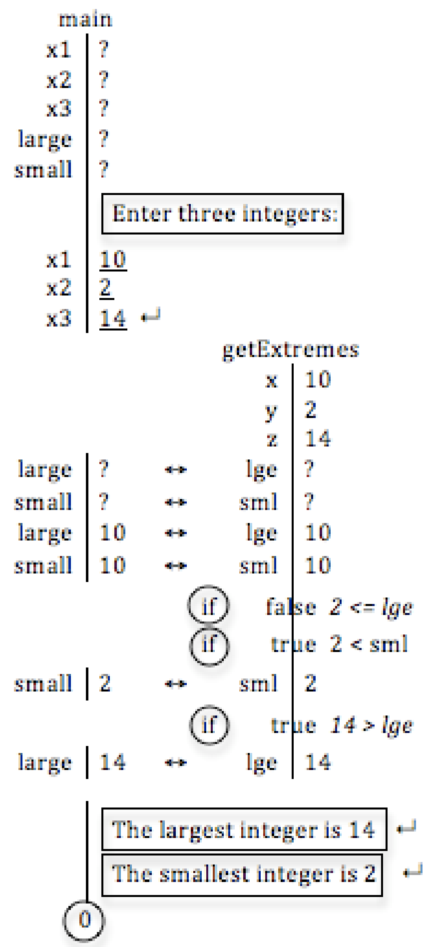

Figure 1. A Program to Prompt the user for Three Integers; Calculates and Prints the Largest and Smallest; using a User-Defined Function for the Calculation

Tracing

The tracing method is described in detail by Warms [3] and Warms & Drobish [4]. According to the method, the student writes down in a specified manner the result of the computer carrying out each of the executable statements in a program. While tracing any program statement in this formal system, the results of executing previous statements are always available. Uniquely, this method provides notations for tracing programs that contain more than one function. There are notations, for example, for statements that transfer control to other functions using call-by-value or call-by-reference, and for statements that return control to the calling function. Figure 1 shows a program that prompts the user for three integers and, using a function, calculates and prints the largest and smallest of the integers.

The Software

The software program, called RandomLinearizer, presents a list of programs to trace. Once one has been chosen, the selected program appears in the center of three panels, followed by an input set. The left panel then contains a randomized list of the elements that make up the trace of the program from that input set. The right panel is initially empty. The student is expected to click on the trace steps in the correct order so that the complete trace unfolds in the right panel. At the same time, the contents of the console window are updated at the bottom of the middle panel.

Figure 2a shows the setup for the trace of a program that uses a function to calculate the sum of two numbers, while Figure 2b shows the completed trace. When the user makes an error, RandomLinearizer displays a window that provides the location and, at times, the nature of the error. Figure 3 shows a diagnostic comment as a user makes a wrong choice in tracing a program.

Student Reaction to the Tracing Method and the Software

Figure 4 contains a questionnaire that was administered to students in the experimental section at the time of the final examination. Questions 1–10 dealt with the tracing method, 11–17 with the software, and 18–20 with the students' programming background. Questions 18–20 were administered to students in the control section as well as in the experimental section, and the responses in both sections were used to determine whether the student was inexperienced or experienced in computer programming. Table 1a shows the results for the responses of the entire experimental section on questions 1–10; Table 1b shows the same results for questions 11–17.

The results of the questionnaire show that students in the experimental section overwhelmingly responded positively toward the method and the software. The students agreed emphatically that tracing helped them learn the material of the course (question 2: Mean = 4.00 on a scale of 1 to 5). When the course material was broken down into general topics, agreement was strongest that the software was helpful when the students were trying to learn how to write programs with functions (question 15: Mean = 4.00). The students responded strongly in the negative to questions which stated that tracing didn't help the student at all (question 4: Mean = 1.64), and the software was not at all helpful (question 14: 1.50).

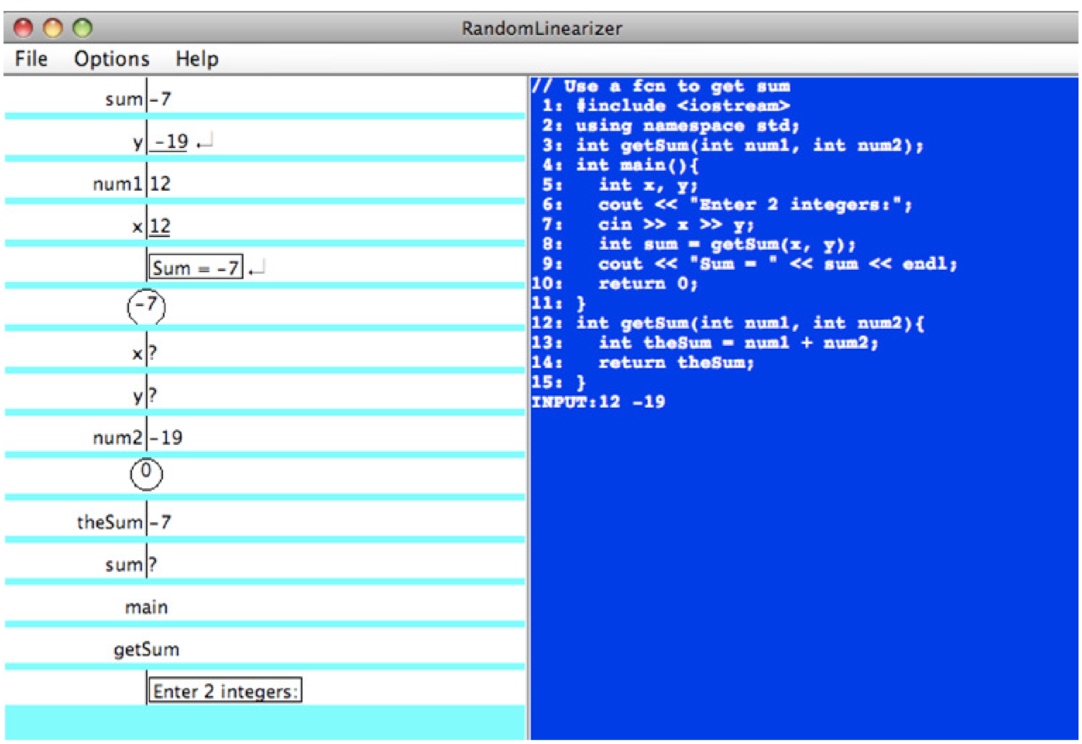

Figure 2a. Setup for Tracing a Program that uses a Function to Calculate the Sum of Two Numbers

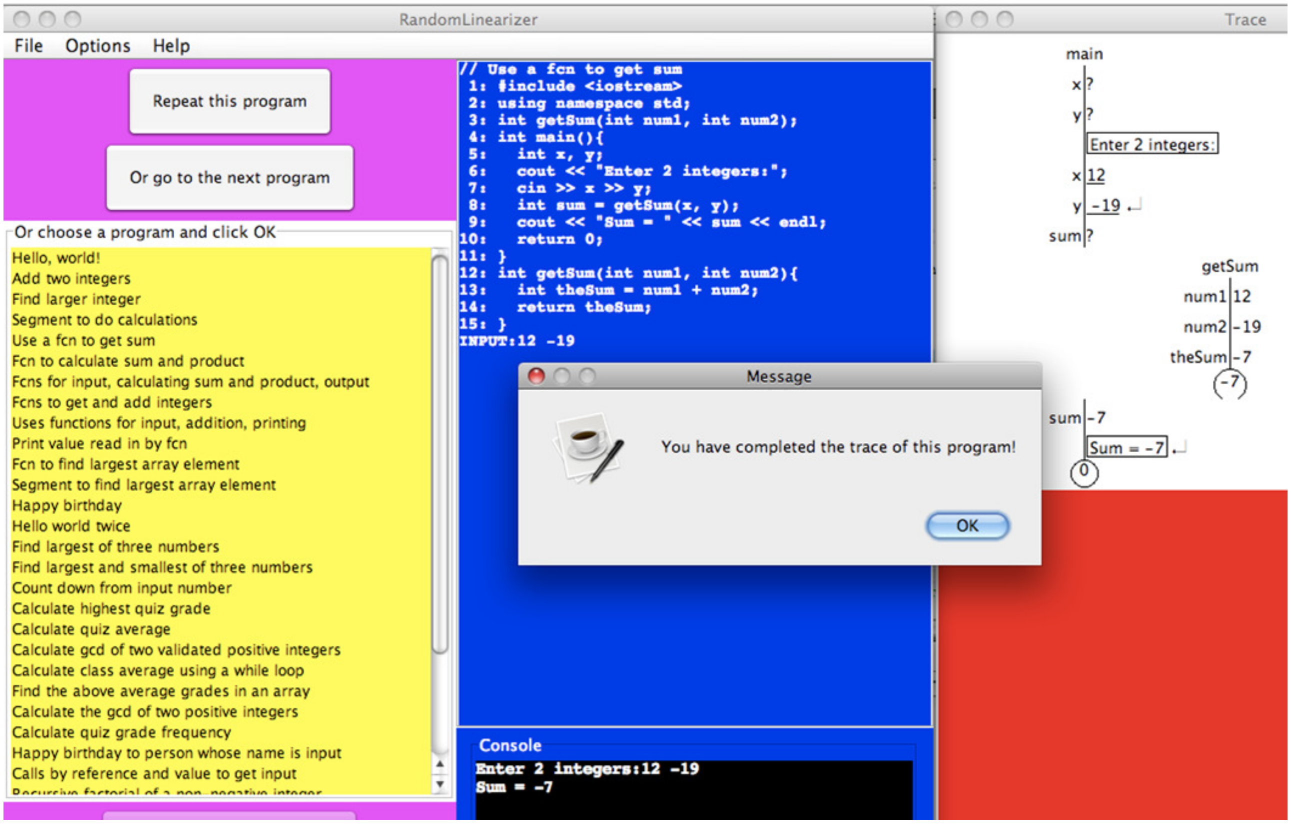

Figure 2b. The Completed Trace for the Program of Figure 2a

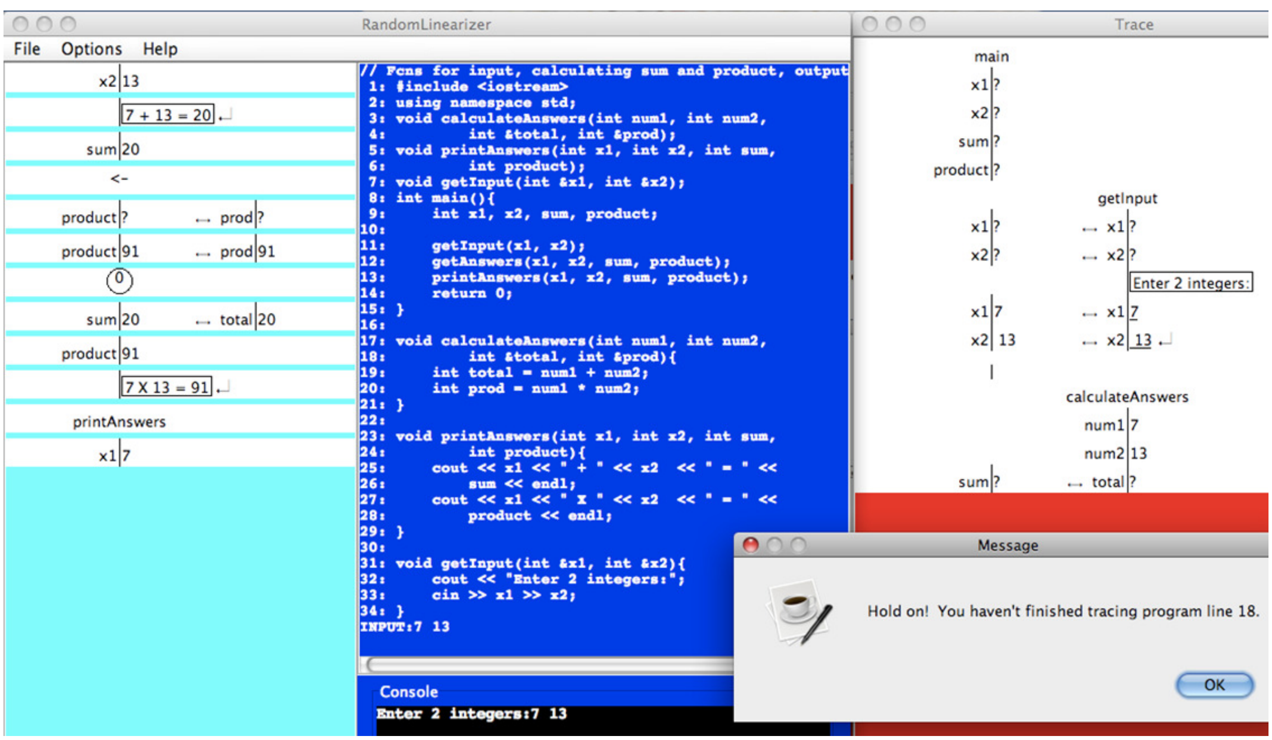

Figure 3. A Diagnostic Comment Appears when the User Selects the Wrong Trace Step

Student ID ____________________

Please fill in this questionnaire even if you decided not to participate in the research on the tracing method. If you decided not to participate your responses will not be used in research.

CMPSC 121
Tracing

Please encircle the degree to which you agree with each statement
(1 = Disagree, 5 = Agree).

1. I understand tracing 1 2 3 4 5
2. Tracing helped me learn the material of this course 1 2 3 4 5
3. Tracing is easy to learn 1 2 3 4 5
4. Tracing didn't help me at all 1 2 3 4 5
5. Tracing helped me follow how a program is executed 1 2 3 4 5
6. Tracing helped me understand C++ 1 2 3 4 5
7. Tracing helped me write programs 1 2 3 4 5
8. Tracing is confusing 1 2 3 4 5
9. I'm glad I learned how to trace programs 1 2 3 4 5
10. It was hard to learn tracing 1 2 3 4 5
11. At times, I used the software to help me understand material 1 2 3 4 5
12. The software was helpful to me when I was learning elementary programs 1 2 3 4 5
13. The software was helpful to me when I was learning how to write programs with loops 1 2 3 4 5
14. The software was not at all helpful 1 2 3 4 5
15. The software was helpful to me when I was learning how to write programs with functions 1 2 3 4 5
16. The software was easy to use. 1 2 3 4 5
17. The software was helpful to me when I was learning how to write programs with arrays 1 2 3 4 5
18. This is the first programming course I have taken in college T ____ F ____
19. I took one or more programming courses when I was in high school T ____ F ____
20. I learned how to program on my own in high school T ____ F ____

Please use this space and the other side for any comments you may have about tracing and the software.

Figure 4. Questionnaire Administered to the Students in the Experimental Section of the Course at the Time of the Final Examination

Table 1a. Mean and Standard Deviation for Questions 1–10 of the Questionnaire

	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10
Mean	4.14	4.07	3.64	1.64	4.14	3.79	3.5	2.93	3.93	3.14
N	14	14	14	14	14	14	14	14	14	14
SD	1.027	0.730	0.929	0.745	0.663	0.802	1.286	1.207	0.829	1.099

Table 1b. Mean and Standard Deviation for Questions 11–17 of the Questionnaire

	Q11	Q12	Q13	Q14	Q15	Q16	Q17
Mean	3.00	3.50	3.64	1.50	4.00	3.71	3.64
N	14	14	14	14	14	14	14
SD	1.414	1.225	1.082	1.019	0.784	0.914	0.929

Response to Method and Software by Prior Experience in Experimental Section

Some of the students in both sections had previously taken computer science courses in high school or college, or had taught themselves how to write programs. Table 2a shows the results of questions 1–10 for the experimental section, broken down by the experience of the user; Table 2b shows the results for questions 11–17.

Table 2a. Mean and Standard Deviation for Questions 1–10 of the Questionnaire as a Function of Experience

Experienced		Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10
yes	Mean	4.00	4.13	3.50	1.63	4.13	3.50	3.63	3.13	3.75	3.00
	N	8	8	8	8	8	8	8	8	8	8
	SD	1.195	0.835	1.069	0.744	0.641	0.756	0.916	1.126	0.886	1.069
no	Mean	4.33	4.00	3.83	1.67	4.17	4.17	3.33	2.67	4.17	3.33
	N	6	6	6	6	6	6	6	6	6	6
	SD	0.816	0.632	0.753	0.816	0.753	0.753	1.751	1.366	0.753	1.211

Table 2b. Mean and Standard Deviation for Questions 11–17 of the Questionnaire as a Function of Experience

Experienced		Q11	Q12	Q13	Q14	Q15	Q16	Q17
yes	Mean	2.63	3.38	3.88	1.88	4.00	3.75	3.50
	N	8	8	8	8	8	8	8
	SD	1.598	1.408	0.991	1.126	0.926	0.886	1.069
no	Mean	3.50	3.67	3.33	1.00	4.00	3.67	3.83
	N	6	6	6	6	6	6	6
	SD	1.049	1.033	1.211	0.632	0.632	1.033	0.753

Students in the experimental section responded positively toward the method and the software regardless of their experience; the inexperienced students among them responded even more positively. The difference in means for the inexperienced and experienced students trended toward significance in their responses as to whether tracing helped them understand C++ (question 6) or was not at all helpful (question 14). The two questions are, in a sense, inverses of one another: question 6 deals positively with the tracing method and question 14 negatively with the software. The direction of the difference in both cases suggests that inexperienced students felt that the method and software were more helpful than did the experienced students.

Conclusions and Future Work

No more than very tentative conclusions can be reached on the basis of this experiment that was carried out with small sample sizes. On the whole, though, students felt that tracing was useful and the tracing software was a useful program. More specifically, a statistically significant result showed that inexperienced students were even more positively disposed to the tracing technique and software than the experienced students. A comparison between the control and experimental sections involved even smaller sample sizes; therefore, no conclusions, however tentative, could be drawn.

Elsewhere [6] it has been conjectured that inexperienced students may feel intimidated by experienced students. In addition, it has been found that the best predictor of success in introductory computer science courses is students' comfort level [7]. Repeating this study on a larger scale will provide better answers to the questions of whether or not a tracing is a tool that appeals to all students; whether or not it helps inexperienced students feel less intimidated by experienced students; and, whether students who learn in an environment in which tracing is taught learn the material better than others who learn in a non-tracing environment.

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Biography

TOM M. WARMS is a faculty member in the department of computer science and engineering at Penn State Abington, where he has taught courses in mathematics, computer science, information sciences and technology, philosophy, and linguistics. He received S.B. and M.S. degrees, both in mathematics, from the Massachusetts Institute of Techology and New York University, respectively, and his Ph.D. in formal linguistics and mathematical logic from the University of Pennsylvania. He has published papers in pattern recognition, psycholinguistics and computer science pedagogy. Dr. Warms may be reached at t1w@psu.edu

QIANG DUAN is a faculty member in the department of information sciences and technology at Penn State Abington. He received his Ph.D. in electrical engineering from the University of Mississippi, and holds an M.S. in telecommunications and a B.S. in electrical and computer engineering. His teaching areas include computer networks and telecommunications, computer programming, system analysis and design, and network security. He has published papers in data communications and computer networking, network virtualization and the Internet, Service-Oriented Architecture and Web services, and Grid and Cloud computing. Dr. Duan may be reached at qxd2@psu.edu

KAVON FARVARDIN is an undergraduate student majoring in computer science at the Pennsylvania State University. He may be reached at kff5027@psu.edu

INDUSTRIAL DISTRIBUTION SIMULATION LABORATORY: TEACHING WHOLESALE DISTRIBUTION SKILLS THROUGH EXPERIENTIAL LEARNING

James L. Toppen, University of Nebraska at Kearney; Richard A. Meznarich, University of Nebraska at Kearney

Abstract

Teaching wholesale industrial distribution applications can be very challenging and it is difficult for students to understand the business world they are preparing for if real-world examples are not used. The Industrial Distribution program at the University of Nebraska at Kearney has designed and built an Industrial Distribution Simulation Laboratory to teach students the concepts involved in technical sales and industrial distribution wholesale branch operations utilizing role playing to simulate real-world experiences. This paper provides detailed examples of experiential learning practices used within the Industrial Distribution program.

Introduction

In recent years there has been an increasing interest in employing active experiential learning techniques, such as role playing, in the college classroom. Faculty recognize that student learners gain more knowledge and insight through action than they do in lecture settings. Faculty are also increasingly more aware of differences in learning styles and the importance of using a variety of instructional techniques to address as many of these learning styles as possible. For example, David A. Kolb [1], who defined learning as the process whereby knowledge is created through transformation of experience, proposed four learning styles in 1984. According to Kolb's model, the ideal learning process engages four learning styles, Converger, Diverger, Assimilator and Accommodator, in response to situational demands. The resulting learning styles are combinations of an individual's preferred approaches.

Convergers are characterized by abstract conceptualization and active experimentation. They are good at making practical applications of ideas and using deductive reasoning to solve problems. One of the main roles of the technical sales representative is to identify appropriate applications to solve a customer's particular problem. Divergers, on the other hand, tend toward concrete experience and reflective observation. They are imaginative and good at coming up with ideas and seeing things from a different perspective. This skill set is especially important for students entering the field of wholesale distribution where the value they bring to the table in the sales process is problem solving. Being imaginative and creative can be very difficult for a new graduate just entering the field. This is reflected in the program's annual assessment surveys of employers.

Assimilators are characterized by abstract conceptualization and reflective observation. They are capable of creating theoretical models by means of inductive reasoning. Accommodators use concrete experience and active experimentation. They are good at actively engaging with the world and actually doing things instead of merely reading about and studying them. Technical sales representatives in the wholesale distribution industry get paid not for what they read about, but for what they produce.

These learning styles are also referred to in the literature with names such as role play, social drama or social theater. Students in technical areas often find it easier to learn and retain information with hands-on activities. Role-play techniques allow students to apply concepts and problems that have been introduced through lectures and readings to a situation that reflects reality. As students are more directly active in the role playing it is more effective in embedding concepts into their long-term memory [2]. Role playing also introduces concepts that are important in professional sales positions such as understanding how knowledge is developed and produced, in particular the use of language and how language constructs knowledge, logic and prominence of voice. Students learn to communicate knowledge in a meaningful and persuasive manner; this is very important during technical sales calls where language skills, leading to effective communication and negotiation skills, are of paramount importance [3].

Role playing also illuminates the divisions and differences between individuals in the sales process. Role playing in the classroom effectively demonstrates that the salesperson and the customer use different information sources and often hold distinct, if not conflicting, views but that resolutions can be reached. Students learn to work with different personalities, beliefs, value systems, abilities and background experiences. They develop a greater appreciation for the range of perspectives held on a particular issue and come to recognize the complexity of the sales and negotiation process and their own role in the process. Simulations are widely used for learning how to negotiate, and professional negotiators have been shown to benefit from role-play simulations [4]. Students need to realize that they may not have all the answers, and there may be no easy answer, but see the critical issues necessary to solve the customer's problems through the sales process [5].

In one of his last books, Jean Piaget, the great developmental psychologist, described knowledge development as a process of equilibration between assimilation and accommodation learning styles. In assimilation, people figuratively fill in their mental map of their world, while in accommodation, they figuratively change that mental map span or alter it to fit their new perceptions [6]. Rote memorization tends to emphasize assimilation. In contrast, learning to climb a tree, swim, or riding a bicycle emphasizes accommodation and involves gaining a "knack" and tends to be the kind of learning that is almost impossible to fully forget. Assimilation learning, as has been well documented, is remarkably easy to forget.

