SPRING/SUMMER 2017
VOLUME 17, NUMBER 2
WWW.TIIJ.ORG

TIIJ International

Technology Interface International Journal

ISSN: 1523-9926

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Published by the
International Association of Journals & Conferences

TECHNOLOGY INTERFACE INTERNATIONAL JOURNAL

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DESIGN AND DEVELOPMENT OF MOBILE GEOTHERMAL LABORATORY EQUIPMENT

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

Abstract

As the development and promotion of renewable energy resources advance, the implementation of geothermal energy has been receiving attention, for it is a source of renewable energy from industry and academia. Geothermal energy (GE) is heat derived from below the earth's surface, which can be harnessed to generate clean, renewable energy. This vital, environment-friendly clean energy resource supplies renewable power around the clock, and emits little or no greenhouse gases, all while requiring a small environmental footprint to develop. GE-related coursework is becoming an important part of science, engineering, and technology curricula. GE courses typically require applied laboratory experiments for the students, unless the course is being taught in programs related to business and education. Laboratory experiments for the related courses require a good laboratory workbook pertaining to what is being taught in the lectures and the related laboratory equipment. There is a variety of laboratory equipment available on the market for GE-related courses. The cost of the equipment generally varies between $20,000 and $100,000 but can be higher, depending on what is expected and required in the course.

Some of the training/laboratory equipment companies offer manuals or workbooks to accompany their equipment. Technical and engineering programs cover specific renewable energy curricula. However, due to excessive costs, some academic programs face budget challenges to buy necessary lab equipment for renewable energy technologies. These funding restrictions mean the programs must seek ways to build their own equipment and prepare related laboratory activities. In this paper, the authors describe the design and development of a mobile geothermal energy training/lab unit. The unit was completely designed and built in the design and production laboratories of an engineering technology program by faculty and students, with the help of a local geothermal company.

Introduction

Various technologies have been developed to take advantage of geothermal energy (GE) systems—heat from the earth. There are three major geothermal technologies available