There are several benefits to ensuring that students receive real-world experience in business processes, current technology and supervision while pursuing a degree in their chosen field of study. One benefit of gaining real-world experience is that students become more prepared to handle business problems and opportunities [7]. Another benefit realized from real-world experience is that students get the opportunity to experience their future work environment before graduation. As Fedorowicz et al. [8] point out, it is especially difficult for a newly minted graduate to grasp more complex inter-organizational technical sales concepts and information flow if the graduate was not exposed to actual business processes and experiences in their education.

Given the apparent success of utilizing role-play pedagogy in the classroom, one may ask the question, "Why wouldn't everyone use role playing as an instructional strategy if it is such an effective method of teaching?" There are several reasons for this. Many college professors, although they are well versed in the theoretical information, may not have had opportunities to work in the real world. This can make it very difficult for some to create real-world role-play activities. If professors have real-world work experience, they can more easily and effectively create these role–play activities. To overcome this problem, one could involve people from industrial advisory boards, or just local people, in that particular business to assist in the creation of realistic role–play activities.

Evaluation is a problem facing many professors utilizing role playing in their courses. The evaluation process is very subjective. As students observe the role play of others, they naturally improve. The first students almost always perform much worse than the students who perform their role-play activities at the end of the exercise. The real goals of having students observe other students' role playing are to have them learn from the mistakes of others. This results in a much higher level of learning for all students. Another problem is trying to create real-world environments in an academic setting. This is why the Industrial Distribution Simulation Laboratory was created. The laboratory provides the real-world setting that assists in making the role-play activities realistic.

The Industrial Distribution Simulation Laboratory

The main reason the University of Nebraska at Kearney created the Industrial Distribution Simulation Laboratory for its undergraduate degree program in Industrial Distribution was to ensure that students are gaining real-world experience in technical sales, current warehouse operations technology and supervision techniques. The laboratory environment replicates an actual industrial distribution branch having a city counter along with a completely stocked showroom (410 sq.ft.), sales simulation offices with inside and outside sales desks (170 sq.ft.) and a branch manager's office (145 sq.ft.). The laboratory has its own internal phone system enabling students to practice their phone and customer service skills. The laboratory also has a completely stocked warehouse (2,100 sq.ft.) complete with various types of racking systems including a mezzanine and conveyor system. Also included in the design are a secure storage area (80 sq.ft.) and an adjacent training room (2,160 sq.ft.) that is also used for industry training.

Students utilize a variety of material handling equipment, bar code readers, and a work-assisted vehicle and forklift to manipulate stock. They perform structured and detailed role-play simulations in picking, packing, shipping, receiving and inventory control. Once an item is shipped from the warehouse, the item is purchased back by the Purchasing for Wholesale Distribution class. Activant's Prophet 21 is the Enterprise Resource Planning (ERP) system used to manage the sales and operations functions within the laboratory. The simulation laboratory is used throughout the industrial distribution core courses for preparing students to enter the workforce as technical sales representatives in the wholesale distribution industry.

Laboratory Simulations: Student Role-Play Activities

One of the most difficult tasks in preparing students for future employment is helping them understand the environment they will be working in upon graduation. Students do not get exposed to the actual wholesale distribution environment until they begin their internship, typically between their junior and senior years. The ID faculty and staff wanted students to experience the work environment early for two reasons. First, to help them better understand the work environment they would be spending the rest of their working life in and, second, to enhance their internship experience.

The Industrial Distribution Simulation Laboratory allows students to simulate real-world tasks in the operation of an industrial wholesale distribution branch. Each assignment includes a discussion of the concepts, required deliverables, objectives, safety procedures, and step-by-step procedures to complete. In order to ensure success of each laboratory activity, students are divided into groups and assigned different roles for laboratory activities. These activities, created by the faculty and staff of the ID program, require students to rotate through the following roles in the laboratory, thereby exposing them to all facets of an industrial distributorship and the tasks involved in each role. For example:

- Outside Sales
- Inside Sales
- City Counter Sales
- Warehouse Manager
- Warehouse Supervisor
- Order Picker
- Shipping and Receiving

One of the best compliments the ID program receives is when companies come into the laboratory and comment, "This is exactly what we do" or "If I had this training, I would have been years ahead in my career."

Sales Simulations

Sales simulation role–play activities begin with counter sales and showroom management, the typical entry-level position in the industrial wholesale distribution industry. Students need to learn how to use the ERP system to look up products and problem-solve customer needs as well as create customer orders. First-hand experience operating an ERP system places students well ahead of their competition upon graduation [9]. The counter sales person has to be able to operate in a fast-paced environment and handle customers both on the phone and in person, as shown in Figures 1 and 2. The role-play activities are designed so that students get experiences in both of these areas including the use of the ERP system to create an accurate purchase order for the customer. Such role playing will help them understand how difficult this process is in a pressure-induced wholesale environment when many normal, although sometimes hectic, daily activities may be competing for their attention [10].

Figure 1. City Counter Phone Role-plays

Figure 2. City Counter Customer Service

Almost every industrial distributor branch has a showroom. The showroom is generally managed by the counter sales people and the branch manager. The showroom management role-play activities are designed to identify items that would be useful in a showroom environment. Students are required to set up the showroom, Figure 3, so that most-purchased items are displayed first. They also need to do research on items that customers most often just come in and pick up. Another role–play activity is designed with security in mind to make sure that the items in the showroom are secure.

Figure 3. Showroom Management

The next progression in an industrial distribution student's career is to, more often than not, move into inside sales. This role has several functions: taking phone orders, assisting outside salespeople, doing takeoffs (see Figure 4) and assisting with counter sales when needed. The inside sales role-play activities (see Figure 5) are designed so that the inside sales person learns how to take extended phone orders, complete limited takeoffs and can problem-solve as they assist the outside salespeople in handling customer problems. Most of their work is completed over the phone and, as such, do not actually work face-to-face with the customer. These role-play activities help the students gain confidence in taking orders over the phone and giving them opportunities to practice organizational skills that are needed to complete accurate orders.

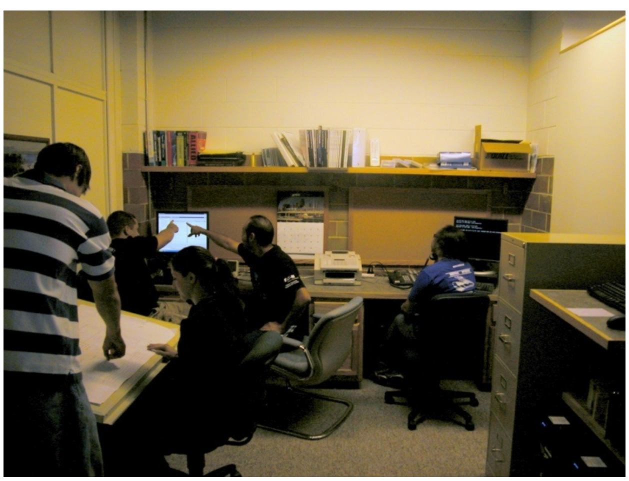

Figure 4. Take-offs

After students have completed several years in inside sales, they often move into outside sales. As outside sales people, they are responsible for the direct servicing and problem solving for the customer. The role-play activities, for an outside salesman, include scheduling appointments (see Figure 6), preparing quotes, responding to requests for proposals (RFPs), and are responsible for 75% of the sales in a typical branch. The sales role-play activities are very important in showing how salespeople interact with the customer.

Figure 5. Inside Sales Role-plays

Figure 6. Scheduling Sales Calls

The first sales role–play activity is designed so that students learn how to set up appointments for sales calls. It is very important that the students and outside sales people feel very comfortable in phone situations. The simulation laboratory has an internal phone system that allows for extensive practice in phone skills. Telephone techniques are one of the assessment areas surveyed each year for graduates of the program. And, it is one of the areas employers continue to state as a weakness on the part of new graduates. The second role-play activity is an actual sales call in the sales simulation office (see Figure 7). The students will use their questioning skills to determine the customers' actual needs and set up a follow-up appointment. The third role-play activity is the presentation of a proposal and learning how to ask for the sale. It is an excellent opportunity for the students to experience several sales situations as they observe other students' responses in the same role-play situations. It is very important that the students learn to think on their feet and listen to what the customers are really saying.

Figure 7. Making Sales Calls

Operations Simulations

In addition to sales, another fundamental purpose of the laboratory is to expose ID students to various branch operational scenarios and Key Performance Indicators (KPIs). This provides a basis for understanding branch operational parameters in a simulated real-world environment. The more that students understand how a branch operates and how it makes money, the more prepared they will be when they go on their required internship and as they start their careers. Students with this knowledge will become much more valuable to their companies earlier in their careers. The following operations simulations take place in the lab:

- Vendor Selection
- Item Entry
- Purchasing
- Picking
- Packing
- Shipment Scheduling
- Receiving
- Put Away
- Cycle Counts
- Forklift Operations, OSHA Training
- Asset-management

Each of these simulations in a branch environment is important to the overall success of the branch. The students must understand the flow of material and how it gets to the customers.

Purchasing, and all its associated activities, is an essential part of the profitability of a branch. The vendor-selection role-play activity is designed to demonstrate how extremely important it is for the students to understand the process needed in selecting the best vendor (see Figure 8). This exercise provides students opportunities to conduct vendor research and to determine the best choice based not only on price but other factors that make quality vendors. In the purchasing process, one has to be certain that the product meets all specifications required by the customer.

Figure 8. Vendor Selection

Once products are selected they must be entered into the ERP system so they can be entered into purchase orders. This item entry must be done in an accurate fashion taking into account the need to be able to identify the item in a search function. Picking exercises are designed so that students will be able to understand picking flow, picking accuracy, the use of bar code readers and assisting pickers in this process. After the items are picked, it is very important that they are packed properly for shipment so the customer receives the product undamaged (see Figure 9).

As a branch management function, the scheduling of shipping is extremely important. The operation needs to be accomplished in a cost-saving manner and still get the product to the customer when it is needed. Students must be able to set up deliveries using a variety of shipping methods, including parcel services and in-house shipping; and they must be able to determine the most profitable method of shipping. Once the product is purchased, it must be received and entered into the ERP system so that the computer recognizes that the product is in the warehouse. Next it must be put away in the proper location so that it can be reached, read and easily picked.

Figure 9. A Conveyor System Is Used in Picking and Put Away

Cycle counts are extremely important in the inventory process at every branch. The students must gain an understanding of the process and the importance of accuracy of inventory. Cycle counts are used to ensure that accuracy is up-to-date so the branch manager does not have to wait until year-end inventory (see Figure 10). It is much easier to correct inventory levels and discover the reasons for gains and losses if it is done on a quarterly basis rather than annually.

Figure 10. Cycle Counting

The movement of materials is done by either forklifts or work-assisted vehicles called WAVS (see Figure 11). The students must not only learn how to operate these vehicles but also how to deliver an OSHA-approved training program. Each student must also understand a profit-loss statement. It is important for each student to understand the financial implications of how the branch is making money (see Figure 12). Each month the branch manager is responsible for determining how to make the branch ever more profitable.

Figure 11. Forklift and WAVE Operations

Figure 12. Branch Financials Role-play

The Activant Profit 21 ERP software being used in the simulation laboratory provides students with the data for the operations that are simulated in the warehouse. This software was chosen because it is one of the most widely used ERP software packages for small- to medium-size industrial distributors. The introduction of Profit 21 into the simulation laboratory was intended to integrate the “Sales and Distribution” and “Materials Management” modules into the lab. In addition to learning Profit 21, students go beyond the physical movement of products. The laboratory simulations incorporate supervisory skill development, decision making and data analysis. These learning components are not only encouraged, they are required in nearly every laboratory exercise. This hands-on learning approach is critical since studies have shown that associative learning, where students perform actual tasks they can apply in a business environment, results in effective learning and future application of knowledge [1].

Conclusion

The Industrial Distribution Simulation Laboratory at the University of Nebraska at Kearney is an integral part of the learning process in the Industrial Distribution degree program. Through extensive role playing and incorporating hands-on application laboratory exercises, students graduating from the ID degree program gain real-world knowledge and experience and are better prepared to immediately begin work upon graduation. This approach benefits future employers as well as students, since graduates require less initial training on the job. Furthermore, employers expect graduates from the ID program to have an understanding of the integration of technology within the industrial distribution field.

The integration of emerging technology, software applications, management and supervisory training, and technical sales and distribution practices into a degree program is an ongoing endeavor. Although significant changes have been made to the ID curriculum, many as a result of input from the ID Industrial Advisory Council, many more changes are planned. To ensure effectiveness throughout these changes, student learning will be tracked and evaluated with a capstone course that will allow students to demonstrate their mastery of technical sales and distribution functions, leadership skills and, most of all, their readiness for a rewarding career in the industrial wholesale distribution field.

Overall, role play is seen to be a beneficial teaching tool as it develops practical professional sales and operational skills as well as academic knowledge. Students generally enjoy this hands-on approach to learning which broadens their understanding of the technical sales process through experiential learning. Although this hands-on comprehensive approach to technical sales and wholesale distribution training is expected to produce effective graduates, continued research is needed to determine the long-term effects of this approach. Future research will help determine if graduates of this approach are more successful than previous students having graduated before the implementation of the simulation laboratory.

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Biographies

JAMES L. TOPPEN is Associate Professor of Industrial Technology at the University of Nebraska at Kearney. He earned his Ph.D. from Arizona State University. He worked in the wholesale distribution industry before joining the faculty in 2008. He teaches professional selling and branch operations courses in the Industrial Distribution program. Dr. Toppen can be reached at toppenjl@unk.edu

RICHARD A. MEZNARICH is Associate Professor of Industrial Technology at the University of Nebraska at Kearney. He earned his Ph.D from Texas A&M University. He had a 25 year career in business and industry before joining the faculty in 2004. He taught electronics and professional courses in the Industrial Distribution program until his retirement in May 2011. Dr. Meznarich can be reached at meznarichra@unk.edu

The State of Security: The Growing Presence of Emergency Management Technologies on College Campuses

Jessica L. Buck, Jackson State University

Abstract

Due to growing threats of terrorism and ongoing natural disasters, emergency management is at the vanguard of societal concern. With such concern, it is essential that disasters or incidents (planned or unplanned) be managed in a way to cause less harm to people and the environment. Emergency and disaster concerns impact federal, state and local government entities; public and private sector organizations; the general public; and the academic community. However, technological innovations may be incorporated to improve the effectiveness and efficiency of situations in which potential emergency events can be minimized or completely alleviated. Technological systems, such as human-computer interaction, can make emergency response easier and allow entities to adopt a user-centered systemic approach so that anyone can use the system. Nevertheless, technological integration with emergency and crisis preparedness and management helps to reduce the uneasiness, possible loss, and costs associated with natural and man-made disasters.

This study examined the types of emergency and crisis incidents that have impacted the international and national general public and college communities. In this paper, the author describes some of the technologies that help to reduce or alleviate potential man-made or natural hazards.

Introduction

In the wake of earthquakes, hurricanes, tornadoes, terrorism and other natural and man-made disasters, emergency management is a pertinent issue that is at the forefront of societal concern. The International Association of Emergency Managers defined emergency management as an agenda where communities decrease danger and handle catastrophes [1]. Emergency management also emphasizes how risks should be avoided. In 2007, the Federal Emergency Management Agency (FEMA) provided the definition of emergency management as, "the managerial function charged with creating the framework within which communities reduce vulnerability to hazards and cope with disasters" [2]. Such disasters may be natural (e.g., hurricanes, tornadoes, typhoons, tsunamis, earthquakes, etc.), or man-made (e.g., terrorism, bio-terrorism, pandemics, school violence, etc.). Regardless of the type of emergency event, there is a dire need for earlier detection and warning to minimize or eliminate altogether the effects of the disaster.

With such considerations, promising inclinations and technologies in emergency response systems are essential for the continuous safety efforts for both the general public and the academic community. Carver & Turoff [3] contend that emergency response systems and processes must be improved with effective and efficient technologies. For example, emergency response information systems and governments should make human-computer interaction easier and adopt a user-centered systematic approach so that anyone can use the system. With this being a concern, there is a demand for more highly skilled people to operate and manage the complex systems.

People with such skill sets in the emergency management information systems must be able to absorb information quickly and discern relevance and reliability to determine a proper course of action for an emergency incident. In an emergency, the computer interface should enhance an emergency responder's capability to plan, train, respond and evaluate the emergency. The human and computer interaction's aim is to provide a means of predicting possible emergency events, securing accurate and timely information, disseminating information and making continuous improvements in emergency management systems. Human and computer interaction is a needed integration, and other technologies serve as an integral facet in the on-going evolution of emergency management [3].

Need for Incorporating Technology into Emergency Management

Because of public anxiety due to the associated loss and cost of disasters, four segments in emergency management must be in place: mitigation, preparedness, response and recovery [4]. According to FEMA, mitigation is the attempt to prevent hazards from developing into disasters. Mitigation further aims to reduce the effects of disasters once they occur, and it emphasizes long-term measures for reducing or eliminating long-term threats. Preparedness entails an unremitting cycle of planning, organizing, training, equipping, exercising, evaluating and improving activities to ensure successful synchronization. Response refers to the mobilization of the necessary emergency services and first responders in the disaster area. Recovery involves the restoration of impacted areas to their previous states. Recovery focuses on rebuilding destroyed property, re-employment and the repair of other pertinent infrastructure. In addition, recovery may involve mental and emotional restoration, where people regain an emotional soundness in the wake of a disaster. In adhering to these segments, technology serves as an asset during times of anguish. Useful technologies assist in

- identifying points where emergency management is required;
- identifying new technological applications to enhance emergency management systems;
- evaluating technology's effectiveness in time reduction in an emergency;
- providing enhancements for community and campus emergency response systems; and
- providing information on strategies to further enhance technology's integration with emergency management.

Although technology has greatly advanced in recent decades, emergency management continues to render improvement. According to Mendonca et al. [5], inventiveness and the development of impromptu organizations can often nullify the benefits of new technology. To ensure that emergency management information systems are able to reach their full potential, they must be designed to allow flexibility in their use, thus leaving room for inventiveness. They further indicate that communication and information technology may be classified according to the combination of process structuring, communication and information processing support it best provides and the emergency response system required.

Where Emergency Management is Required

Emergencies are generally unexpected, and most are presented without fair warning. It is the responsibility of the highest levels of government to the average citizen to provide individual, community, national and international safety. Such responsibilities may fall within the realm of storing non-perishable food items, water and batteries in preparation for a forecasted storm, to having emergency respondents and incident commanders posted with plans of actions before and during a sudden incident. Effective emergency management depends on methodical integration of emergency schemes at all levels of government and non-government involvement [6]. Activities at each level (individual, group, community) impact the other levels. Frequently, the responsibility may be placed on governmental emergency management with the institutions for civil defense or within the conventional structure of the emergency services. In the private sector, emergency management is occasionally referred to as business permanence planning. This is the development and justification of a practiced logistical plan for how a group or institute will re-establish itself, either partially or completely, within a prearranged time after a disaster or extended disruption. Nevertheless, adequate use of innovated technologies positively impact efficiencies when considering time reduction before and after a disaster.

New Technologies and Time Reduction

One integral technology in planning and time reduction is the use of the Internet. The Internet performs numerous capabilities that are vital in emergency management. According to Ozceylan and Coskun [7], Internet utilization aids in heightening awareness through Web pages that inform citizens. Internet utilization allows opportunity for community discussion groups; making disaster plans available online; providing educational disaster management material to schools, libraries, other community related places; and providing support for training or drills that can be used to support cultural factors. Ozceylan and Coskun further insisted that the development of a specific type of information system would better assist in minimizing or alleviating some emergencies, but that such systems may not improve response times of those dispatched to the emergencies. However, technology and information system utilization will increase the country's progress level, and it will promote more favorable socio-economic situations for disaster management for future implementations. Nevertheless, governments and administrators of local jurisdictions must support technology in every area. Databases may provide various forms of emergency-management-related data to policy makers. There are, though, departments designed to follow new developments in disaster management areas. In addition, networks with other countries' emergency management organizations aid in creating citizen groups to check to see if political decisions might be considered political factors.

In addition, Ozceylan and Coskun affirm that databases, decision-support systems, knowledge-based systems, GIS, Web-based databases, satellite systems, digital libraries, satellite communications, remote sensing, source data automation systems, data collection systems, simulations, intelligent systems, archived data for past disasters, transaction processing systems, simulations, communication systems and software, management information systems, intranet, data mining, data warehouses, resource management and planning systems are some examples of information systems and technologies which can be used to support emergency management processes. These all may be used collaboratively in enhancing emergency response efforts. Another technological approach that may be used in emergency management initiatives to reduce disaster risk and to increase response quality is Embedded Intelligent Real-Time Systems (EIRTS) [7].

Technology Application

The Main purpose of utilizing information systems and information technology (IS/IT) is information sharing among different entities and organizations; resource (equipment, man power, money) planning and management; decision support for upper-level administrators or managers; forecasting; effective and fast communication; administration and coordination of organizations and other related agencies; public education (Internet); response-team training; simulations of different disaster scenarios; damage assessment; and informing the public during and after disasters.

Better hardware, software and telecommunication networks for disaster management, connection among different agencies and offices, Internet-based systems and backup systems can be used to support technological factors. The existing literature maintains that IT such as computer networks, virtual reality, remote sensing, geographic information systems (GIS) and decision-support systems are enhancing disaster communications. . Internet/intranets and spatial analysis systems may assist during the mitigation and preparation phases. Satellite communications, remote sensing, cellular and radio communications may also be used during the emergency phases [8]. With the latest technologies rapidly growing in implementation, there is still innovative thought on how college campuses may further benefit.

Technology on College Campuses in Emergency Events

In light of the Virginia Tech massacre in 2007, Johnson and Keen [9] indicated that the university's law enforcement re-evaluated security plans in the aftermath of the event. Such utmost concerns rapidly moved to campuses in Delaware and North Carolina, where patrols increased to calm faculty and students, and to ensure that the act was not repeated on campuses. Soon, college campuses throughout the U.S. began to make efforts to permanently improve emergency plans. College and law officials assessed campus security programs, which caused a review from the Columbine High School shooting massacre and the University of Iowa shooting incident, which occurred 16 years prior to the 2007 Virginia Tech shooting. To aid in early warning and possible prevention, technology may be an integral facet to promote progressive efforts.

In 2007, Swartz and Hopkins [10] expounded on advanced technology serving as emergency warning devices. The authors reflected on the Virginia Tech shooting where there were 33 deaths. In identifying that there were four email alerts, it was suggested that text messaging may have been the best method of warning students. In 2007, at least 35 universities and colleges had an emergency system which alerted students of planned or unplanned incidents. In addition to e-mail and cell-phone communications, social networking is used to announce emergency events. Today, all campuses have this and other sophisticated technologies to aid in the safety of students, faculty and staff.

Summary

Emergency systems must be improved with effective and efficient technologies in order to meet such societal concerns. Systems such as human-computer interaction can make emergency response easier and allow entities to adopt a user-centered systemic approach so that anyone can use the system. Nevertheless, technology must be integrated with emergency preparedness to reduce the uneasiness, possible loss, and costs associated with natural and man-inflicted disasters. This study evaluated the integration of technology and activities with recent concerns of emergency management. With such events generated by natural or man -made disasters, valuable approaches must be enforced to reflect the current state of technology. Such innovations will assist in developing a deeper admiration, which reflects personal emergency consideration, producing exclusive and constant awareness.

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Biography

DR. JESSICA L. BUCK is an Assistant Professor of Technology in the Department of Technology (under the College of Science, Engineering, and Technology) at Jackson State University in Jackson, MS. She also serves as the Program Coordinator of the Technology Education Masters Degree Program. In addition, she serves as advisor of the Jackson Sate student chapter of the Association of Technology, Management, and Applied Engineering (ATMAE) and the trustee for the Delta Beta chapter of Epsilon Pi Tau Technology Honor Society. Dr. Buck currently serves as Vice-President of the Student Division of ATMAE (2011-2013). Dr. Buck may be reached jessica.l.buck@jsums.edu.

INTRODUCING SCIENCE TECHNOLOGY ENGINEERING AND MATHEMATICS IN ROBOTICS OUTREACH PROGRAMS

Basile Panoutsopoulos, Central Connecticut State University

Abstract

Outreach programs organized and supported by universities, government and industry have been used to mobilize educational resources and to address current social, cultural, and economic issues facing the world. Robotics has been an instrument of outreach programs that has found wide support in many middle and high schools. There are various options for implementing a robotics program and many organizations that sponsor regional competitions of these programs come out with a different theme every year. In addition to the robot, which is the central piece of the overall activity, the competition includes research on a prescribed topic, presentation of findings, team work, construction of the robot and its accessories, and programming to perform a specific task using an object-oriented language or simple programming. Although these activities are designed to inspire Science, Technology, Engineering and Mathematics (STEM), a connection with them is missing during the preparation for the competition. In this paper the author discusses a formal presentation of topics from mathematics, physics, engineering and technology—which are used directly or indirectly in the final product—to a working robot that performs a specific task. Various topics such as mathematics, physics, engineering and technology that are already studied in school are integrated into the robotics program. Other topics may or may not be so familiar to all members of the team. Abstract topics are applied and used to solve practical problems along the way.

Introduction

Various studies have addressed the subject of poor performance by students in Science, Technology, Engineering and Mathematics (STEM) [1]. Robotics has been proposed as a way to improve performance in the various STEM fields [2]. During the Third International Mathematics and Science Study (TIMSS), fourth-grade students from the U.S. tested well in both mathematics and science compared with their international counterparts; eighth graders performed near the international average, while the twelfth graders performed below the international average [3]. Four years later at the Third International Mathematics and Science Study Repeat (TIMSS-R), the U.S. students showed no improvement since TIMSS [4]. The reported results indicate that the progress in STEM is inversely proportional to the grade for U.S. students. The House Science Committee developed a new National Science Policy, which aimed to strengthen STEM in preschool through college [5].

As an approach to increase interest and, hopefully, the number of students seeking to study and have a career in a STEM-related field, outreach programs have been developed, funded and supported by various government agencies (personal communication with the Naval Undersea Warfare Center Division outreach program which provides equipment and housing resources to the First Lego League), private companies [6], universities [7] and associations [8-10]. An extensive report of STEM programs can be found in a report published by the Office of the Under Secretary of Defense, Acquisition, Technology and Logistics [11]. States are passing legislature in support of STEM [12].

Outreach programs have been developed all over the country and middle schools, high schools and universities are promoting the STEM effort [13]. The usual outcome in robotics is the construction of a structure, usually a "robot", that performs a specified function. Other efforts have also been developed that use computer-based construction [14], construction and simulation [15], and mathematical modeling in physics [16]. Hands-on learning opportunities are necessary for providing students with the essential excitation to explore science, technology, engineering and mathematics. Currently, hands-on experience usually stops at the build and program phases [17].

Robotics and STEM

From this analysis, the author proposed a number of topics from science, technology, engineering and mathematics to be integrated with the various activities in robotics. The goal of the proposed enhancement is to introduce students to the applicability of the various topics, possibly already known from the STEM-related courses, to stimulate the thinking process on how to apply principles already known to the problems under consideration and, finally, to clarify misconceptions and provide deeper understanding. Due to space limitations only a limited number of topics are presented here.

Problem Solving

Problem definition, solving and optimization are among the basic functions that need to be taught, studied and practiced. There is extensive literature on the subject [18]. The typical problem is of the form "Design a robot that can accomplish a number of tasks." Most of the time among the various robotics teams, the solution follows in a trial-and-error approach for both construction and programming. This, clearly, is the synthesis process. Although the trial-and-error approach is appropriate in a number of problem scenarios, more typical robotics problems can be solved in a more efficient way by a student that has experience in the analysis process, knowledge of basic physics, mathematics, and technology, and can integrate all these towards the final goal. There is no unique approach to problem solving. Nevertheless, the first step should be the implementation of a formal solution process that includes a definition of the problem.

Programming

Programming is the ordered listing of a sequence of events designed to accomplish a given task. Computer programming is a plan or a routine for solving a problem on a computer. A combination of computer instructions and data definitions enable computer hardware to perform computational or control functions. The trade-off is the parametric analysis of concepts or components for the purpose of optimizing the system or some trait of the system [19].

The specific programming language to be used depends on the robot setup, but the programming principles are universal. The programming language "C" is used mostly with the FIRST (For Inspiration and Recognition of Science and Technology) Tech Challenge (FTC) and FIRST Robotics Competition (FRC), while the First Lego League (FLL) uses the object-oriented language NXT-G. The programming environment for FLL is shown in Figure 1.

Algorithms

Before the program code is written (the equivalent of the solution process), an algorithm must be developed using the steps needed to solve the problem under consideration. Two components of an algorithm are the actions needed to go from the statement of the problem to the solution of it, and the order in which these actions need to be processed. The development of an algorithm can be a one-person job, but final development and optimization demands a brainstorming session. Algorithm development offers the opportunity to introduce the concept and practice of brainstorming and team work. Software tools are available to assist in this process [20]. Both approaches have been used successfully by the author with a number of LEGO FLL teams.

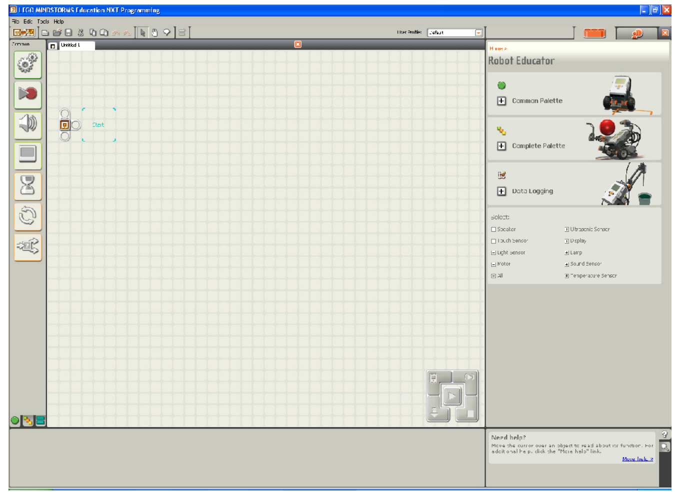

Figure 1. The Programming Environment for LEGO Robotics using Mindstorms NXT-G

Flowcharting

An advantage of flow-charting is the pictorial view of various events. A serious disadvantage is the fact that such a diagram becomes complicated for a complex problem. But even in this case, flowcharting can still be used if the main problem is split into smaller problems. Furthermore, it can be used to describe the overall programming approach. Flowcharting should start with learning the basics and then proceeding to the use of modern computer flowcharting tools.

Structured Programming

Structural programming is any software development technique that includes structured design and results in the development of structured programs. And, structured design is any disciplined approach to software design that adheres to specified rules based on principles such as modularity, top-down design and stepwise refinement [21]. An advantage of structural programming is the use of various constructs. These can be used to demonstrate the development of logical statements. Figure 2 presents the three basic constructs of Sequence, Repetition and Selection. Figure 3 illustrates the implementation of the Repetition (loop) construct in Lego Mindstorms NXT-G Robotics programming language.

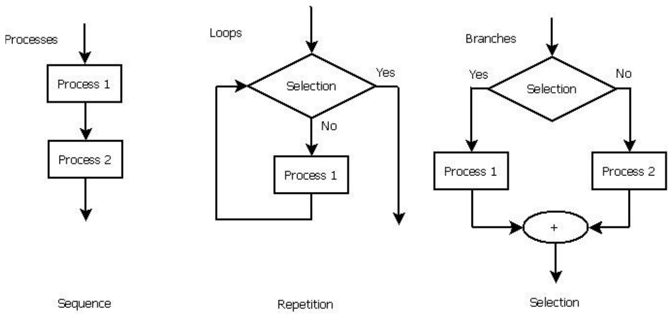

Figure 2. The Three Basic Constructs of Sequence, Repetition and Selection

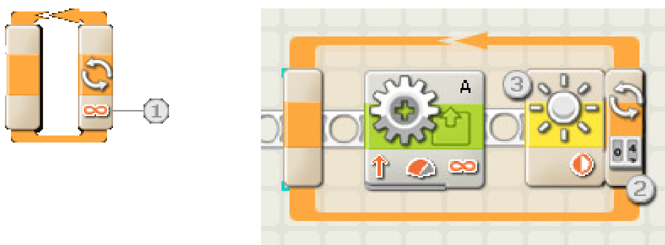

Figure 3. The Repetition (loop) Construct (a): Implementation (b) in Lego Mindstorms NXT Robotics Programming Environment

The Design Process

The design process is applied equally well to algorithm development and the solution process of a problem. Students have the opportunity to immerse themselves in the design process. Due to the nature of the design process, many solutions are possible (parametric solutions). Students have the opportunity to evaluate each one of the solutions based on the specifications and constrains of the problem and to select the one that best fits the current needs. It was applied by the author to a group of middle school students to teach construction skills using the step-by-step approach to build various LEGO-based structures [22].

Algorithm and Top-Down Design

Simple problems can be solved using an algorithm, following the top-down approach, which provides the solution in sequential steps. For more complex problems, the principle of "Divide and Concur" can be applied again and again until the problem is reduced to a number of simple problems that can be solved in sequential steps.

Pseudocode

Pseudocode is natural language like programming language statements. Pseudocode can help in the writing process of the programming code. The pseudocode normally only describes executable statements such as input, calculation and output.

Analysis

Analysis is a process of mathematical or other logical reasoning that leads from stated premises to the conclusion concerning the qualification of an assembly or components. Analysis is examination for the purpose of understanding [19]. Analysis is suggested as the first step in learning new concepts as it usually has a unique solution and can be found using sequential steps.

The Synthesis or Design Process

Students have to work in an opposite mode. The results of analysis are specifications for the synthesis. One approach must be selected and implemented. The differences between the analysis and the synthesis processes need to be stretched. Design is the process of defining the architecture, components, interfaces and other characteristics of a system or component. It is the result of the synthesis process that provides sufficient details, drawings or other pertinent information for a physical or software element that permits further development, fabrication, assembly and integration, or production of a product element. Design is also the act of preparing drawings or other pertinent information for a physical or software element during synthesis within the systems engineering process [19].

Analysis, Synthesis, Physics and Mathematics

Physics and mathematics can easily be applied in robotics. In particular, mechanics and Euclidian geometry are among the major areas of application. The motion of a robot takes place on a plane. Commonly, the robot moves on circular wheels and moves along a prescribed path. A common problem in programming the robot is determining how many degrees a wheel must rotate in order for the robot to travel the distance from one point to another.

Consider an example within the analysis phase: What is the rotation required by a circular wheel of radius R to cover distance L? [22]. Based on Figure 4, the distance traveled by a wheel of radius R or diameter D after rotation of d degrees can be determined by Equation (1):

$$L = C\frac{d}{360°} = 2\pi R\frac{d}{360°} = 2\pi\frac{D}{2}\frac{d}{360°} = \pi D\frac{d}{360°} \quad (1)$$

The synthesis phase problem will be of the form: How many degrees, d, a wheel of radius R or diameter D needs to rotate in order to travel distance L? Based on the analysis, the answer would be

$$d = \frac{L}{C}360° = \frac{L}{2\pi R}360° = \frac{L}{\pi D}360°$$

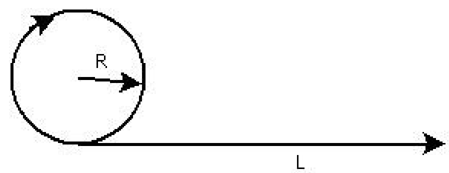

Figure 4. Wheel of Radius R Rotating Along a Straight Path

Virtual Prototyping

Virtual prototyping is used extensively today in industry. It allows the construction, evaluation and optimization of the performance of the design robot in a virtual environment. The designed structure and the satisfaction of the specifications are verified. Virtual prototyping can save valuable time, minimize cost and improve the overall design. Virtual prototyping generally precedes physical prototyping. However, for instructional reasons, the order can be reversed in order to give students the opportunity to grasp the physical reality before the virtual. The virtual components resemble the physical, and the closer the resemblance, the better and more accurate the simulation. Figure 5 shows a virtual prototype of an automobile using MLCad [23].

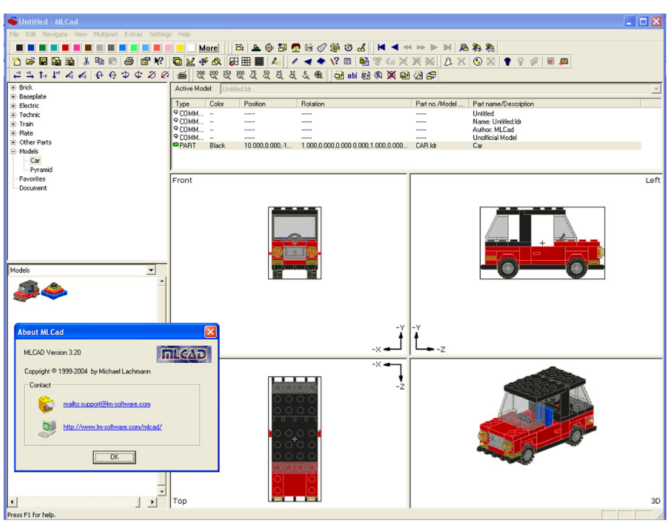

Figure 5. Virtual Prototyping of a LEGO Pieces-Based Automobile using MLCAD

Physical Prototyping

Various robotic constructions are available [24]. Students use current technology and basic skills to build a structure. This phase requires persistence and repetitive testing to evaluate the performance of the structure. Due to variations in parameters between two identical structures, one can get different performance. A common source is the voltage of the battery. Two identical structures have batteries at dissimilar voltages. This will have an effect on the current through the motor which, in turn, will have an effect on the angular speed and, eventually, on the performance of the robot. The effect of the voltage applied to a motor and its angular speed is shown in Figure 6 [25].

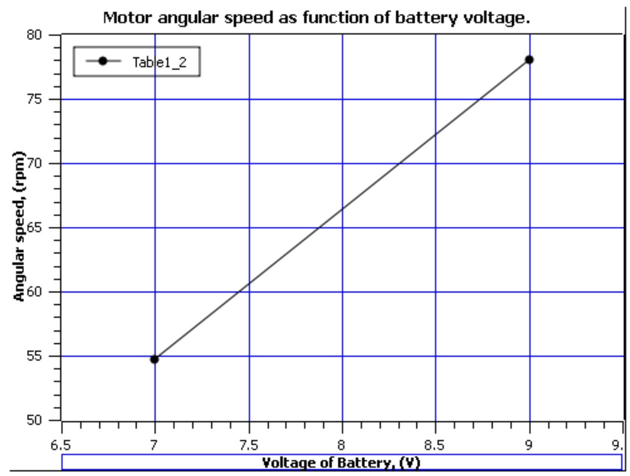

Figure 6. Angular Speed as Function of the Applied for a LEGO Motor

Plotting data

Visual communication requires the presentation of information in terms of tables, graphs or equations. In order to understand and evaluate performance, and plan future approaches, students need to tabulate collected data, plot them, and express them in the form of an equation.

System

A system is a set of interconnected elements that achieve a given objective through the performance of a specified function [19]. It is an integrated whole composed of diverse, interacting specialized structures and subjections. Any system has a number of objectives and the weights placed on them may differ widely from system to system. A system performs a function not possible with any of the individual parts and is generally a complex entity.

Example: The Self-Propelled Automobile

A self-propelled LEGO-based automobile was designed for straight-path and circular-path motion. The linear distance traveled as a function of the rubber band rotation of the wheel shaft provided material to discuss linear and non-linear behavior, validity of domain and breaking of the rubber band. Here, data were collected and presented in the form of a table (Table 1), a graph (Figure 6) and an equation to be determined. The linear approximation of the data is provided by a graphics program [26]. Approximation to a straight line is found using Equation (2).

$$y(x) = mx + b \tag{2}$$

Next, the slope, m, and the y intercept, b, must be determined. From physical considerations, $b = 0$, because there is no displacement when there is no winding of the rubber band. The slope can be found by selecting any two points to a first approximation. Selecting different pairs will give different, yet similar slopes. The concept of best fit of a straight line to data points can be introduced at this point for the appropriate level students. In the current study, the y intercept was considered as the first point because the straight line must pass from there with the last datum as the second point.

$$m = \frac{\Delta y}{\Delta x} = \frac{(5.23 - 0)\,\text{m}}{(4 - 0)\,\text{turns}} = 1.3\frac{\text{m}}{\text{turn}}$$

Finally, the equation takes the form shown in Equation (3).

$$y(x) = 1.3x \quad \text{m} \tag{3}$$

Table 1. Distance Traveled as a Function of Rubber Band Rotation

Number of rubber band rotations	Distance traveled (m)
0	0
1	1.57
2	2.92
3	4.42
4	5.23

The graphing program's linear fit option gives:

$$m = 1.33, b = 0.17, \quad y(x) = 1.33x + 0.17$$

Now students can go back and calculate, either from the graph or from the equation, the number of rotations of the rubber band in order for the self-propelled automobile to travel a specific distance. Although the current results point to a discrete system, the equation and graph transform it into a continuous system. An appropriate locking mechanism on the automobile will provide the fractional number of turns and, thus, the possibility of collecting more data.

Figure 6. Linear Distance Traveled by the Self-Powered LEGO -Based Automobile

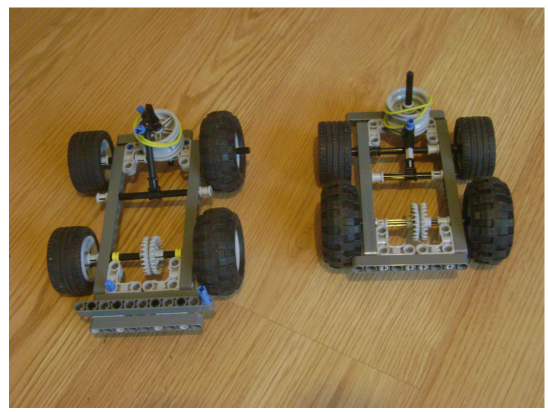

Figure 7. A Self-Propelled Car for (a) Circular (wheels of different diameter) and (b) Straight-Path Travel

Various configurations will travel different distances [27]. This is another parameter of the study, the effect that is, of the weight on the distance traveled. Further, the study can be extended by considering various surfaces. The number of rubber bands will be another parameter of the study. Extension of the study can be made by considering the physical reality of the system. There is no system when the rubber band breaks. This provides an upper limit on the domain of the function as well as on the range. In addition, winding of the rubber band in the opposite direction makes the automobile move in the opposite direction leaving all numerical results identical. Additional concepts to consider are even and odd function, domain of a function, direction of motion, limits of validity of a model, etc.

Conclusion

Problems related to low performance in science, technology, engineering and mathematics persists in education today. Robotics has been proposed and implemented as an approach to increase awareness and interest in the subject and the number of future professionals in the areas of STEM. The most popular approach has been to build a structure, a robot, and program it to perform a specific task by trial and error. In this study, the authors reviewed a number of topics from the STEM areas and proposed that they be included in the building and programming processes. Using a structured, methodological approach in implementing and interrelating concepts from all areas of STEM that apply knowledge acquired and resemble practice clarifies the various concepts and shows their value in solving problems and possible practical applications to the students.

Future Work

It is suggested that complete units of teaching either single-discipline or multidiscipline aspects of STEM be developed. Such units can be developed not only for the various robotics teams but also for elementary, middle, high school and university levels in areas such as mathematics, physics, programming, mechanisms, systems, sensors, etc. with emphasis on concepts and their use to solve problems.

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Biography

BASILE PANOUTSOPOULOS holds a Ph.D. from the Graduate Center of the City University of New York, a ME in Electrical Engineering from The City College of the City University of New York, a MS in Applied Mathematics and a BS in Electrical Engineering from New Jersey Institute of Technology. He joined the Department of Computer Electronics and Graphics Technology during the Fall semester 2010. Before, he worked for eighteen years with the Naval Undersea Warfare Center, initially in New London, CT, and later in Newport, RI. He has taught courses in Physics, Mathematics and Electrical Engineering and Technology. His interests concentrate in Electromagnetics and Applications, Radio Frequency Telecommunications, Bioelectromagnetics, Energy Systems, Applied Mathematics, and Pedagogy (especially Problem Solving techniques). He volunteers in LEGO Robotics and Mathcounts Clubs. Dr. Panoutsopoulos may be reached at Basile.Panoutsopoulos@ccsu.edu

UNDERGRADUATE STUDENT PARTICIPATION IN APPLICATIONS-BASED RESEARCH

David L. Stanley, Purdue University; Ronald Sterkenburg, Purdue University; Denver Lopp, Purdue University

Abstract

As the role of engineering technology in applications-based research grows, so do the opportunities for students to become involved. Some will argue that research activities should be limited to graduate students who, by virtue of their study and maturity, are typically better equipped and prepared for these roles. On the other hand, practical research of this type often demands a great deal of hands-on preparation and support of the type that matches well with the skill sets of undergraduate students. This study explored these issues, focusing on the demands of applications-based research in comparison with the readiness of undergraduate students for such activities. The benefits of these experiences for the students in question was examined and included impact on graduate school success and interest in graduate study. The National Test Facility for Fuels and Propulsion (NaTeF), a federally funded research project at Purdue University for which the lead author is the principal investigator, was utilized here as a case study.

Introduction

Undergraduate students face increasing challenges today in preparation for the job market, which is presently achieving slow growth, at best. Tuition costs are rising and scholarship funding has not grown at a rate that offsets these increases. Summer employment for students is not what it has been, often forcing students to assume a greater debt load to continue their education. Even though the economy does show signs of turning around, state tax revenues continue to fall below predictions, leading to cuts in funding for virtually all programs, including higher education. Students attempting to acquire the knowledge, skills and abilities necessary to compete in the job market following graduation are often faced with difficult choices. If financial circumstances dictate, they may find it necessary to take a job outside the university or seek employment in the university related to their field of study. Working in the academic setting, they could expect to expand their skills, knowledge and experience in their particular disciplines, while also earning money or possibly credit. Moreover, such opportunities would enable them to develop a better understanding of research. Their involvement may begin with the preparatory and foundational work that must be performed in advance of the actual research, support activities and the practices necessary to ensure high-quality outcomes. Over time, they may take part in the design and conduct of tests and experiments, which form the basis for a great deal of the application-based research typically undertaken in engineering technology disciplines. Finally, for those who may choose to continue their education beyond the baccalaureate level, participation in these activities as an undergraduate may give them a competitive advantage for graduate research opportunities.

NaTeF Research Opportunities

Undergraduate participation in research has been foundational for the federally funded research project entitled The National Test Facility for Fuels and Propulsion (NaTeF). This initiative was undertaken by a group of faculty members at Purdue University to enhance the practical aviation fuels research capabilities of the Aviation Technology (AT) program. Although this project does not involve basic research, a term widely used in academic circles, it is very much focused on practical research and development activities, which require knowledge and skills distinctly different from those found in the laboratories of science and engineering, for example. The NaTeF project lays the groundwork for a set of advanced technical capabilities, test protocol and investigative methods that will be used in future testing and development. The majority of the undergraduate students working on the NaTeF project are enrolled in the Aeronautical Engineering Technology (AET) program and have strong technical knowledge and skills and significant laboratory experience, which necessitates that they apply test protocol and procedures to achieve reliable experimental results. This laboratory background, in particular, prepares the AET students to take an immediate role in the NaTeF project.

While aviation and aerospace has almost unlimited opportunities for research, concerns with emissions, fuel costs and fuel supplies have all served to elevate the importance of research into new fuels for the aviation industry and faculty members in the AT program at Purdue University. Determined to develop a secure domestically sourced fuel, the United States Air Force plans to certify its fleet of aircraft for operation on alternative fuels and blends by 2016 [1]. With the Air Force effectively sweeping aside obstacles to progress by establishing these goals, the overall effort to develop new fuels has benefitted tremendously over the last few years. This upswell in fuels research interest led to positive outcomes in many ways for the AT program.

In the period from 1995 to 1998, AT professors David Stanley and Denver Lopp conducted research into the operation of turbine engines on turbine fuels mixed with soy methyl esters. Results of this work led to additional bio-fuels research involving Agricultural and Biological Engineering (ABE) and AT faculty members at Purdue. The ABE researchers developed a soybean-based bio-diesel with a much-suppressed freezing point, and the AT faculty members supervised students who conducted test operations with the fuel in a turbine engine. At that time, the AT department had a number of highly valued assets, including engine test cells and several turbine and piston engines. However, while these AT research assets had been adequate to support initial testing efforts, it was realized that both the facilities and the equipment required significant updating if they were to be used for cutting-edge fuels research in the future.

Following an evaluation of the critical needs related to fuels research, professors Lopp, Stanley and Thom developed and submitted a proposal for congressional funding to support the necessary upgrades. Federal funds, eventually totaling approximately $2.7M, were approved beginning in October, 2009, for this purpose, to be administered through the Air Force Research Laboratory at Wright Patterson Air Force Base. Four faculty members, four graduate research assistants, and as many as eight undergraduate students at any one time were working on the project year-around, which has an end date of January 21, 2012.

In the first phase of the project, work was completed on the AT turbine engine test cell to develop an advanced data acquisition system and exhaust emissions capabilities for use with the turbofan installation currently in the test cell. The expectations were that this test cell would be the equivalent of industrial test facilities with the capability of evaluating engine performance and exhaust emissions when operating on new aviation fuels. In another area of the project expected to play a very important role for fuels development, a materials testing laboratory was under development, where the effects of new fuels on aircraft materials, including gaskets, seals and o-rings, may be analyzed. This application research is critical to the future of alternative aviation fuels. It must logically be conducted in parallel with the development of new fuels to ensure compatibility and avoid wasted effort that leads to blind alleys and unworkable products.

In parallel with these efforts, work also began on establishing similar capabilities for piston engine test operations in another NaTeF test cell. Aviation gasoline, specifically 100LL - “100 low-lead” - has been under fire by the EPA for a number of years due to the fact that it contains tetra ethyl lead (TEL). Often referred to simply as “lead”, this additive, known to cause neurological problems among young children, was eliminated from over-the-road fuels in the early 1990s. However, when added to gasoline in small amounts, TEL has great value as an anti-knock ingredient, and developing a lead-free gasoline that performs as well as 100LL has proven to be a difficult task [2]. This research effort continues, and it is expected that the NaTeF piston-engine facilities will play an important role in the test and development work to solve these problems.

Along with these facility and equipment upgrades, another goal of the NaTeF project was to establish an administrative structure to support and facilitate research activities. As a part of this plan, a director would be selected to oversee the daily operation of NaTeF. Given that these test cells and the equipment therein will continue to have an educational application, it is likely this will be a faculty member with a certain percent effort dedicated to these purposes. A search was also done for a lab manager with a background in chemistry or chemical engineering for the Materials Testing Laboratory.

NaTeF Undergraduate Students

While all AT students may find a niche for themselves in the NaTeF program, AET students, in particular, bring a level of technical experience and knowledge to these activities that are a particularly good fit. AT students pursue a B.S. degree in one of three undergraduate plans of study: Aeronautical Engineering Technology (AET), Aviation Management (AM) or Professional Flight Technology (PFT). The AET program has evolved significantly over time, beginning over 50 years ago as a two-year program that included the Airframe and Powerplant (A&P) mechanics curriculum. AET is now a four-year engineering technology B.S. degree program with ABET (Accreditation Board for Engineering and Technology) accreditation. Graduates of the program may still elect to test for the A&P mechanics certificate, completion of which is indicative of a broad knowledge of the aircraft, applicable regulations and principles of repair and support. These credentials are widely valued in the aerospace manufacturing industry as well, enabling graduates to work in engineering and related positions.

While some educational emphasis in the program clearly remains on hands-on, applied study, engineering technology topics receive additional focus. Laboratory activities in this plan of study cover a wide variety of topics including electronics, manufacturing, materials, powerplant technology and aircraft systems. In the laboratory, students develop knowledge of and skills with hand tools, electrical and electronic equipment, and tools and equipment used in manufacturing and assembly. A great deal of emphasis is applied to systems engineering and integration, which is important for the support of the considerable interrelated but distinct systems required for flight. Graduates of the program are highly sought after in the aerospace manufacturing industry for their knowledge of the aircraft and associated lifecycle issues, certification and related aviation regulations, manufacturing processes, and general project management skills, to name a few. As a result of their study and experience with a wide variety of mechanical, electrical and electronic tools and equipment, practical laboratory activities, and test procedures, AET students are uniquely qualified for the test-cell environment, which makes them prime candidates for the NaTeF project.

Technology graduate students take TECH 646, Analysis of Research in Industry, which gives them many of the basic analytical tools they need to participate in funded research activities. While undergraduate students generally have not taken any of these research preparatory courses, they gain considerable knowledge of testing procedures and protocols through their extensive undergraduate laboratory experiences. Typical AET laboratory projects each begin with a research or test question to answer, a set of procedures to follow, and conclude with project outcomes, the description of which must meet well-defined criteria. This experience base has a direct application for undergraduate students working on NaTeF and other research projects. For the fuel system design effort the NaTeF students are undertaking, as an example, they must understand the demands that sound research and testing practice place on control and measurement of flow, blending of fuels, and fuel system purging procedures. Such considerations must be identified and evaluated as part of the design effort. Clearly, these experiences will be very valuable for undergraduate students as they later move into experimental and research design in graduate school.

The underpinning philosophy of the NaTeF effort has been to apply a research approach to each developmental phase of the project. The goals of the project are to create a facility, testing and development capabilities, and the fundamental testing protocol to enable practical research. Success in this project requires a thorough understanding of the requirements of research and intimate knowledge of aircraft and engine operation. From an educational perspective, one gauge of success is improved student preparation for graduate education and an increase in program enrollment.

Undergraduate Participation in the NaTeF Project

From the beginning of this initiative in October, 2009, to the present, the number of undergraduate workers has varied from a low of four to as many as eight. The number of graduate research assistants (GRAs) has remained constant at four over the course of the project, to date. The duties of the GRAs vary considerably as several of them are assigned to specific technical development activities, while one GRA is specifically responsible for oversight and scheduling of undergraduate students. This particular graduate student has taken a lead role in general work planning, recruiting and oversight of undergraduate students for NaTeF. He collects resumes and supporting information from those undergraduate students interested in working on the project, compares their skills and experiences with NaTeF jobs and tasks, and makes recommendations for student selection to the NaTeF faculty members.

Facilities preparation has been a major task undertaken largely by the undergraduate students on the NaTeF project. They have been given the charge of scoping the work and determining the supplies and equipment necessary to accomplish the various jobs, which range from planning the positioning of and facilities requirements for the exhaust emissions and data acquisition equipment to be installed in the test cell to painting and all the preparation work that entails. Undergraduate students have planned the logistics and timing of the work at each step along the way involving activities on three different floors in the building, all of which are test cell interrelated.

Undergraduate students are designing the new fuel system for the test cells. The current phase of work for NaTeF was primarily focused on the turbofan test cell; however, several test cells comprise the NaTeF facility, and a new fuel system is necessary for the research activities and the continued educational function of these engine facilities. Fuel storage, the fuel distribution system to the test cells, and control of the fuel are interrelated but separate design efforts undertaken by the undergraduate students, with mentoring oversight provided by both the GRA and the faculty members in charge of the overall NaTeF project. The teams working these fuel design elements meet routinely to ensure that their separate efforts meet the overall goals for the complete system.

Considerations for the fuel system design include:

- Fire code for the fuel storage area, distribution system, and the test cells
- Engine requirements for fuel quantity and pressure

- Storage tank size, selection and location
- Sizing of the distribution system
- Experimental / research requirements for alternative fuel and fuel blending capabilities
- Access for delivery of fuel to the storage tanks
- Remote control of the fuel system

As a part of this fuel design project and other related work, undergraduate students were charged with specification of the equipment to purchase. They had to develop a detailed understanding of the NaTeF research anticipated for the future in comparison with the capabilities of the equipment under consideration for that purpose. These NaTeF experiences give them a solid foundation to build upon as they move towards graduate school.

Although not specifically a part of the NaTeF effort, a number of AET students are supporting the research effort by undertaking projects in their senior design course that address specific NaTeF issues. One of these efforts is to establish a safety program for the test facilities, while the other is focused on developing operational procedures for the test cell. For both of these specific projects, students must evaluate the educational and research use of the facilities, conduct a survey of the stakeholders involved in fuels research, and develop procedural documentation to be followed by NaTeF personnel.

As indicated earlier, one measure of success in this project is the preparation of undergraduate students for graduate school, and increased program enrollment. Although the results to date are largely anecdotal, due to the short duration of the project to date, NaTeF undergraduate student workers have generally displayed an increased interest in pursuing graduate study. It is unclear as to the real cause of this; however, these students do appear to be better prepared for graduate school as a group than those who came before them. It is the opinion of the authors that participation in the applied, practical research of NaTeF leads students to develop an improved understanding of research and experimentation, in general, which will serve them well in graduate school.

USMC-funded Research Projects

Aeronautical Engineering Technology students are also involved in several other funded research initiatives, including the United States Marine Corp (USMC) project on the CH-53K rotor blades. According to professor Sterkenburg, the lead AT investigator on this and other USMC-sponsored projects, the undergraduate researchers are involved in all steps of the research process: recognizing a problem, literature review, developing experiments and running experiments, purchasing materials, collecting data and reporting the research results in a journal or conference proceedings. The outcomes of this project were significant and included the following [3]:

- Titanium quick patch repairs for use in battle-field conditions
- A new hybrid structural joint
- Environmental testing procedures to determine the effect of foreign matter on composite materials

A notable outcome of this project was a patent granted for the hybrid structural joint developed from composite materials. AET students also participated in another USMC-sponsored project to research the use of ribbonized organized integrated (RIO) wiring systems. Students investigated the applications of RIO and prepared a report on its advantages and disadvantages for the sponsor. It should be noted that a common element extending through all of these research activities and the AET curriculum is data collection and interpretation. Virtually all test and research work is heavily dependent upon accurate and repeatable data collection which, in turn, is very much reliant on sound instrumentation and careful adherence to consistent procedures in the test cell. It should be no surprise that data, instrumentation and procedures are strongly emphasized throughout the AET undergraduate laboratory experience.

The AET Curriculum

Research and student projects in engineering technology programs are generally applications based and focused on the needs of the industry. Realizing this, the AET faculty developed two new courses, AT 496 Senior Project Proposal and AT 497 Senior Project, to fill a void in this area. Elements of Six Sigma, which embody process improvement, are at the heart of many of the senior design projects, and are taught and utilized throughout the AET curriculum. It is expected that senior design projects, where possible, will address industry problems and issues with the idea that students will develop an understanding of the challenges and expectations they will face in their careers. Some of the projects focus on NaTeF technical challenges, in which case the stakeholders are primarily the faculty members overseeing that work. The structure of the senior project courses relies heavily on student teams, primarily due to the fact that such a model creates an industry-like environment for complex project and problem solving. Team projects also demand a high level of organization, cooperation and communication, all of which are fundamentally important tenets of an engineering technology education.

While these courses are designed for seniors, the AET faculty have resolved that new research opportunities occurring earlier in the undergraduate experience should be introduced, a strategy which will not only pay dividends for research but will also provide an essential revenue stream to support the laboratories for the fundamental mission of education. This is increasingly important during times when funding generated by tuition and state support cannot be expected to meet the needs of these programs in the future [4]. This interest in expanding student experience in research supports the educational model of a research-focused university, deepens the education students receive, and is foundational to the technology philosophy for collaboration with industry [5]. Engineering technology research must provide value to industry to resolve practical, applications-based problems and challenges. Incorporating this philosophy early on with engineering technology students adds value to their education, while also building the partnering relationships with industry.

Conclusion

As engineering technology programs, in particular, advance the model of industry-based and practical research, the opportunities for undergraduate students to participate in these activities are expanding. The rationale for active collaboration between undergraduate programs and industry is clear. The research opportunities afforded by such relationships are appropriate to the mission of the educational unit; the experiences students gain prepare them for their careers, and the industry sees the benefit of investing in the programs.

The appropriate role for undergraduates in research must be established and several considerations apply. First and foremost, a match between the demands of research and the readiness of the students must exist. Much of the research effort undertaken by the AET program is applications-based, and very practical in nature. It often demands a great deal of hands-on work and preparation, but may also involve considerable test work, which includes a thorough understanding of standard protocol and procedures. In the case of test work, experimental design, set-up and operation are often a large part of the effort. In the NaTeF project, undergraduate students, with the mentoring guidance of graduate research assistants and faculty members, are undertaking these elements with great success.

Faculty members in the Aeronautical Engineering Technology program are currently funded for several research projects of the type that create opportunities for undergraduate student participation. In the NaTeF case study example, a great deal of student effort is focused on facilities planning and preparation and specification of equipment. All of this work has been guided by a research philosophy, with focused inquiry into future plans and essential capabilities laying the groundwork for sound decision making. In the USMC-sponsored research project, students participated in experimental design for testing purposes as well as the actual conduct of the actual research. For both the NaTeF and the USMC-sponsored projects, undergraduate students formed an effective workforce to accomplish the tasks at hand. One undergraduate team utilized their background and experience to design an entirely new fuel system for both test cells, including storage tanks, pumping system, pipes and control. Another team developed a complete safety system for the turbine test cell, while a third assisted a faculty member in the design and fabrication of a test rig for use in compatibility studies. The AET curriculum emphasis on laboratory projects, testing and protocol, and process management prepares these students to participate effectively in these initiatives in appropriate roles. It is also fitting that the demands of research and project work have led to significant changes in the curriculum to better prepare students for their roles in these activities. AET program graduates are finding employment with aerospace companies in engineering positions where their broad knowledge of aircraft, support and repair processes gives them an advantage over others.

Finally, it should be noted that, while the evidence is anecdotal at this stage, there appears to be a direct correlation between undergraduate participation in applied research and increased interest in graduate school. Moreover, these students generally are better prepared, more enthusiastic and more productive in graduate school than students who have not been involved in research projects. This only makes sense, as one might safely assume that undergraduate students taking such an interest are more highly motivated for higher education.

Acknowledgments

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Biographies

DAVID STANLEY is an Associate Professor in the Aeronautical Engineering Technology program at Purdue University. He is the principal investigator of the NaTeF project and co-director of the Air Transport Institute for Environmental Sustainability (AirTIES) Center. Prof. Stanley teaches primarily powerplant courses. He may be reached at dlstanley@purdue.edu

RONALD STERKENBURG, Ph.D., is an Associate Professor in the Aeronautical Engineering Technology program at Purdue University. He is the lead AT investigator for the USMC-sponsored programs, and has directed several design / build / fly projects in which students from engineering and AET worked together to achieve impressive results. Prof. Sterkenburg may be contacted at sterkenr@purdue.edu

DENVER LOPP is a Professor of Aviation Management and an award-winning teacher at Purdue University. He is a Co-PI of the NaTeF project and co-director of the Air Transport Institute for Environmental Sustainability (AirTIES) Center. Prof. Lopp has led many aviation industry collaborative projects involving undergraduate students. Prof. Lopp may be contacted at denver@purdue.edu

LEARNING-ENABLED COMPUTER ASSESSMENT OF SCIENCE LABS WITH SCAFFOLDS METHODOLOGY

Prema Nedungadi, Amrita Vishwa Vidyapeetham; Raghu Raman, Amrita Vishwa Vidyapeetham

Abstract

The crucial role of hands-on science experiments in the school science curriculum is universally accepted. However, a formal assessment of practical skills is lacking, with most schools employing traditional theory-based or multiple-choice questions (MCQs) to evaluate students. In this paper, the authors present a framework for learning-enabled assessment of practical skills, which gives due consideration to both the structure of the practical assignments and the feedback that promotes learning. This approach opens up many new possibilities that require constructivist learning and higher-order thinking skills. Judgment of skills based on performance reports may decrease students' confidence, whereas scaffolds used during the assessment process can improve students' proficiency. The design of various online scaffolds—used during assessment that help students focus and redirect their efforts to the appropriate task needed for mastery of a skill—are discussed here. Early studies have shown that students prefer these types of assessment to more traditional ones, where intervention includes appropriate hands-on simulation or interactive animation or a given concept.

Introduction

The National Focus Group on "Teaching of Science" suggested prevention of marginalization of experiments in the school science curriculum. In this regard, investment is required for improving school labs to promote an experimental culture. However, there seems to be two main difficulties.

1. Experiments require a certain minimum infrastructure; a lab with basic equipment and materials. Azad et al. [1] have shown that learners have access to the physical lab for only a short period of time; thus, the learning cycle is limited as the time is often insufficient for trying different scenarios.
2. Assessment of practical skills in science in an objective manner is a difficult task. The difficulty increases manifold if the assessment is to be carried out with a large. This lack of infrastructure and, more importantly, lack of reliable assessment has resulted in the unfortunate neglect of experimental work in many schools.

The Central Board of Secondary Education (CBSE) in India has mandated continuous assessments in both theory and practical skills. As per the current assessment scheme, theory and practical examinations have a weight of 60% and 40%, respectively. The practical examination is comprised of two components.

1. A multiple-choice format, which raises a question of how to test accurately when the majority of the questions are multiple choice, where intelligent or random guessing is common? It should be noted that there are no negative marks for incorrect answers.
2. The other component is the actual performance of the experiment by the student in the lab.

Currently, CBSE has made sure that expensive equipment is not part of the practical curriculum so that most schools can afford it. Online labs can remove this limitation and allow students to practice in all areas of experimentation, irrespective of the expenses or cost involved. Integrating online labs with assessment of practical skills can offer support for the Continuous and Comprehensive Evaluations (CCE) program mandated by CBSE.

Scaffolds Used During Assessment

One of the most important components in course evaluation is the assessment of lab work. Today, lab work is often judged by the results (summative assessment) observed in the written lab reports (reporting-related skills) submitted by students after experimentation, rather than evaluating the skills acquired by students and providing immediate feedback (formative assessment) while conducting the experiment in the lab (procedure-related skills). Practical skills assessment needs to evaluate both reporting and procedure skills. Weights for procedure and reporting skills in each experiment need to be determined based on the lab objectives set for that particular experiment. An often neglected but important component in making learning effective is the assessment of learning, as traditional assessments of labs are often limited to theory and multiple-choice questions.

The objective of this study was to design and develop a system for Computer Assessment of Practical skills (CAPS) capable of assessing an experiment's procedural, manipulative and reporting skills. Having these experiments available online addresses the issues of simultaneous access for large numbers of students and being able to evaluate them.

Literature Review

Bryce and Robertson [2] in their review of the literature regarding assessment in the lab wrote that in many countries teachers spent a considerable amount of time in supervising lab work, but the bulk of science assessment is traditionally non-practical in nature. Based on a study in the context of learning in Biology conducted by Yung [3] in Hong Kong, he presented data that demonstrate the complexity of assessment in school science labs. He claims that even as we enter the 21st century, teachers continue to assess their students using paper and pencil tests, thus neglecting many of the most important components of students' performance in the science lab in general, and the inquiry laboratories in particular.

Continuous assessment of practical work is necessary to adequately cover the variety of tasks and skills that comprise a total program of science-based practical work. The advantage of the continuous assessment of students' work in the lab is discussed in detail in a comparative study by Ganiel & Hofstein [4]. Computer Assisted Assessment (CAA) can stimulate, motivate, be diagnostic and reinforce learning by providing directed feedback [5].

Gibbs et al. [6] addressed the purpose of lab work as follows:

- Developing practical skills
- Familiarization with lab equipment, techniques and materials
- Developing data-recording and analysis skills
- Developing experimental design and problem-solving skills
- Developing communication and interpersonal skills
- Developing technical judgment and professional practice
- Integrating theory and practice
- Motivating students

Even in schools with labs, considering the varied ability level of students, the allocated time for experiments is often not enough for all students to complete their tasks satisfactorily and gain sufficient experience through the process [7]. Scaffolding is the precise method that enables a learner to achieve a specific goal that would not be possible without some kind of support [8]. Puntambekar & Hubscher [9] described the central features of scaffolding as: common goals, ongoing diagnosis, dynamic and adaptive support, dialogues and interactions, and fading for transfer of responsibility. Scaffolding can also be characterized as helping the learner with the more difficult or extraneous portion of the task, thereby allowing the learner to complete the primary learning objectives, the real task, of the activity [10]. Scaffolding is also linked with formative assessment through the shared characteristics: eliciting prior knowledge, providing feedback, teaching for transfer, and teaching students to self -assess [10].

Human tutor scaffolding may be more valuable than computerized or written scaffolding because of a human tutor's ability to pick up on subtle cues from the student [11]. However, several authors acknowledge that one-on-one scaffolding cannot readily occur in a classroom with many students and one instructor.

Amrita Learning

As part of the Amrita Learning Initiative, an Adaptive Learning Management System (ALMS) was created. ALMS emulates a one-on-one tutoring system based on intelligent learning principles. Various modalities support the different visual, auditory and kinesthetic learning styles, and learning preferences support tutorials, animations, videos, graphics, simulations and summary or detailed information [12]. The initial application of ALMS was in the development of adaptive assessments with automatic presentation of multimedia tutorials for intervention based on proficiency levels [13].

Amrita Learning Online Labs

Amrita Learning Online Labs (ALOL) is based on the idea that lab experiments can be taught using the Internet, more efficiently and less expensively, and offered to students who do not have access to physical labs. It was developed to supplement the traditional physical labs. It may even replace the traditional labs as is the case with rural schools in India, where lab facilities are missing, enabling them to compete with students in better schools, thus bridging the digital divide [14]. ALOL further helps students prepare themselves before attending a lab by becoming acquainted with the equipment, going through pre-lab exercises and taking pre-lab quizzes, both on the content of the work and on the safety considerations of the lab, all through online exercises.

Raman & Nedungadi [14] have detailed the steps to provide students access to online science labs and to perform, record and learn experiments anywhere, anytime. There are ranges of learning models in which these resources can be used and the benefits of using these as learning aids have been widely accepted. Online labs may be offered as a pre-lab learning tool to provide additional activities, to support teaching or learning of a concept and to evaluate the student. It can also be used as supplementary learning in schools which have the physical equipment to perform the experiments, but have no physical labs.

Computer Assessment of Practical Skills (CAPS)

Assessment can be enhanced using multimedia to assess higher-order thinking skills and problem solving, and can enrich the experience. In the Amrita system, students can explore, construct and experiment before coming to a solution.

CAPS tests the following skill areas:

- Procedural and manipulative skills
- Concepts and understanding skills
- Reporting and interpretive skills

Implicit feedback occurs with ALOL in that the learners see the results of their action. However, in order to provide formative assessment to assist learning, further feedback is required.

With CAPS, students will be able to

- perform the actual experiments on the computer and record answers (steps followed in performing the experiment will also be recorded and observed);
- manipulate, observe and interpret or predict during assessment even with multiple-choice questions; and,
- get immediate feedback on their actions.

Assessment of Procedural and Manipulative Skills

Under this category, a student must be able to select the appropriate apparatus (Figure 1) or sequence the steps (Figure 2) needed to perform the experiment and remove unrelated ones. The student should know the limitations of the apparatus and be able to assemble and handle the instrument. The student should be able to rectify errors in an apparatus and dismantle the experimental setup.

The student may be asked to choose either the correct apparatus or the materials needed for an experiment, or assemble the materials for a given set. For example, a commonly used experiment for Newton's Second Law of motion is the cart experiment, where the cart accelerates when an external force is applied to it. The aim of this experiment is explore the relationship between the magnitudes of the external force and the resulting acceleration.

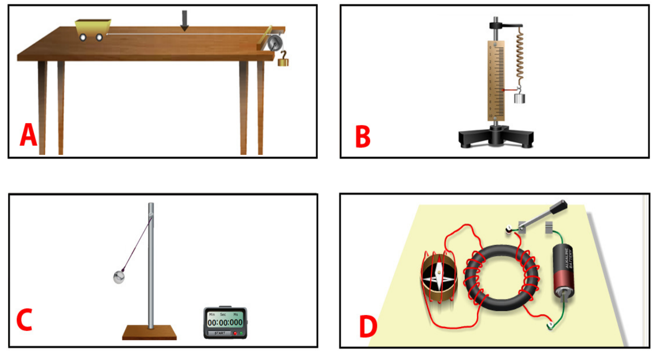

Figure 1. Assessment Asking the Student to Select the Right Apparatus

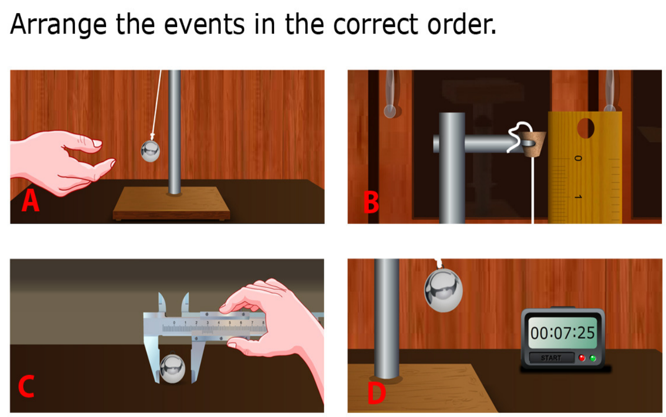

Figure 2. Assessment Asking the Student to Sequence the Steps for the Experiment

The variables for this experiment include changing the friction, the weight of the cart, the weight to be hung, and the distance moved by the cart. In another instance of this simulation, time is a variable while the distance is fixed.

Assessment of Concepts and Understanding the Experiments

This includes reading the instruments correctly, noticing the color changes or any visible changes, locating the desired parts in a specimen, and understanding the scientific concepts and applications of the experiments. The sample question of Figure 3 shows the scaffolds used for an experiment.

Choice a) is the incorrect observation and, hence, the correct answer choice. In case a student incorrectly selects choice b) instead of a), the first interactive animation (Figure 4) shown would be to teach the learner that b) is actually a valid choice; the second animation (Figure 5) would show that a) is an incorrect choice. The student can perform both simulations to understand the concepts.

In an experiment to test the pH of a given sample using pH paper, four students recorded the following observations:

Sample Taken	pH paper colour turned
a. Water	Blue
b. Dilute HCl	Red
c. Dilute NaoH	Blue
d. Dilute Ethanoic Acid	Orange

Which one of the above observations is incorrect?

Figure 3. Multiple-Choice Question Testing Understanding of Concepts

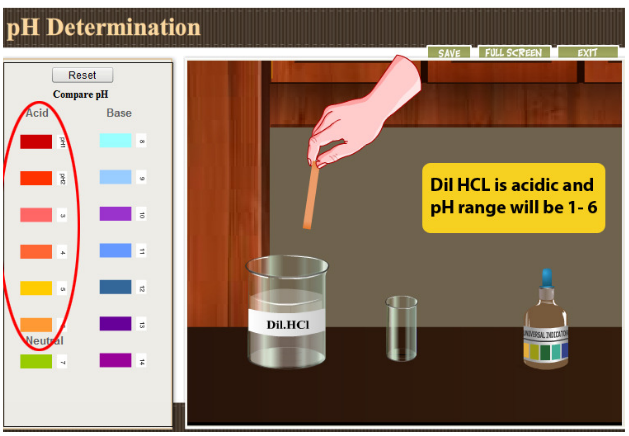

Figure 4. First Scaffold to Learn From the Error

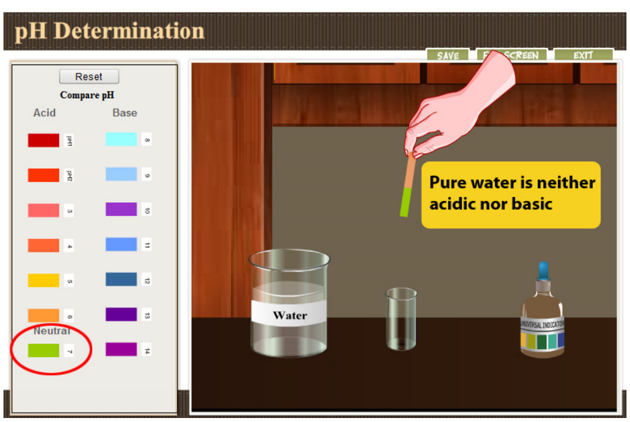

Figure 5. Second Scaffold to Help Learn From the Same Error and Show the Right Answer

The simulation of Figure 4 shows that dilute HCL is acidic based on the color change. Its pH value can be obtained by comparing the color of the pH paper to the colored boxes with the PH value shown against each box. The simulation of Figure 5 shows that water is neutral based on the color change of the pH paper and thus is non acidic.

Assessment of Reporting and Interpreting Skills

These include recording the observations, data and information correctly and systematically; classifying and categorizing the data; making correct calculations with observed data and using the right formulas; reporting results using correct units and symbols; and, interpreting the results correctly.

- Record the observations, data information (Figure 6)
- Choose the appropriate graph and label them
- Plot the data points on a graph (Figure 7)

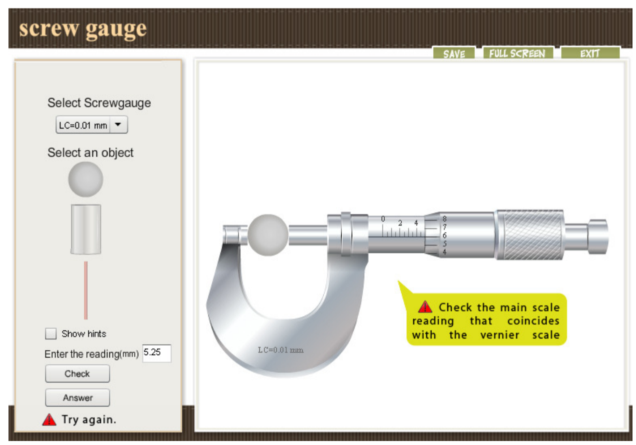

Figure 6. Assessment with Feedback to Compare Student Reading of Data to Stored Experimental Data

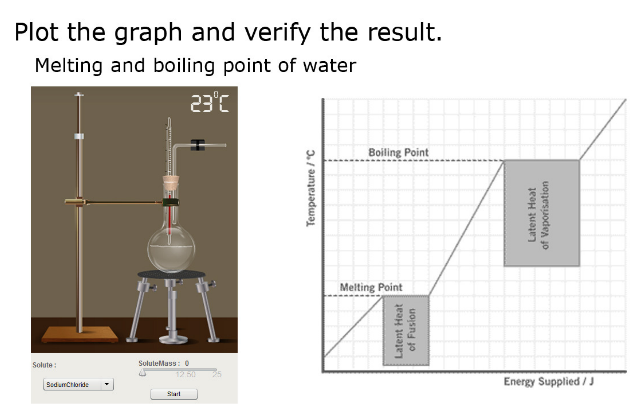

Figure 7. Assessment to Plot a Graph Based on the Simulation

Take the case of assessing a student's ability to record observations. A simulation is shown with a fixed starting set of variables and viewed up to the end. This part is a passive viewing by the student and can be replayed as necessary. Then, the student may be asked to choose the correct table format and enter the variables and the recording observed. Sample questions can include recording information about the experiment, observing results and creating a graph for the readings.

Assessment Scheme for a Sample Experiment Based on Skill Areas

Table 1. Weights for the Different Skill Areas

Skill Area	Weight
Procedural and Manipulative Skills	35%
Concepts and Understanding	40%
Reporting and Interpretative Skills	25%
Total	100%

The weighting for the different skill areas can be varied based on the nature of the experiment and, as such, the assessment scheme must be transparent to the students.

Recording and Reporting of Experimental Data

Every input from the students is tracked, including the current state of the experiment, mouse clicks, variable changes, pages visited and time spent. This provides a complete history of all student activity. Based on the analysis of this data, the learning style and the student level, scaffolding intervention—in the form of thinking clues, tutorials, reviews or help—is provided, much as the teacher would do in such a situation. Such data can provide insights for both teachers and students into strategies, common mistakes and missing concepts after exercises. It is also possible to distinguish between a problem-solving attempt involving guess work.

This project was implemented for a period of 13 weeks with 36 students and 3 teachers. A total of 3 sets of experiments were considered. On average, each student spent 2 sessions of 25 minutes each per week working on the system. Table 2 summarizes the results of a questionnaire given to the students. A 5-point Likert scale was used to administer the survey.

1 = Strongly Disagree
2 = Disagree
3 = Neutral
4 = Agree
5 = Strongly Agree

Table 2: Results of Questionnaire Proposed to the Students

Questions	Average
Simulations were helpful to understand the con-	4.9
I like the way system provides hints during ex-	4.7
I like the way I can manipulate the equipments	3.8
The system is easy to use	4.7
I like the fact that I can see the results of my	4.9
I like getting immediate feedback on my work	4.8
I do not see too much advantage of CAPS over	2.6
The actual process of using CAPS is enjoyable	4.8
The project should be extended to all Science	4.7
It has helped me understand concepts in the	3.5

Given the high costs of building a physical lab and the amount of time it occupies in the school curriculum, effective assessment of practical skills is important. Though there are many online labs, such learning-enabled assessments for online experiments with scaffolds are still not commonly available.

The main considerations of a new technique for assessing online labs discussed here are:

- Design and architecture of online labs with scaffolds built into assessment for online labs for procedure, manipulative and report-related skills.
- Additional costs and time involved to build such scaffolds for the online assessment, taking into account the time spent in creating animations, taking videos, drawing graphics, making simulations, preparing tutorials, procedure or detailed information and developing the appropriate software.
- Early studies have indicated that the majority of the students are interested in learning-enabled online assessments.

Current work includes large-scale qualitative and quantitative studies to analyze and measure differences in learning concepts using traditional and scaffold methodologies, adapting online labs and scaffolds that are specific to mobile/tablets.

Acknowledgement

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Biography

PREMA NEDUNGADI is a PI for the Online Labs for Schools from Department of IT and a joint Director for the Center for Research in Advanced Technologies for Education (CREATE) at Amrita Vishwa Vidyapeetham where her research projects include areas of Adaptive Assessment and Learning, Virtual Simulation Labs, Language Labs and Collaborative Authoring and Learning Platforms. Her prior background includes 15 years of Software Architecture and Management at Sybase Inc. and Redbrick Systems (IBM), California. Dr. Nedungadi can be reached at prema@amrita.edu

RAGHU RAMAN is the Principal Investigator from Amrita for the National Mission on Education through ICT (MHRD) project on ERP and the Principal Investigator for Online Labs for Schools from Department of IT, Government of India and for the Measuring Learning Consortium, under the HP Catalyst Initiative . He heads the Center for Research in Advanced Technologies for Education, CREATE @ Amrita, guiding research projects in the areas of Adaptive Learning Systems, ERP Systems, Virtual Labs with scaffolds, Intelligent Video surveillance, Multimedia technologies in education that has societal impact. Raghu has over 22 years of executive management experience from NEC Research Labs, IBM, and Informix etc. Dr. Raman can be reached at raghu@amrita.edu

INCIDENCE OF TUBERCULOSIS AND ITS DETERMINANTS: A SYSTEMS GMM ANALYSIS

Elsy Thomas Kizhakethalackal, Bowling Green State University-Firelands; Debasri Mukherjee, Western Michigan University

Abstract

In this study, the authors used dynamic panel specifications on an unbalanced panel of 112 countries using annual data from 1990 to 2005. These specifications support the influence of basic education on lowering the incidence of infectious disease. The lagged values of the dependent variable were also found to be significant in all systems GMM specifications, thereby supporting the contagious nature of the disease. Though a considerable amount of aid has been directed towards infectious disease control (controlling the spread of communicable diseases), the achievement of these health goals remains rather questionable among recipient economies. The policy implications of this study are that aid could be diverted towards strengthening systems by investing in both health and human infrastructure.

Introduction

Over the decades, developing countries have seen a shift both in the amount of aid and the purpose for which it is disbursed. The emphasis changed from structural adjustments in the 1980s to conditionality in 1990s, to more recent decades witnessing donor financing towards social services such as health and education [1]. This move has been along the lines of meeting the new global priority, the Millennium Development Goals (MDGs), where the emphasis is on improving human infrastructure. The Millennium Development Goals (MDGs) are eight international development goals broken down into twenty-one quantifiable targets that are measured by sixty indicators. They have been adopted by 189 nations and signed by 147 heads of state and governments. These goals respond to the world's development challenges and are agreed to be achievable by the year 2015. They include fighting infectious diseases such as tuberculosis and AIDS, reducing child mortality, improving maternal health, reducing extreme poverty, and developing a global partnership for development, to name a few.

In this study, the authors looked at health-aid to see if it could lower a specific infectious disease, called tuberculosis—one of the most widespread infectious diseases in developing countries and which results in a large number of deaths in the economically productive age group of 15-59 years. Standard linear mean regression was used on annual level data to explore the dynamic nature of the relationship and to see if by exploiting this dynamic nature any significant impact of health-aid on this specific infectious disease could be found. Of particular interest was the impact of disaggregated health-aid on the incidence of tuberculosis. Analogous to the growth literature, which uses an institutional quality index, the authors used primary schooling completion rate as a proxy to measure human infrastructure which is a key prerequisite for improving health standards/ outcomes of developing countries. Longitudinal data analysis methods were used on an unbalanced panel of 112 developing countries from 1990-2005. These dynamic panel model specifications (systems GMM) account for issues of serial correlation, heteroscedasticity and endogeneity among some of the explanatory variables in the estimations. These specifications confirm that, among the covariates considered, education does play an important role in lowering the incidence of infectious diseases. It was also found that there is a significant lagged effect of the incidence of tuberculosis, which basically supports the contagious nature of the disease. Unfortunately, health-aid was consistently found to be ineffective.

Related Research

Thiele et al. [2] used a Tobit regression analysis to test if sectorally disaggregated data on aid by purpose does have a significant impact on meeting MDGs for a sample of 140 recipient countries. The findings indicated that while aid has been effective in fighting infectious diseases like HIV/ AIDS, it has not helped lower the incidence of tuberculosis or malaria, nor has it helped increase primary education levels. They attribute part of this failure to insufficient targeting of aid. Momota et al. [3] used a two-period overlapping-generations model to examine how the spread of infectious diseases (e.g., HIV, Malaria, syphilis) influences individual preventive behavior (i.e., health investment) and resource allocation. That study also examined how one-shot foreign (medical) aid influences the welfare of individuals in recipient countries. The findings suggest that agents' preventive behavior induces the cyclical spread of infectious diseases. They also found that one-shot medical aid may likely suppress the spread of the disease at a given time but, given the cyclical nature of the disease in developing economies, people need to be more vigilant. Finally, then, they found one-shot foreign aid to be undesirable. Martin et al. [4] developed a theoretical model that generates the optimal budget allocation to maximize social welfare for 23 programs of care (namely, infectious diseases, cancer, circulation) administered by the English Primary Care Trust. Using an instrumental variable method, they empirically tested two large programs of care: cancer and circulation. The findings suggested that healthcare spending can improve health outcomes. Shiffman [5] and Landis [6] both compared donor funding priorities to the burden of diseases. Shiffman's study indicated that funding does not correspond to the burden of the disease and identified funding towards infectious diseases like respiratory infections and malaria to be highly insufficient. Landis extended his work to all diseases and concluded that while health areas such as basic healthcare and infrastructure, health education and personnel development have witnessed a decline in allocations, infectious diseases such as HIV/AIDS have received a larger share of the resources. Both papers concluded that funding patterns do not reflect the needs of the developing world and suggest an increased need for funding communicable disease control.

Data

The sample in this current study covered 112 developing countries spanning the years from 1990 to 2005. Annual level data were used though the number of observations varied across specifications depending on the control variables used. The dependent variable was incidence of tuberculosis per 1000 people. The independent variables used in this study were as follows:

- GDP per 1000 people, measured in constant 2005 U.S. dollars
- Primary schooling completion rate, which was used as a proxy for education and existing human infrastructure
- Density per square kilometer
- Government health expenditure per 1000 people, measured in constant 2005 U.S. dollars
- The GINI index which measures the level of income inequality and which is also an important factor that may contribute to the further worsening of the health outcomes among developing economies
- Health-aid per 1000 people, measured in constant 2005 U.S. dollars
- The number of physicians per 1000 people

Physician stock was used as a proxy for the existing health infrastructure. Several period dummies were used to check if the implementation of the Millennium Development Goals or the changes in donor financing towards health-related issues have had a significant impact in lowering the incidence of tuberculosis.

The health-aid term was considered in order to check for the diminishing effects of health-aid. Interconnecting the health-aid term with physician stock or government health expenditure also helped us determine whether the existing amounts of physician stock or government health expenditure would improve the effectiveness of health-aid in reducing the incidence of tuberculosis. In system GMM estimation, the number of instruments grows quickly with the number of time periods and covariates. To control for the rapid growth of instruments, the maximum number of lags of the dependent variable and lags of the endogenous variables (used as instruments) was limited to one.

Health-aid is an important covariate of interest. Ideally speaking, it would be best to use only that component of health-aid that is disbursed specifically for tuberculosis control. However, due to the lack of data at this level, data on health-aid—aid that is specifically directed towards health outcomes—was used. Following the conventional practice of aid-growth-poverty literature, a one-period lag of health-aid was used to subdue any possible endogeneity effect. The variables and data sources are listed in Table 1.

Table 1. Variables and Sources [7], [8]

Variable	Source
Incidence of tuberculosis (per 100,000 people)	WDI, 2007
GDP per capita	WDI, 2007
Health-aid	OECD, CRS
Primary completion rate, total (%)	WDI, 2007
Physicians (per 1000 people)	WDI, 2007
Population, total	WDI, 2007
Population density (per square km.)	WDI, 2007
GINI index	WDI, 2007
Health expenditure per capita	WDI, 2007

Note that period averages were not taken; rather, annual level data were used to examine the dynamic nature of the interrelationship between health-aid and the incidence of tuberculosis.

Descriptive Statistics

Table 2 represents the summary statistics. On average there are about 2 instances of tuberculosis that are reported per 1000 people per year. The incidence of tuberculosis is as high as 11 cases per 1000 people in some developing countries. Though these numbers do not seem large, the fact remains that a large number of deaths in productive ages occur due to this communicable disease; furthermore, there could be some level of misreporting/lack of reporting. The availability of physicians, on average, is very low. The maximum number of available physicians per 1000 people among these sample countries is about 8 physicians. Governments of developing economies spend a substantial amount on the health needs of the population. The GINI index measures inequality in income distribution and is expressed in terms of a percentage. The higher the percentage, the greater the level of inequality. The average density is about 106 people per square kilometer. The average primary completion rate is about 66%. On average, about $1,280 (in constant 2005 U.S. dollars) per year of health-aid is disbursed per 1000 people.

Table 2. Sample Summary Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
Tuberculosis	723	2.26	1.84	0.05	11.41
Govt. Health expenditure	347	15.15	1.18	12.51	18.01
Physician	723	0.66	0.93	0.01	7.88
Health-aid	723	7.16	1.62	1.45	12.59
Density	723	3.886	1.33	0.42	7.07
GDP	723	17.91	1.08	15.89	21.13
Education	723	65.79	28.37	10.78	143.67
GINI	291	43.37	8.00	28.15	62.35

Estimation Method and Statistical Tests

Given the longitudinal nature of the data set used in this study, the authors used panel data estimation techniques. Panel data analysis endows regression analysis with both spatial and temporal dimensions; i.e., cross-sectional and periodic observations of the set of variables. The system GMM estimators proposed by Arellano & Bover [9] and Blundell & Bond [10], [11] were used in order to explore the effect of our main variable, interest (health-aid), on the incidence of tuberculosis. Even if the lagged dependent variable and the error terms are uncorrelated, the introduction of the lagged dependent variable makes random- and fixed-effect estimates inconsistent because the lagged dependent variable would be correlated with the transformed errors [12]. To overcome this problem, the systems GMM estimation technique was used. This technique was first introduced by Arellano & Bover [9] and developed by Blundell & Bond [10], [11], and accounts for the bias introduced by the lagged dependent variable. To understand this method, let us consider a dynamic panel data model of the form shown in Equation (1):

$$Y_{it} = \alpha_i + \delta Y_{it-1} + X_{it}'\beta_k + \varepsilon_{it} \tag{1}$$

where $u_{it} = \alpha_i + \varepsilon_{it}$

Here, Y_{it} is the dependent variable (incidence of tuberculosis per 1000 people) for country *i* at time *t*. X_{it} is the set of relevant macroeconomic covariates such as health-aid per 1000 people, government health expenditure per 1000 people, gross domestic product per 1000 people, education, physician stock per 1000 people, density per square kilometer, the GINI index, interaction terms and period dummies. And where β is the *k x 1* parameter vector associated with the independent variables defined above; α_i represent the special effects for each country and which are considered to be constant over time, t , and are specific to individual units [13]; and, u_{it} is the i.i.d. (independently identically distributed) error term. This specification uses more moment conditions, whereas lagged differences are used as instruments for level equations and lagged levels are used as instruments for difference equations.

In this study, two important tests were conducted to serve as a check for the validity of the estimators [14], [15]. The first was the Autocorrelation test where the null hypothesis is not a second-order serial correlation in the error term of the first-differenced equation which requires that

$$E[\Delta u_{it} \Delta u_{it-2}] = 0$$

Another test for the validity of the instrument is Sargan's [16] test of over-identifying restrictions which requires that

$$E[W' \Delta u \;] = 0$$

Stated another way, the instruments are uncorrelated with first difference errors, where W is the instrument matrix [17]. If the null hypothesis is rejected, it implies that either the number of instruments must be reduced or a more appropriate set of instruments must be found. Thus, in both of the tests, the null hypothesis had to be accepted. The consistency of system GMM estimators depends on the validity of the instruments and the absence of second-order serial autocorrelation.

Results

The results of the estimation procedure for the systems GMM estimator are reported in Table 3. Also included in this table are the two-step robust estimator coefficients, the *p* values corresponding to the Sargan test, and the second-order autocorrelation tests.

Table 3. Systems GMM Estimation

Tuberculosis	1	2	3	4
Tuberculosis (Lag 1)	0.97*** (14.92)	0.88*** (11.73)	0.98*** (26.18)	0.94*** (23.62)
Physician	0.02 (0.85)	-0.02 (-0.61)	0.02 (0.31)	0.03 (1.05)
GDP	-0.09 (-0.75)	-0.06 (-0.38)	-0.07 (-0.71)	
GINI	0.001 (0.35)	-0.001 (-0.25)	0.003 (0.70)	0.003 (0.79)
Density		-0.04 (-0.61)		
Education	-0.004** (-2.22)	-0.004* (-1.90)	-0.003* (-1.67)	-0.003* (-1.89)
Health-aid (Lag1)	-0.01 (-0.51)	0.002 (0.14)	0.06 (0.60)	0.20 (1.63)
Health-aid (Lag1)			-0.01 (-0.73)	
Govt.Health Expenditure (Lag 1)	-0.12 (-0.67)	-0.18 (-1.19)	0.01 (0.06)	0.02 (0.18)
Health-aid * Physician (Lag 1)			0.001 (0.15)	
Health-aid * Govt.Health Expenditure (Lag 1)				-0.01* (-1.72)
Constant	1.71 (1.22)	2.38 (1.09)	1.65 (1.29)	-0.99 (-0.46)
Sargan	0.8606	0.8173	0.7169	0.8532
2Order Auto-correlation	0.6879	0.5410	0.9099	0.5810
t statistics are reported in the parenthesis				
*significant at 10%, **significant at 5%, ***significant at 1%				

Across all specifications, the coefficients corresponding to the lagged values of the dependent variable and primary levels of education were found to have a significant impact on the incidence of tuberculosis. It was also found that the lagged values of the dependent variable turned out to be positive and significant, which supports the contagious nature of a communicable disease like tuberculosis. Additional findings suggested that the education variable turned out to be negative and significant in almost all specifications. Thus, given the basic nature of the disease (communicable), basic levels of education can substantially help lower the incidence of tuberculosis. This could be attributed to factors like better awareness of the nature of the disease and better understanding of detection and prevention measures that could help avoid the possible spread of infectious diseases—for example, exposing oneself to sunlight and better cross ventilation helps kill germs. The period dummies used in this study always turned out to be insignificant in all specifications.

Improving nutritional intake and living conditions (hygiene and sanitary conditions) could further improve the results of the health outcomes. Education, then, acts as a prerequisite in laying the foundation for an improved, healthy lifestyle and also helps us perform better during the productive ages which will have a direct impact on our earning capacities. The complementarity between health-aid and government health expenditure seen in our fourth specification indicates the need for greater coordinated efforts between donor countries and recipient governments in order to have a successful impact on health outcomes. Thus, the overall conclusion of the systems GMM confirms that health-aid by itself does not help lower the incidence of tuberculosis. Government efforts may help in improving health outcomes along with health-aid, but not by itself. Primary completion rate, however, was found to help lower the incidence of tuberculosis across all specifications. Finally, donors could channel some of the funds towards developing the human infrastructure and strengthen the health infrastructure.

Summary

Over the last decade there has been a decisive move on the part of donors to finance social services such as health and education, with a substantial amount of aid going towards infectious disease control. This study looked at the impact of health-aid and other covariates like primary completion rate (used as proxy for education) on the incidence of tuberculosis. Also considered were the effects of dynamic panel specifications on an unbalanced panel of 112 countries using annual data from 1990 to 2005. These specifications supported the influence of basic education on lowering the incidence of infectious disease. It was also found that the lagged values of the dependent variable were significant in all of the systems GMM specifications, thereby confirm-ing the contagious nature of the disease. The health-aid variable never seemed to have a significant impact on the incidence of tuberculosis. Though a considerable amount of aid has been directed towards infectious disease control (controlling the spread of communicable diseases), the achievement of these health goals remains questionable among recipient economies. According to MacKellar [18], there is room for improvement in the process of preparing poverty-reduction strategies through the allocation of official development assistance.

The failure of health-aid to have the desired impact could be attributed to various factors. The weak health systems among developing countries can be considered as an important determinant of the ineffectiveness of health-aid. Lack of coordinated efforts on the part of donor countries and the recipient economies in meeting desired goals could also be a factor. Martin et al. [4] emphasize promoting program budgeting as it enables policy makers to make informed decisions about where their limited budgets are best spent. Shiffman [5] indicated that there needs to be a more balanced allocation of resources. Since, by their nature, these diseases are highly contagious, some amount of the health-aid could be diverted towards educating the general population on early detection, causes, treatment/prevention measures, nutritional aspects, hygiene and sanitation, improving living conditions, etc., which could help lower the incidence of tuberculosis to a large extent. This also ties in with the work by Momota et al. [3] which emphasized that one-shot medical aid would no doubt suppress the disease level during the next time period; however, when the pattern of the disease is cyclical, and in spite of a large aid package, one-shot aid is not desirable. Basic levels of education play a key role in lowering the incidence of tuberculosis; hence, both donors and recipient governments could direct a part of the funds towards meeting basic educational standards across the population at large. From a policy perspective, aid could be diverted towards developing the human infrastructure and strengthening the health infrastructure.

A major drawback of this analysis lies in the fact that there is limited data on aid going specifically towards tuberculosis control. More efforts could be undertaken to collect more detailed data on communicable diseases, which could help in a more meaningful analysis of the issue. Since such data issues were encountered in this study, health-aid data were used as the closest approximation. Future work could focus on other infectious diseases like HIV, malaria, etc.

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Biographies

ELSY THOMAS KIZHAKETHALACKAL is an assistant professor in Economics at Bowling Green State University Firelands College. Her research interests include health economics, applied econometrics and development economics. Dr. Kizhakethalackal may be reached at ekizhak@bgsu.edu

DEBASRI MUKHERJEE is an associate professor in Economics at Western Michigan University. Her research interests include theoretical and applied econometrics, with emphasis on panel data and nonparametric modeling. Dr. Mukherjee may be reached at debasri.mukherjee@wmich.edu

A CASE STUDY FOR ANALYZING THE IMPACT OF STAKEHOLDER DECISIONS ON PROJECT DURATION

Richard D. Bruce, Missouri State University; Martin P. Jones, Missouri State University; R. Neal Callahan, Missouri State University

Abstract

Job cameras are utilized by owners, developers, and prime contractors to communicate with stakeholders, increase site security and improve productivity. Most of the literature on job camera technology is focused on developing automatic object recognition at a jobsite to assess progress. Furthermore, there is insufficient literature regarding how owners may utilize job camera data to make planning, design and construction decisions. This case study analyzes the archived job camera photographs associated with the construction of a popular retail store on twenty-five separate sites in an effort to identify a relationship between planning, design and construction decisions on project duration. Researchers used an Analysis of Variance (ANOVA) to determine if there were statistically significant differences in the mean wall duration (dependent variable) based on four shell designs, five different sequence schemes and four start seasons. Results indicated statistically significant differences (.05 alpha) in mean wall duration based on start season (F=4.835, sig.=.010). The mean wall durations of the single decorative block wall system were not significantly lower than the cavity wall system. Similarly, the mean wall durations of projects with block being installed ahead of steel were not significantly different than projects installing steel ahead of block.

Introduction

Job camera technology has been used since the late 1990s by owners to keep the public aware of construction progress, by developers to showcase their talents, and by construction companies to streamline their processes. Its construction management applications have evolved from manual monitoring to automated tracking of construction progress [1]. While the benefits to existing and future projects exist in the literature, including a cost/benefit analysis [2], there is insufficient literature regarding how the data may be used to determine how project stakeholder decisions impact duration of the construction phase.

The authors present here a case study involving a single retail store developer building the same store on multiple locations in the southeastern United States. The planning, design and construction of each store is unique. While these stores share common corporate standard specifications to keep all stores close to the signature brand, each store has a different architect who designs the particular store to fit the location. Some of the choices made by the architect and engineer include such structural elements as the number of steel columns and the exterior wall composition. Once the store is designed by the local architect and the corporate office has approved the design, the construction manager may determine the order of construction. Upon receiving approval from store's corporate office and local city officials, the developer may initiate construction. The building start, therefore, may be in any of the four seasons.

If the developer knew that a relationship existed between the shell design, sequence scheme, when the project is started and duration of previously completed stores, the completion date of the project could be more accurately predicted and the designer could be better informed to make profitable decisions. In addition, the developer would be able to identify the impact of uncontrollable items on the schedule. For instance, if steel is backordered and the sequence scheme has to shift from installing steel before the block wall to after the block wall, the developer will be able to identify the added duration. Similarly, if pre-construction development activities get delayed so that the project is now starting in the winter months as opposed to the summer months, knowing the impact of such a change ahead of construction will assist the developer in mitigating the risk. Analyzing these variables, which are driven by stakeholder decisions and their impact on the project's construction schedule, was the focus of this study.

Data from the case study are reviewed to address three main research questions with regard to the impact stakeholder input has on project duration. These questions are as follows:

1. Is there a significant difference in the mean duration based on shell design?
2. Is there a significant difference in the mean duration based on sequence scheme?
3. Is there a significant difference in the mean duration based on start season?

Literature Review

While the researchers did not find previous research concerning the use of job cameras to study durations of similar projects on multiple sites, they did find several studies utilizing job cameras. This research will be presented here first. A second underlying principle in this study is the basis for such stakeholder decisions such as shell design, sequence schemes and start seasons. A third idea presented in this review is using job cameras to increase communication between parties in order to make better decisions.

Utilizing Job Cameras

Research based on job cameras is broadly divided into two approaches: human interpretation and computer pattern recognition of the images. In regard to human interpretation, job cameras have been used to train construction management students by requiring them to identify and sequence construction site activities uploaded to publically accessible websites [3]. This allowed students with little to no job-site experience to improve their performance on identifying and sequencing project activities.

The majority of the published literature regarding the use of job cameras has focused on developing electronic hardware and computer software to automatically recognize and interpret camera images. Even the research based on human interpretation (manual) can be assisted by hardware and software pre-processing of the image database. Some of the earliest work using this approach linked the images chronologically with the planned schedule [4]. The purpose was to later compare the actual progress of construction with the planned schedule. A real-time adaptation of this comparison between planned and actual progress was accomplished using secured Internet tools like video conferencing and shared whiteboards [5]. This allowed the remote jobsite to be electronically linked to the company's headquarters where analysis and decisions could be made in real-time.

Researchers have used four-dimensional models (4D: space and time) overlaid onto job camera images to enhance the comparison between as-planned and as-built construction progress [1]. A system of color coding was used to mark the as-built progress onto the as-planned model and schedule, thus providing a visual 4D progress report that claims to convey much more information than textual reports could.

Manual analysis of job camera images is time-consuming and tedious. Computer-automated image analysis was developed to identify (track) types of materials and equipment in jobsite images [6]. The purpose of the research was to automatically index images based on their content so that they might be easily retrieved later for a variety of planning and scheduling purposes. The research was continued by developing an interface between those indexed images and typical construction management systems and tools [7]. The concept of tracking construction resources (via jobsite images) was extended to a real-time capability [8]. The research showed it was possible to track not only static construction resources but also moving objects, including humans, and had the potential of improving safety at jobsites. Brilakis and Soibelman [9] streamlined the automated classification of objects within job camera images based on the expected shape of objects by considering the material type, date, time, location, etc. Another approach to enabling automated classification is based upon breaking down a construction project into work packages assigned to specific individuals or subcontractors [10]. The goal was to allow construction projects to be monitored more effectively by comparison of the as-built to the as-planned schedules. Teizer and Vela [11] focused on the automated tracking of personnel by using both stationary and moving cameras. The accuracy of automated object recognition can be enhanced by using 3D CAD information overlaid onto jobsite images [12]. The research reported 75% accuracy in the automated detection of 84 concrete columns within one jobsite.

Bohn & Teizer [2] reviewed state-of-the-art job cameras for project monitoring. The review reported that the benefits of using job cameras greatly outweighed the costs and that interviews of construction managers indicated they planned to continue to use job cameras in the future.

Case Study Stakeholder Decisions

Like most project types, construction projects include stakeholder decisions throughout the project life cycle including planning, design and construction. In regard to this case study, the independent variables were based on decisions from three entities. The developer is responsible for determining the start season in the planning phase; the designer selects the shell design in the design phase; and, the construction manager chooses the sequence scheme in the construction phase. Start season is usually driven by the desire to open the store as soon as possible. Thus, as soon as the developer is able to secure an agreement with the tenant to rent the completed store, the developer hires a construction manager and starts construction of the project. The goal at that point is to deliver the store as soon as possible so the developer/landlord is able to start receiving monthly rent payments from the tenant.

Shell design for the case study involved the selection of either a single-wythe or double-wythe (cavity wall) system. The benefit of a cavity wall system is that the air space between the two walls provides added insulation [13]. An alternative wall system involves a single-wythe wall with insulation placed either within the block or on the interior surface. Another perceived benefit of a cavity wall is that if water were to drive through the exterior brick it would travel down the inside of the cavity and then out installed weep holes, thus never reaching the structure's interior. While there are now single-wythe systems with drainage mechanisms, the old water permeance issues still plague the decision process. Groot and Gunneweg's [14] study of 26 historic mills in the Netherlands supports the selection of cavity walls for water tightness. This 2004 study found that when water permeates through a single-wythe brick wall, it causes damage to the brickwork, rots the interior wood structure, and adversely affects the living conditions within the mills. While construction methods, quality of workmanship, type of mortar and other variables play a part in both studies, Anand and Ramamurthy [15] found similar water issues in a single-wythe interlocking masonry block. Studies such as these fuel designer skepticism, yet single-wythe systems are used. In the present study, for instance, two of the twenty five stores utilized a single-wythe wall. The remaining stores utilized a double-wythe cavity wall system.

Sequencing is determined by the construction manager based on several planning factors including physical constraints. An example of a physical constraint is that a below-grade footing would need to be excavated before it could be reinforced. Thus, reinforcement could not take place before the hole was created. Researchers have created sequencing alternatives based on more specific constraints; for instance, driving activities can be delayed whereas non-driving activities may not be delayed [16]. The researchers in this 2007 study also pointed out that, due to the limitation of the current Critical Path Method (CPM) scheduling technique, construction managers often make changes to single activities rather than switching from one activity sequence scheme to another.

Stakeholder Portals

While the preceding section was written from the standpoint of the case study, each one of the preceding decisions is generally made by the party identified. These decisions are often made without consideration of the other two parties. For instance, the architect is not responsible for project duration, thus would not need to be consulted by the developer to determine start season or sequence scheme. The job camera website address, however, could be shared with all stakeholders to increase communication.

This is not a new concept. Web-based collaboration tools have been used for years and include job camera data, schedules, payment applications, requests for information and other communication tools [17]. Where these tools fall short, however, is in their treatment of the other stakeholders in the decision process. Collaboration tools are generally used to exchange files during a particular project rather than analyze past projects. By following the analysis techniques utilized in this study, stakeholders could start to see the possible connections between their past decisions to make better future decisions.

Methodology

Database

The primary researcher (first author) in this study has been utilizing job camera photographs to augment such construction education courses as plan reading, estimating, scheduling, and project control, since 2004. In 2006, he learned of a publicly available website provided by a developer specializing in constructing a popular retail store chain in the southeastern United States. The instructor contacted the provider of the site and was granted permission to use the information in his courses, research and papers. The website includes archived digital photographs from the construction of 38 retail stores. The interface allows the user to select a project and then click on a visual calendar of the project. Upon selecting a day, the user is able to see high-definition digital photographs of the project being constructed. The camera, which is located on an adjacent tower or building, takes a photograph every ten to fifteen minutes and uploads it to a server.

Samples and Data Collection

The researchers accessed the 38 stores on the job camera server. Of the 38 stores available on the server, four were removed from this study because they included various architectural elements that were drastically different from the standard model. Another nine stores were removed because they had one or more weeks blacked out making it impossible to identify a start date. This left 25 stores in the sample.

The researchers began listing the projects in Excel with the project number, location, model, sequence, concrete masonry unit (CMU) start, Brick End, Calendar Days and Start Season. The project number and location were assigned by the developer and had no meaning other than referencing the store on the job camera interface. Tables 1-4 provide the three separate shell design models, five distinct sequence schemes, duration calculations and the four start seasons.

Table 1. Shell Designs

Shell	Shape	Wall composition	Exterior Columns
1	Box with angled entrance	CMU/Brick cavity wall	thirteen
2	Box without angled entrance	Decorative block	six
3	Box without angled entrance	CMU/Brick cavity wall	thirteen
4	Box without angled entrance	Decorative block	three

Table 2. Sequence Schemes

No.	Order of Construction
1	Footing, starter block, exterior columns, slab, wall, interior columns, joists, roof
2	Footing, starter block, slab, wall/exterior columns, interior columns, joists, roof
3	Footing, wall, exterior/interior columns, slab, joists, roof
4	Footing, exterior/interior columns, wall/slab, joists, roof
5	Footing, wall, exterior/interior columns, joists, slab, roof

Table 3. Wall Durations

Row	Column F	Column G	Column H
Row 1	Block Start	Brick End	Calendar Days
Row 2	11/11/2008	1/9/2009	=(G2-F2)+1

Table 4. Start Seasons

No.	Month CMU Started	Start Season
1	December 21-March 19	Winter
2	March 20-June 19	Spring
3	June 20-September 21	Summer
4	September 22-December 20	Fall

Research Questions and Variables

The primary research question asked if there were significant differences between the mean wall durations based on 1) shell design, 2) sequence scheme or 3) start season. The wall duration represents the dependent scale variable for each of the research questions. Wall duration was chosen because it was the only duration that could be consistently identified on each of the projects. Several of the projects started their photographs with the footings already in place making it impossible to identify a true project start date. The independent variable changes for each research question. In the first research question, the independent variable is the shell design. As shown previously, there were four separate and distinct shell design models based on their shape and structural elements. In the second research question, the independent variable is the sequence scheme. Here, there are five separate schemes. In the third research question, the independent variable is start season.

Since a one-way analysis of variance (ANOVA) was used to compare the means of two or more independent groups [18], and all three research questions had two or more independent groups, the statistical analysis tool was utilized on all three research questions. A significance level of 0.05 was utilized.

Results

Table 5 shows the mean durations for each of the shell designs. There was no statistically significant difference between the mean duration based on shell design (F=.364, sig.=.780). Because models two through four had just one case each, two out of three of the ANOVA assumptions could not be met: normality and homogeneity of variance.

Table 5. Means Comparison of Wall Duration by Shell Design

Shell Design	Mean Duration (calendar days)	N
1	75.77	22
2	89.00	1
3	87.0	1
4	60.00	1

Table 6 shows the mean durations for each of the sequence schemes. There was no statistically significant difference between the mean duration based on sequence scheme (F=1.066, sig.=.399). Here, again, sequence scheme one included just one store. So the same assumptions violations noted above apply.

Table 6. Means Comparison of Wall Duration by Sequence Scheme

Sequence Scheme	Mean Duration (calendar days)	N
1	68	1
2	68	3
3	69.78	9
4	79.33	9
5	96.33	3

Table 7 shows the mean durations and Tukey's post-hoc significant differences test results for each of the start seasons. There was a statistically significant difference between the mean duration based on start season (F=4.835, Sig.=.010). Post-hoc test results indicated the significant difference was between projects starting in the winter months–December 21 through March 19—and those starting in the spring—from March 20 through June 19—as well as between those starting in the winter months and those starting in the summer months—from June 20 through September 21.

Table 7. Means Comparison and Significant Differences for Wall Durations by Start Season

No.	Mean Duration (calendar days)	N	Sig. Differences	Sig.
1	96.00	6	1-2	.039
2	68.25	8		
3	58.80	5	1-3	.011
4	81.17	6		

Conclusions and Recommendations

The focus of this study was to analyze the impact of stakeholder decisions with regard to building shell design, sequence scheme, and start season on project duration for the case study. Researchers analyzed construction progress photographs, acquired with the developer's job camera, of one chain store being built on several locations. The mean duration of each store was compared based on each of the three variables.

While the statistically significant results of the third research question, which indicated that weather adversely affected the duration of an outside activity, was predictable, the other two results were not. Constructing two walls, as in a cavity wall system, should take longer to construct than constructing a single wall. This was found not to be the case. Similarly, installing a building shell with thirteen exterior steel columns should take longer than a shell utilizing only six columns. The results of research question one, however, indicated that such selection had no significant impact on the duration of the project. In regard to sequencing, installing materials out of sequence should take longer than installing per plan. However, results of research question two indicated that sequence scheme did not have a significant impact on the duration of the wall.

Given the results of this research, it would appear that the architect does not need to consider shell design to accelerate a schedule. Furthermore, a cavity wall system is just as fast as a single-wythe wall system; thus, its selection need not be considered in regard to completion time. A future study of this data could analyze the impact of start season and shell design on project duration. In other words, if the project must start in the winter months, is it better to use a single-wythe design or a cavity wall design? Similarly, it appears that the construction manager's decision concerning sequence scheme does not impact the project's duration. If steel is back-ordered, for instance, masonry block may be installed prior to steel without the backlash of a delayed project. Future researchers might consider adding more projects to this sample to determine if average durations using the single decorative block decline. As indicated in Table 5, 23 out of 25 (92%) of the projects utilized the cavity wall design. If one were to add 21 additional projects utilizing the single-wythe design, perhaps the means would be significantly lower.

In addition to assisting future researchers address similar questions, this research may assist project stakeholders in communication. Other chain-store developers with multiple site partners could analyze their projects in a similar manner and share the results with their designers, construction managers and other partners. Future planning meetings may utilize the data to make better decisions before the start of the expensive design and construction phases.

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Biographies

RICHARD D. BRUCE received a Ph.D. in Technology Management from Indiana State University in 2008. He is an assistant professor at Missouri State University where he teaches construction estimating, scheduling, and project management. Dr. Bruce may be reached at RichardBruce@MissouriState.edu

MARTIN P. JONES received a Ph.D. in Materials Science and Engineering from the Johns Hopkins University in 1987. He is an assistant professor at Missouri State University where he teaches engineering economy and construction safety. Dr. Jones may be reached at MartinJones@MissouriState.edu

R. NEAL CALLAHAN received a Ph.D. in Engineering Management from the Missouri University of Science and Technology in 1999. He is an associate professor at Missouri State University where he teaches project management and is Director of the Project Management Master's program. Dr. Callahan may be reached at NealCallahan@MissouriState.edu

Employing Virtualization for Information Technology Education

Timur Z. Mirzoev, Georgia Southern University

Abstract

This manuscript presents teaching and curriculum design for Information Technology classes. Today, students demand hands-on activities for the newest technologies. It is feasible to satisfy this appetite for exciting education by employing server virtualization technologies to teach advanced concepts with extensive hands-on assignments. Through utilization of virtualized servers, students are able to deploy, secure and manage virtual machines and networks in a contained environment. Various techniques, assessment tools and experiences will be analyzed and presented by this manuscript. Previous teaching cases for Information Systems or Information Technology classes are done using non-commercial products, such as free VMware Server or VMware Player. Such products have very limited functionality in terms of networking, storage and resource management. Several advanced datacenter functions, such as Distributed Power Management (DPM), vMotion and others, are not available in desktop versions of that type of virtualization software. This manuscript introduces the utilization of commercial software, such as vSphere 4.1, with full datacenter functionality and operations for teaching Information Technology classes of various levels.

Introduction

Virtualization is utilized by various areas of Information Technology (IT) fields and provides the basis for technologies, such as cloud computing, green computing, server consolidation, disaster recovery and many others [1]. Virtualization has been used in various areas of IT in commercial/business settings [2]. IT infrastructure is rapidly adapting to new technologies based on virtualization. While there is still confusion about cloud computing technology [3], it is one of the innovative IT concepts that is based on server and storage virtualization [4].

Higher education is responding to the advantages of virtualization technologies as well [4-7]. Many schools have approved teaching virtualization courses to students and are now faced with the challenge of providing hardware/software support for even freshmen-level classes [7]. Lungsford's approach, as well as many other authors', to teaching IS or IT classes using virtualization is done using non-commercial products, such as free VMware Server or VMware Player. Such products have very limited functionality in terms of networking, storage and resource management and are not used in commercial datacenters. This manuscript introduces the utilization of commercial software, such as vSphere 4.1, which is also a foundation for cloud computing applications.

When utilizing lab computers for deployment of several virtual machines, there is always a concern for protection of the operating systems of lab computers—students may damage software, which results in the reinstallation of operating systems and software packages. A typical solution to "secure" a lab environment is to lock computers so students are unable to change vital setting on laboratory machines [7]. However, classes of various levels present a dilemma to the support personnel of universities; how is it possible to combine administrative rights for senior students and at the same time "lock" computers for freshmen students? Interestingly enough, commercial applications of hardware and software solutions for virtualized environments provide the resolution to the stated question. Ghostine argues that virtualization of desktops is the answer to the challenges presented to IT support in higher education [6].

Virtualization is based on a time-sharing of hardware concept developed by MIT in 1961 [8]. Virtualization brings server utilization without significant investment, which in its turn boosts return on investment significantly [9]. Interestingly, cloud computing, the basis for virtualization, is also not a novel idea either [10]. Adopting virtualization technologies to teach classes does present challenges but most importantly, opens a wide range of opportunities for faculty to teach newest technologies independent from university IT support. Students' productivity [6] and their interest for Information Technology education increases with the usage of virtualization since full control to fully functional virtual machines (VMs) can be granted without impacting laboratory settings [2]. Besides, via employment of virtualization with server clustering, power consumption, load balancing of servers and the operating cost using x86-based servers is significantly decreased [4], [6].

This manuscript analyzes commercial hardware and software platforms for delivering classes to Information Technology students. Several techniques and approaches including load balancing and power consumption of servers will be discussed.

Server Virtualization

There are common misinterpretations of virtualization technologies. It is important to understand that *virtualization is not emulation or simulation*. In simulation systems, there are mostly software processes that simulate reality in order to attempt to investigate a real process [11]. Emulation, on the other hand, is a process where some original software and hardware environment is being imitated and presented in a different system [12]. Virtualization allows sharing of hardware resources among various entities, and requests are sent and processed through a virtualization layer to underlying hardware. For example, VMware virtualization systems are mostly based on dynamic resource management using tickets. "Resource rights are encapsulated by first-class objects called tickets" [13]. "VMware invented virtualization for the x86 platform in the 1990s to address underutilization and other issues, overcoming many challenges in the process" [14].

Virtualization is now an integral part of commercial IT environments [7], and it is being increasingly utilized with introductions of new technologies, such as vSphere 4.1 and EMC's VPLEX storage systems. There are two main types of virtualization approaches: 1) host-based (Figure 1) and 2) bare-metal hypervisors (Figure 2).

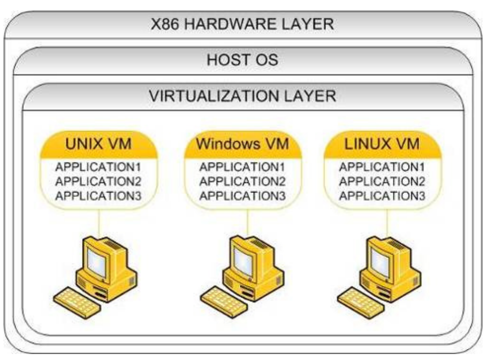

Figure 1 .Hosted approach in virtualization [15]

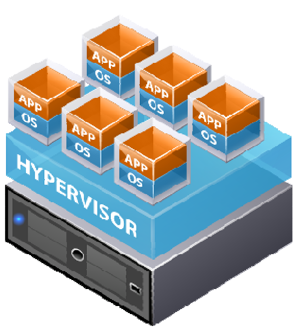

Figure 2. Hypervisor approach [Source: VMware vSphere 4.1: Install, Configure, Manage – Revision A]

A host-based approach installs a virtualized layer on top of the existing operating system, Linux or Windows. In the bare-metal approach, *the virtualization layer is the operating system*, which eliminates the OS layer that exists in the host-based approach. Bare-metal hypervisors are the most commonly used in commercial datacenters, whereas host-based virtualization is mostly used in small or educational environments.

Despite the approach to virtualization, many benefits may be enjoyed with either host-based or hypervisor (bare-metal) virtualization [4], [7]. Previously, only commercial systems heavily utilized virtualization to save energy and capital costs via consolidation of physical servers. Today, education facilities use commercial systems mainly for the following reasons [6]: 1) to provide cutting-edge technology for teaching, 2) to create secure, independent classroom environments, and 3) to increase utilization of servers for teaching several classes on the same hardware and software platforms. Additionally, this manuscript describes an innovative approach in energy savings via deployment of Distributed Power Management. Today, the costs of powering and cooling are very significant factors in large-scale datacenters [16].

Hypervisors

Hypervisors (hosts) are essential hardware and software platforms that create a foundation for virtual infrastructure. Each hypervisor is capable of running multiple various operating systems independent from each other. This approach allows teachers to run multiple unsecure operating systems that do not affect university networks or storage systems. Multiple hypervisors may be managed as clusters by special management software, which eliminates the need for cumbersome administration of each hypervisor separately. There are several clusters of servers that different classes utilize; therefore, the IT1130 cluster would be a cluster of servers for the Introduction to Information Technology course IT1130 and so on. All server clusters are located under 2210 Datacenter, which is the laboratory in the College of Information Technology. For example, Figure 3 depicts an IT1130 cluster of hypervisors that is managed by "VCMAIN08" (hypervisor management platform) vCenter in 2210 datacenter.

Virtual Machines

A virtual machine (VM) is a set of files that is located on a storage system accessible to hypervisors. Each VM has its folder with a file for memory, BIOS, configuration, virtual disk and others. Figure 4 presents a set of files for a Windows 2003 VM. Virtual machines are simply operating systems that are managed by hypervisors.

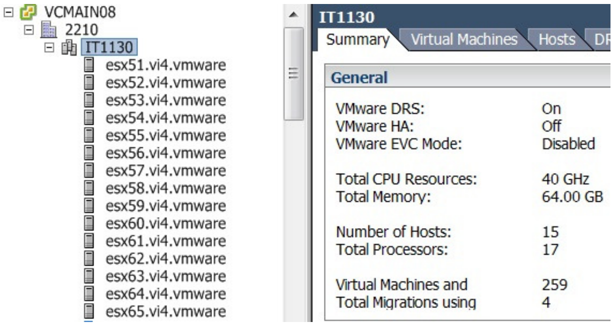

Figure 3. IT1130 Cluster with 15 ESX Hypervisors

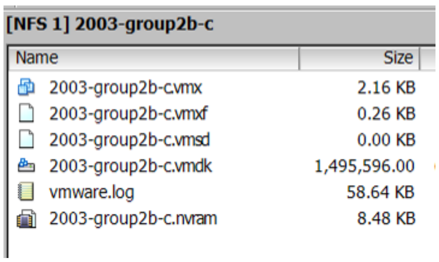

Figure 4. Files of a Windows 2003 Virtual Computer

Virtual computers have virtual hardware, BIOS and all other aspects of physical computers. Frequently, the operating system (OS) is not aware that it is running as a virtual machine; it really depends on if the operating system is a virtualization-aware OS.

Network Storage

Storage is an essential component for virtualized environments [5]. It provides a common storage for VMs, ISOs and other types of files. Depending on the I/O load of storage, commercial-grade systems use different multipathing policies with load balancing on RAID configurations. A number of concurrent server connections can significantly impact the performance of storage systems—specifically, if many students are attempting to deploy multiple VMs on the same storage system simultaneously. Most commonly used for storage systems are Storage Area Network (SAN), Network Attached Storage (NAS) and IP SAN. This manuscript describes several approaches to load balancing of student laboratory operations.

Teaching Design

The reason virtualization is heavily employed in the learning process of IT students is due to a high level of utilization of hardware of physical servers. In physical, non-virtualized environments, utilization of servers is around 8 – 12%. In virtualized environments, the utilization rates go up to 100%. (Sixty-five percent is the recommended rate.) In education, virtualization presents a faculty member with a powerful environment where multiple technologies and concepts can be learned on the same platform. For example, any type of operating system can be installed in a vSphere 4.1 environment, and multiple networks can be set up for different groups of students. Students in the introductory course learn how to deploy DHCP, DNS, Linux storage systems and many other essential topics. Commercial-grade systems like ESXi servers in a vSphere 4.1 environment allow for a full-scale deployment of IT systems. Free or small environment virtualization products, such as VMware Player, VMware Workstation and others, offer limited functionality in terms of networking, storage and many other options. Figure 5 presents a variety of networks that are used by different students based on their permissions.

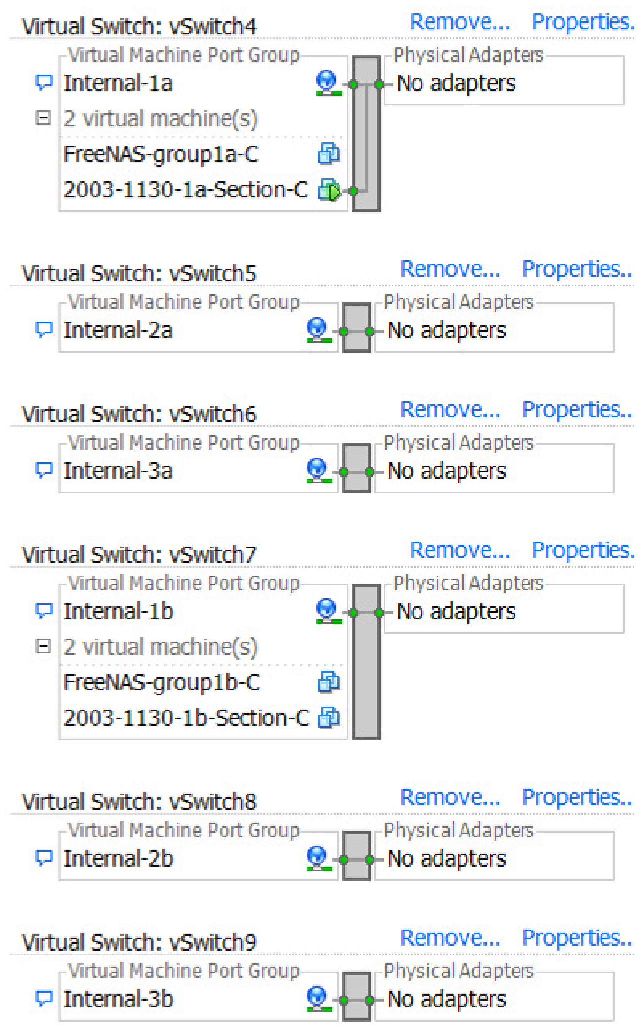

Figure 5. Multiple Networks for Student of "a" or "b" Groups

For example, from Figure 5, “Internal 1a, 2a and 3a” networks are designed for students of “a” groups only. Virtual machines “FreeNAS-group1a-C” and “2003-1130-1a-Section-C” (“C” indicates the section of the class) utilize network “Internal 1a.” To the students of “b” groups, these networks are not visible. Simply put, groups “a” or “b” of students can *concurrently* deploy DHCP and DNS virtual servers *on the same physical server*, and there are no conflicts or collisions. Such a learning environment for networking is not possible with non-commercial systems; there are no tools, such as Active Directory permissions and privileges (which are used in the presented environment), that can be assigned in free or small environment virtualization products, such as VMware Player, VMware Workstation and other systems.

There are three IT courses that utilize virtualization technologies described by this manuscript: 1) Introduction to Information Technology (freshmen-level), 2) Datacenter Management (senior-level), and 3) Information Storage and Management (senior/graduate-level). The first two courses are described in detail; the third course has originated from an EMC Academic Alliance agreement and is an extensive course on network storage technologies.

Each class is challenged with a number of hands-on laboratory exercises. For example, Introduction to IT has 10 labs, Datacenter Management has 27 labs, and Information Storage and Management has eight labs. The number of hands-on activities has been increasing progressively due to the overwhelming interest of the students who take these courses. Today, IT education is evolving into a form that better accommodates industry needs; furthermore, industries are now eager to sign partnership agreements with educational institutions to better prepare the future workforce [17].

Students’ knowledge is assessed through conventional tests and quizzes. Additionally, students submit their labs in the format of an MS Word file with screenshots of accomplished tasks. This approach encourages academic integrity in the classroom and creates a better assessment environment for a faculty member. Windows CIFS network share is used for submissions of the assignments and lab instructions. This network share is located on one of the Openfiler storage servers.

Introduction to Information Technology Course

There are several labs in the IT1130 course. In fact, the major portion of a student’s grade comes from the completion of laboratory exercises, not from tests or quizzes. Each lab has detailed instructions, and there are 10 labs during each semester. For most of the labs, students are required to submit screenshots of completed labs on a designated folder on the shared drive (CIFS share). Students from all classes were successful in sharing one shared drive. The shared drive has helped the faculty member with posting documents, instructions, manuals and specific files for the teaching assistant. Most importantly, the described network share presented the faculty member with the ability to access all of the homework submitted via a centralized location.

At the end of the class, IT1130 students have to decide whether they want to take a hands-on final examination or a regular test.

Datacenter Management Course

The IT4234 course is a very popular course among IT students. IT4234 is a part of the Networking and Datacenter Administration specialization for IT majors. This class is a three-hour, once-a-week course that presents students with advanced virtualization concepts, and the information presented in this course is the foundation for popular cloud computing technologies. The IT4234 course is 60% hands-on. Unlike the IT1130 courses, there are no screenshots of completed lab assignments required in the IT4234 course. However, the completion of each lab was verified by the instructor and/or teaching assistant. The teaching assistant had taken the same IT4234 course previously and was personally present during each class session. After students complete the course, there is an option to take a certification exam by VMware and become a certified professional. So far, students have positively and enthusiastically commented on the course structure and many became interested in the virtualization subject. If fact, there are several success stories where student received employment offers with Fortune 100 companies.

Laboratory Infrastructure and Setup

In order to utilize virtualization technology for teaching, it is imperative to have several hardware/software systems in place. The main components of the setup for teaching are: 1) x86 servers, 2) network storage, 3) networking equipment and 4) software and licensing. In order to set up an infrastructure that is independent from the university IT infrastructure and support, a faculty member needs to possess an in-depth knowledge of these systems for correct deployment. Once the systems are in place, ongoing maintenance is required. Maintenance could be achieved without extensive involvement of a faculty member; a teaching assistant with certain rights and privileges to the systems may easily maintain the laboratory environment.

Physical Servers

There are a total of 31x86 servers deployed for three courses:

- Fifteen Dell R610 servers are used for Datacenter Management and Information Storage and Management courses.
- Both courses are senior-level with two students receiving access to one server that has 8 GB of RAM, two four-core 2.26 GHz Intel Xeon processors and eight network interface cards (NICs).
- Fifteen IBM x335 servers are used for the Introduction to Information Technology freshmen course, which typically has several sections. At least 60 students utilize a total of 40 GHz of CPU and 64 GB of RAM resources. Each IBM server has at least 4 GB of RAM, one dual-core 2.4 GHz Intel Xeon processor and four network cards.
- One Dell R610 server is used for support and administration of the entire laboratory environment. It has 24 GB of RAM, two four-core 2.26 GHz Intel Xeon processors and eight NICs.

Shared Storage and Networking

Storage is, perhaps, the most challenging component of the laboratory setup. The reasons are due to the following facts: 1) commercial storage systems are always expensive, and 2) open-source operating systems are a challenge to correctly set up and administer. However, with the use of virtualization technologies, it becomes somewhat easier to administer and deploy different storage environments. The following is a list of storage devices used for the laboratory environment:

- Three Openfiler servers are used for Network File Systems (NFS, used for UNIX/Linux shares). Each server has a dual-core AMD Athlon 7750 processor, 4 GB of RAM and three NICs. One NIC is used for management of the server; the other two are used for load balancing in link aggregation mode. Each server has a 500 GB hard disk for the Openfiler operating system and two 500 GB hard disks in software RAID 0 mode.

- One Openfiler server is used for a Common Interface File System (CIFS, used for Windows network shares), and it has the same configurations of CPU, RAM and network as the other Openfiler servers. There are four 500 GB drives that are set up in a software RAID 0 configuration, for a total of 2 TB of space used for ISO images, support files and, most importantly, assignment submissions from students.

Resource Utilization

In the laboratory setup, there are several ways that available hardware is used. Thirty-one Dell servers are used for the IT4234 Datacenter Management course, and they are always powered on. Students of the IT4234 course rely on server availability twenty-four hours a day and seven days a week every week since the class requires students to finish 27 laboratory exercises during 16 weeks. The Dell iSCSI server is always on and provides storage for the Dell servers with installed ESX 4.1 operating systems.

Figures 6 and 7 present similar diagrams for both cabinets—IT1130 and IT4234. However, these server cabinets are quite different from each other. The IT4234 cabinet is a powerful pool of resources in comparison to the IT1130 cabinet. The memory of each Dell server is 8 GB, and the instructor's server has 24 GB of RAM. Combined, the total RAM available for the IT4234 course is 264 GB with 560 GHz of CPU cycles. All of these physical resources are not put into a cluster due to the need for each group of students to fully administer each individual server. Students of the IT4234 course have full administration rights to their servers. Currently, there are four servers (including the instructor's server) that are used to support the infrastructure of the IT4234 course.

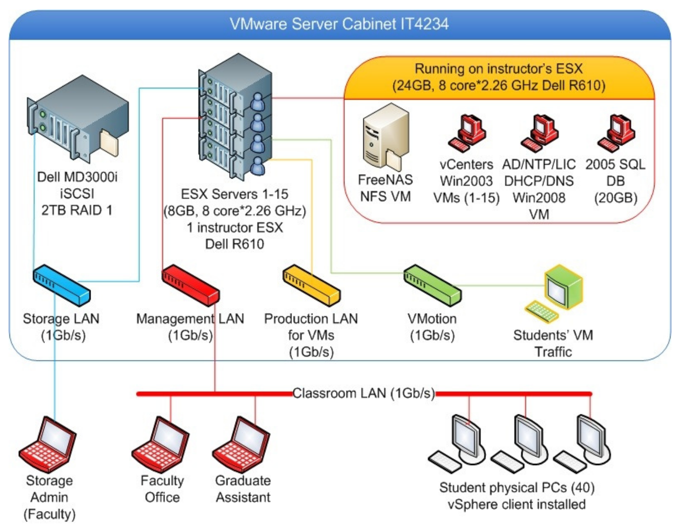

Figure 6. Infrastructure Setup for the IT4234 Course

The number of support servers fluctuates since it depends on the number of students that sign up for the class. There are two students assigned to each physical server, so the practical limit of the class size is 15—two students per server, with 30 servers available.

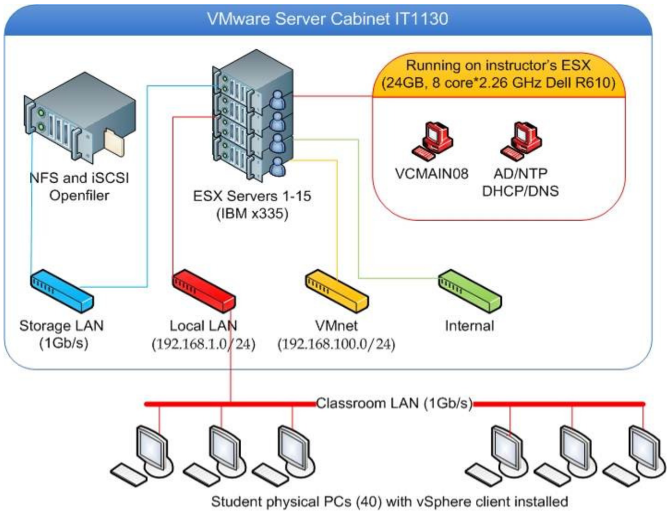

Figure 7. Infrastructure Setup for the IT1130 Course

The IT1130 cabinet is extensively used by about 60 students each semester. The resources of this cabinet are utilized in a different way from the utilization of the IT4234 cabinet. IT1130 students have restricted access to the *cluster* (IT1130 cabinet) of resources, not the individual servers. The total resources available in the IT1130 cabinet are 40 GHz of CPU cycles and 64 GB of RAM. Given the fact that the total number of virtual machines is close to 300, the IT1130 cabinet reaches the peaks of its utilization almost every class time.

As mentioned earlier, 15 IBM servers are put into one cluster of servers, which enables load balancing of VMs across the cluster. For example, if a VM machine is seeking resources to utilize, the vCenter will move it as necessary to a different server if no resources are left on the source host. Each student is responsible for each laboratory exercise. Each student has an individual login and credentials, but each section has the same logins. For example, Section C students have logins “group1a, group1b.” Section F uses the same logins but creates different VMs. Additionally, the cluster of servers can be put into standby mode to save on power consumption and the cooling of servers.

Distributed Power Management

IT4234 servers are always powered on and available to students since there is a number of challenging laboratory exercises in the Datacenter Management course. On the other hand, due to the fact that there are 15 physical servers that provide hardware resources to several sections of the IT1130 course, power consumption and cooling of these servers was an important consideration for implementing a green IT solution [18]. Fifteen IBM servers have been set up with power management schema that allowed putting servers in standby mode while servers are not in use. A server schedule was created in order to accommodate students’ needs for assignment completions. The schedule was shared with the students of the IT1130 course (both sections C and F). Students are able to come to the laboratory and work on individual assignments. A number of scheduled tasks were set up in order to accommodate server availability. Figure 8 presents one of the scheduled tasks. It shows that the server cluster powers on servers on Monday, Wednesday, Friday, Saturday and Sunday at 11am.

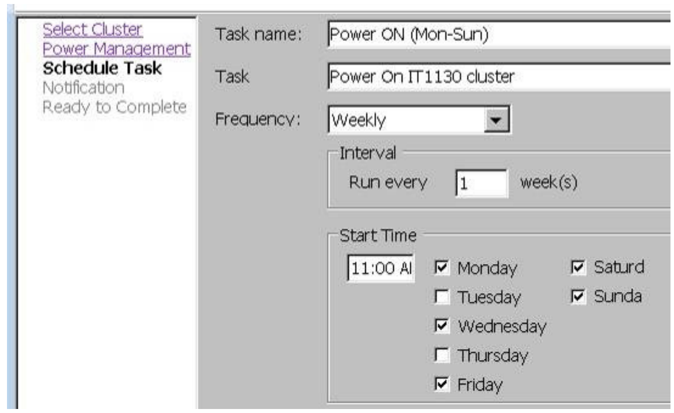

Figure 8. Scheduled Task to Power a Server Cluster

A separate task to power the cluster needs to be additionally scheduled. With such implementation of Distributed Power Management (DPM), the laboratory environment becomes power-efficient, and electricity is not wasted. Additionally, when other classes take place, the noise level of servers is significantly reduced once the servers are placed into standby mode. Table 1 provides a sample server schedule for IT1130 servers only; IT4234 servers are always powered on.

Table 1. Server Distributed Power Management Schedule

Time	MWF
8:00 – 8:50a.m.	
9:30 a.m. – 12:15 p.m.	IT 4234A [M]
10:00 – 10:50 a.m.	IT 3234A [WF]
11:00 – 11:55 a.m.	SERVERS ON [MW]
12:00 – 12:50 p.m.	SERVERS ON [MW]
1:00 – 1:50 p.m.	SERVERS ON [MW]
2:00 – 3:15 p.m.	IT 1130C [MW]
3:30 – 4:45 p.m.	IT 1130F [MW]
5:00 – 6:15 p.m.	SERVERS ON [MW]

Figure 9 depicts servers in standby mode. Two servers are running in case any virtual machines need to power on; additionally, if more hardware resources are required, the cluster-wide settings will wake the servers to provision-requested hardware. With DPM, the server power consumption was dramatically reduced. Such a solution promotes green computing and virtualization technologies, and students realize the benefits of these technologies. Distributed Power Management is mostly implemented in commercial datacenters, and now it is being used in information technology education [18].

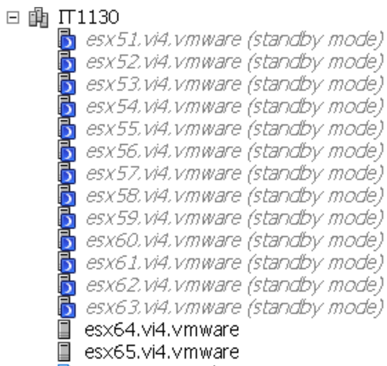

Figure 9. IT1130 Servers in Standby Mode

Green computing is a popular terms in today's terminology. By the Distributed Power Management technology presented here, green computing is used for teaching virtualization, storage and other topics in various classes. However, DPM is another feature that is not available in non-commercial virtualization platforms, such as VMware Workstation or VMware Player, that have been reviewed by many educators, such as Dale Lungsford and others [7].

Challenges and Recommendations

The setup and design of IT courses presented by this manuscript create an opportunity for a faculty member to deliver exciting curriculum with a significant learning experience for students. Students that take these courses receive an opportunity to learn many aspects of IT systems to the full extent. The described virtualization approach does not impact university IT infrastructure in terms of the conventional approach (i.e., without the usage of virtualization).

Based on experience with the one approach to virtualization by one company, students are able to apply their skills in any virtualized environment despite vendor differences. Once the concept of virtualization is understood by students, they do not have any problems adapting to any vendor-specific environments.

One of the biggest challenges in implementing the teaching and the infrastructure setup is the burden on the faculty member's time and his or her involvement with the deployed systems. Once the systems are operational, there should be a teaching assistant with good virtualization and storage skills to take over. Faculty should be prepared to constantly monitor and administer running systems since updates to servers, VMs and configurations may change or require an upgrade.

Based on the experiences resulting from teaching IT courses using virtualization, the following are some recommendations for teaching:

a) Appropriate commercial training on virtualization and network storage is highly recommended for a faculty that is going to deliver courses using virtualized environments. Most of the commercial training can be achieved free of charge with proper agreements with companies that have educational programs. The training requirements are available at the participating industries' websites, and the specific training courses' name are omitted here in order to exclude advertisement in this research publication.

b) A teaching assistant, specifically a student who has taken the Datacenter Management course or who is certified in virtualization technologies, with technical skills is a very important person. Faculty will struggle to deliver the course without any help. The university's IT helpdesk is not expected to participate in preparation for classes, so most of the time a faculty member will rely on the teaching assistant.

c) The teaching assistant may be paid as a student worker for IT services. Most of the students that support virtual infrastructure receive attractive job offers right after graduation.

In addition to teaching recommendations, here are some hardware and software recommendations:

a) Usage of commercial-grade systems is the most desirable setup in laboratories. Most of the described systems are highly available, clustered resources with distributed power management and deployment of resources on demand.

b) Many IT companies are willing to donate equipment to educational IT programs that have a distinct plan for teaching. A big portion of the utilized equipment for the lab environment described by this manuscript was donated free of charge to our IT program.

c) Internal funding, such as technology fee requests and grants, may help to acquire hardware resources. One of the approaches to creating a virtual infrastructure is to deploy so-called Network Development Group (NDG) servers. NDG creates laboratory environments for Cisco and VMware Academies and proved to be a valuable solution in education.

d) Accessibility to the laboratory setup was accomplished through a secured VPN connection to the faculty's office computer, which has two network cards: one for the university network and one for laboratory access. This gave the author access to the lab environment from any PC with Internet access.

Here are some specific recommendations for storage:

a) Openfiler open-source operating systems performed very well with multiple concurrent connections. Originally, FreeNAS open-source system served as NFS share, but Openfiler demonstrated to be a more stable and reliable choice. Openfiler can be deployed on any regular PC and serves as network storage; so the cost of storage can be minimal.

b) NFS performed better than iSCSI for concurrent ESX connections on Openfiler systems.

c) Commercial-grade NICs in link-aggregation (802.3ad) mode is a highly recommended configuration (about $30 each). For example, the use of Intel Gigabit GT network cards on storage servers was found to be very effective and stable with Openfiler systems.

d) Enterprise-level hard disks with at least 32 MB of onboard cache memory are recommended. Desktop/home-grade hard disks are not recommended. Seagate Constellation ES ST31000524NS 1 TB drives performed very dependably under multiple I/O simultaneous requests from all the servers.

e) The described storage systems worked great with software-based Linux RAID configuration (default software RAID configuration in Openfiler), so there was no need to purchase expensive RAID controllers.

f) It is recommended to distribute the load of server connections to storage across multiple storage servers. The way storage servers distributed the load of I/O processing was in the following fashion; there were three NFS Openfiler systems. Each one served five groups of students, and one Openfiler server served as a CIFS share for the submission of all homework and for information sharing.

g) The cost of Dell servers was about $3,000 – $4,000 for each student server and $5,000 – $6,000 for the instructor server. A Dell iSCSI server was purchased for about $13,000; however, all of these prices have changed dramatically, and many open-source systems today can replace expensive hardware.

Virtualization has greatly enhanced the learning experience for our IT students. Additionally, our university received international recognition for teaching advanced curriculum.

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Biography

TIMUR MIRZOEV is a professor of Information Technology at Georgia Southern University, College of Information Technology. Dr. Mirzoev heads the International VMware IT Academy Center and the EMC Academic Alliance programs at Georgia Southern University. Some of Timur's research interests include server and storage virtualization, cloud computing, storage networks and disaster recovery. Currently, Dr. Mirzoev holds the following certifications: VMware-certified instructor (VCI), VMware-Certified Professional (VCP) 4, EMC- Proven Professional, LefthandNetworks (HP), SAN/iQ and A+. Dr. Mirzoev may be reached at tmirzoev@georgiasouthern.edu

THE IMPACT OF INDUSTRIAL ESPIONAGE AND THE VALUE OF PROTECTING A COMPANY'S INTELLECTUAL PROPERTY RIGHTS

Brian Cazzell, Realize, Inc.; Jeffrey M. Ulmer, University of Central Missouri

Abstract

Industrial espionage is a viable threat that companies need to safeguard themselves against. The objectives of this study were to examine the nature of this crime and the methods used to commit the crime, to provide examples of how this crime impacts the U.S., to describe the laws that protect intellectual property, to describe the steps a company should take to decrease its vulnerability, and to provide engineering technology students with a primer on industrial espionage. Finally, the study concluded with the development of a reference list for managers and engineering technology students who will someday become managers regarding steps to reduce their own risk.

Introduction

Does a mother's secret recipe book have value? What about secret recipes that have been handed down through multiple generations? Perhaps such a secret recipe contains "Grandma's chocolate chip cookie recipe" or "Aunt Edna's homemade lasagna" recipe; special recipes that have been perfected over the years with love and care. Suppose someone bakes those items for a luncheon at work or a social gathering for friends and after the food is tasted by others, someone asks for the recipe. Hesitantly one might say, "Sorry, it's a secret family recipe." Much to the disappointment of others, the individual has basically preserved what is rightfully theirs. It may seem trivial but, in essence, that individual has just protected their intellectual property rights.

On a larger scale, what if the secret recipe was something that could be used as value? For example, a person decides to bake and sell Grandma's cookies as described earlier for a profit. Now everyone is clamoring to get their hands on those delicious goods. If the secret recipe was ever leaked to the public, profits, and the individual's future as a cookie baker, would soon be over. This scenario has been depicted many times in national television ads for Bush's Baked Beans©. In the commercial series, the Bush's loveable family dog, Duke, constantly threatens to publicize the family's secret recipe for making the beans. It may seem comical to the viewer but, in reality, the result could be devastating for the Bush's baked bean business. Whether the information is leaked or stolen, it is still classified as industrial espionage, which is a very serious crime that is punishable by law.

According to the Office of the National Counterintelligence Executive, industrial espionage is defined as, "The theft of sensitive information that has independent economic value and that the owner has taken reasonable measures to protect, regardless of the perpetrator's country of origin or whether a foreign government agent can be linked to the theft" [1].

As a business owner or manager, or student who will someday be a manager, the following should be known:

- What type of information these criminals are willing to steal.
- What avenues they will take to steal it.
- The impact of industrial espionage on businesses.
- How to protect a company from becoming a victim of this crime.
- What laws protect a business from this crime and the challenges courts face when applying them.

Trade Secrets Defined

In order to effectively combat this crime, one must first understand what type of information criminals are searching for, i.e., trade secrets. The definition of a trade secret according to the U.S. Department of Labor's Occupational Safety and Health Administration website is information that "may consist of any formula, pattern, device or compilation of information which is used in one's business, and which gives him an opportunity to obtain an advantage over competitors who do not know or use it" [2]. In addition, it is a trade secret if it is used in a repetitive process and directly related to a formula such as a list and amount of raw materials used in a product, a specific manufacturing process that is not common knowledge, or even a list of clients.

As a reference, patents document a machine or process improvement to an existing device and convey ownership to the patentee. Trademarks are designs, symbols or wordphrases owned by a person or a company. Lastly, copyrights are very similar to trade secrets, but they are designed to protect the original work of a person, whether the idea or product is a song, book or photograph [3]. Basically, trade secrets can range from how a product is manufactured to the actual ingredients which are used to make the product. Some classic examples of trade secrets are the formula for Coca-Cola© or the Colonel's Secret Recipe of 11 herbs and spices at Kentucky Fried Chicken©. Most businesses in a market economy develop their own trade secrets to give their product a distinction among their competitors' products. One of the biggest reasons companies need to keep trade secrets from their competitors is to protect and maximize their future profits. Trade secrets are also critical in developing and growing a company's market share by giving its products or services a differentiating quality from its competitors.

Methods of Industrial Espionage

Now that we know what type of information is being stolen from companies, let's look at how it is being stolen. Once a person has decided to commit industrial espionage, there are a few avenues he can take to steal this information. Usually, the crime is committed by an employee working for the company who already has access to the trade secrets. Since many larger companies have their own research and development divisions, many employees may have first-hand knowledge of new products coming out onto the market. In most cases, employees with strong ethics and loyalty will be bound to confidentiality agreements required for working in that division or on a project. However, an employee with questionable ethics may not feel equally bound to those agreements so he may decide to sell information to an employee of a business competitor for a large monetary payment. The consequences of this action may end up costing a company millions of dollars in lost profits as a result of diminished market share due to rival companies introducing an identical or substitutable good or service. In addition to the lost profits of future sales, a company may also lose the money it invested in researching and developing the new product. In most cases, larger companies with their own R&D divisions spend millions or possibly billions of dollars each year in researching and developing new products. For example, the drug manufacturer Pfizer reported over two-thirds of their cash flow is reinvested into research and development of new products [4]. With so much time and money invested in developing products, companies have to find a way to protect their investment by keeping their "secret formulas" to themselves. This type of industrial espionage would be hard to detect since there would be no signs of forced entry onto the company's premises.

A recent article in the Washington Post titled "Data Theft Common by Departing Employees [5]" described just how bad this trend is really getting. According to the article, a survey was conducted by the Ponemon Institute to determine the relationship between data theft rates by employees who have either been laid off, fired or changed jobs in 2008. According to the research, nearly 60% of 945 survey respondents admitted to stealing email lists, non-financial business information, customer contact lists, employee records and financial information. Of those 60% who admitted to stealing this protected information, the majority indicated they did so "in order to leverage a new job" [5]. Figure 1 is a summary of the different types of information commonly stolen by the 567 out of 945 survey respondents that indicated they had stolen protected information from their company [5].

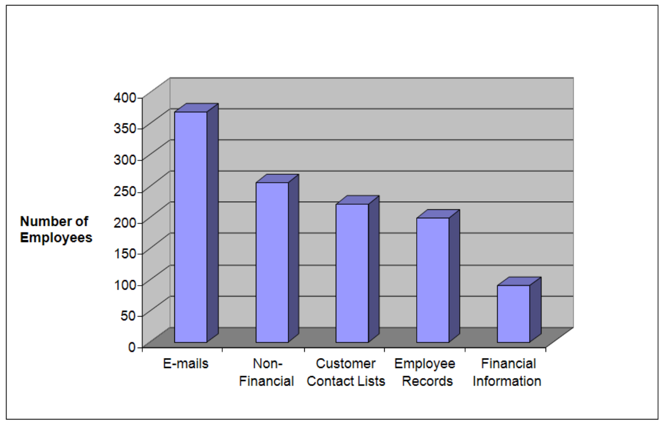

Figure 1. Data Theft Categories

In addition to theft by an employee, other thieves may be lurking on the outside of a company. This is a direct result of the rapid technological growth in affordable surveillance equipment. Now, with the help of a few simple gadgets, it is becoming easier for someone to commit industrial espionage from the outside of a company without being caught. Items that were once considered only available to law enforcement—such as phone taps, electronic eavesdropping devices, computer hacking software, and other professional spy gear—are now available to anyone looking for it. With the help of these simple gadgets, thieves could easily monitor phone conversations, hack into the company's IT network and gain access to files, or even utilize video monitoring devices to videotape confidential or secret activity within the company.

Impact of Industrial Espionage

According to the American Society of Information Security (ASIS), as much as 75% of a company's market value is held in intellectual property assets or, in other words, their trade secrets [6]. In August, 2007, ASIS released a survey report entitled “Trends in Proprietary Information Loss” [6]. The survey has been conducted every two to three years since 1991 by ASIS in collaboration with the Office of the National Counterintelligence Executive. The purpose of the survey is to study and track the impact of industrial espionage on U.S. businesses. According to the 2007 report, which was based on survey results conducted in 2006, 144 companies that responded reported losses ranging from less than $10,000 to more than $5.5 million per company [6]. That’s quite a staggering amount, especially in the current state of the U.S. economy. Size of the company does not appear to matter, as it appears that any company is prone to this type of theft. The report indicated that approximately 10% of the survey respondents were companies with an annual revenue of less than $10 million and, on the other hand, approximately 7% were companies with greater than $10 billion in annual revenue, while the greatest segment, 20.8% of respondents, were companies whose annual revenue was between $1 billion and $4.9 billion. According to the U.S. Commerce Department, “intellectual property theft is estimated to top $250 billion annually...and also costs the United States approximately 750,000 jobs, while the International Chamber of Commerce puts the global fiscal loss at more than $600 billion a year” [7].

One example of the impact of industrial espionage occurred between 1999 and 2001 at Corning, Inc., a manufacturer of electronic components for consumer electronics and telecommunication systems. During this time an employee discovered blueprints of a future liquid crystal display (LCD) project in the waste bin at a warehouse. After closely examining the documents, he realized there was a potential for selling them to an Asian competitor, PicVue, for a profit. He contacted PicVue’s president and arranged for a meeting to discuss plans to sell the blueprints which contained the proprietary information. A deal was struck between the two and for the next two years the Corning employee continued to sell blueprints marked for destruction to PicVue for a small payment of $25,000. The crime might have gone on for several years but PicVue approached a third party developer, Saint-Gobain, who ironically was involved in the development process on the same blueprints with Corning. Concerned by this, Saint-Gobain contacted Corning to alert them of a possible case of trade secret theft. Corning consequently contacted the FBI who launched a full investigation. In the end, it was determined that the intellectual property stolen by the Corning employee was valued at approximately $100 million. When the trial went to court in 2006, the Corning employee pleaded guilty and was sentenced to 4 years in prison and fined $20,000. Additionally, PicVue was ordered to pay Corning $15 million in damages [7]. This problem could have been entirely avoided if Corning had instituted better follow-up measures to ensure their secret blueprints and documents were actually destroyed immediately instead of placing them in an unattended bin out in the open for other employees to find.

Steps to Mitigate Risks

With so many different areas to cover, it’s hard to know where to start. However, a few basic guidelines should help drastically reduce the chance of a company being ripped off. First and foremost, training and educating employees about the consequences of leaking sensitive information about the company would be very cost effective and the least time consuming. The training may include having employees sign a proprietary document stating they are aware of the sensitive nature of the information they possess and the consequences of sharing it with anyone. Employees may also be trained in the importance of protecting their passwords to their workstation computers along with other simple steps to protecting information stored on them.

Second, all documents containing sensitive information can be moved to one central room and access to that room can be monitored by installing card reading devices on the door. This will allow a company to keep track of anyone who enters or exits the room along with the exact date and time of their entrance. This method may be costly and have a few drawbacks, but the company would still be able to maintain strict accountability for its records. As new biotechnology is being developed in this area, more reliable scanning devices are available that can be used to scan the employee’s retina or fingerprint instead of a card which could be stolen or used by someone else. Automated Fingerprint Identification Systems (AFIS) are readily available. The Federal Bureau of Investigation (FBI) has an exhaustive list of approved and certified AFIS devices on its website [8].

Another easy way to protect a company’s information is to ensure that employees are properly disposing of paper containing sensitive information. According to a California-based company known as Instashred Security Services, Inc. [9], many different types of forms should be properly shredded but are often overlooked; for example, forms that contain customer data, inventory records, proprietary programs, sales statistics and financial statements. Companies such as Instashred can be hired to securely remove any paper or media products containing sensitive information from a company and destroy them before heading off to a recycling bin, thus guaranteeing the information contained on the paper will be lost forever. These three steps should be used as a starting point but there are many other ways to protect a company from industrial espionage that could be utilized depending on the size of a company's budget.

Legal Aspects of Trade Secrets

Trade secrets are considered intellectual property similar to copyrights, trademarks and patents; however, the laws that protect each of these are vastly different. Originally, trade-secret laws were developed as common laws in the 1800s, but the need for specialized legal protection of these property rights steadily increased over the past few decades. In 1985, the National Conference of Commissioners on Uniform State Laws drafted the Uniform Trade Secrets Act (UTSA), which has since been adopted by most states. This Act states that a court shall preserve the secrecy of an alleged trade secret by reasonable means, which may include granting protective orders in connection with discovery proceedings, holding in-camera hearings, sealing the records of the action, and ordering any person involved in the litigation not to disclose an alleged trade secret without prior court approval [10]. In addition to the UTSA, Congress passed the Industrial Espionage Act in 1996. The primary role of the act is to "prohibit economic espionage, to provide for the protection of United States proprietary economic information in interstate and foreign commerce, and for other purposes" [11]. Combined, these Acts provide courts with guidance in determining how to apply trade-secret laws which differ from patent laws in that they address different, non-inventive subject matter and focus on conduct instead of technology" [12].

The task of applying these laws is not an easy one. Courts must first decide if proper ownership of a trade secret exists [13]. Ownership usually belongs to the person who created the formula, recipe or other process. Another factor courts must decide is what type of misappropriation has occurred; in other words, how the information was obtained or used [13]. In order to determine liability, courts must decide if a trade secret was sold or obtained as a result of someone spying, eavesdropping, or as a result of any other suspicious method. Courts must also consider if the person or company that obtained a stolen trade secret knew that the source of the information was not legally obtained. If the company knew the source was not legally procured, but proceeded to take the information from the source anyway, then both parties would be held liable. Once a court has determined if any of these actions apply to the case, it will have to award an appropriate level of compensation to the victims and punishment to the criminals. Compensation usually includes damages which are based on the actual loss caused by the misappropriation and the defendant's unjust enrichment [13]. If the act of stealing the information is determined to be spiteful or intentional, then punitive damages may be awarded to the criminal also.

Summary

Economically speaking, industrial espionage is wreaking havoc on the stifled global economy. With figures ranging from a few million to hundreds of millions of dollars lost each year by companies, to the startling amount of between $250 billion to $600 billion lost per annum in the U.S., it is hard to ignore the magnitude of this problem on the aggregate economy. Despite having a legal system that is capable of prosecuting these crimes, criminals are continuing to commit this act with the help of new technologies which make it harder to detect. Protecting a company from industrial espionage may seem like a daunting task, but three simple steps can be followed to decrease a company's risk of exposure to this type of crime as long as managers are willing to invest a little time and effort. Here is a list of common safeguarding practices:

- Educate employees to the risks by holding formal training sessions.
- Limit access to trade-secret information to only those who need to know.
- Destroy data or printed documents which contain trade-secret information immediately after it is no longer necessary to keep.

Finally, managers must always be on guard for new technology, which would make stealing trade-secret information easier and less detectable. By staying educated of new technologies and theft mechanisms, managers, employees and engineering students who may become managers someday, will be able to quickly identify any signs of suspicious activity in their organizations. This ability is a company's first line of defense in protecting itself from the crime of industrial espionage.

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Biographies

BRIAN CAZZELL is a Client Success Manager at Realize, Inc.. He assists engineers in planning and building rapid prototype (RP) models with stereolithography (SLA) and urethane casting processes during the pre-production stage of the product life cycle. He received a master's degree in Industrial Management from the University of Central Missouri. He retired from the U.S. Navy in 2009 where he most recently served as the Leading Chief Petty Officer of the VA/DoD Integration Support Team in Great Lakes, Illinois, and as a Certified Master Training Specialist at the Center for Naval Leadership in Ingleside, Texas. He is a member of the Society for Manufacturing Engineers. Mr. Cazzell can be reached at brian.cazzell@realizeinc.co

JEFFREY M. ULMER, Ph.D., is an Associate Professor of Engineering Technology and Industrial Management at the University of Central Missouri in Warrensburg, Missouri, teaching both undergraduate and graduate students. Ulmer is an American Society for Quality Certified Manager of Quality & Organizational Excellence and a Certified Six Sigma Black Belt. He is also a trained Lean Six Sigma Black Belt (from the Regal-Beloit Corporation) and has worked for 25 years in industry in the areas of product engineering, quality assurance / control, and production management. Dr. Ulmer may be reached at julmer@ucmo.ed

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Philip D. Weinsier, Ed.D.
Editor-in-Chief
Phone: (419) 433-5560
E-mail : philipw@bgsu.edu
Bowling Green State University Firelands
One University Dr.
Huron, OH 44839

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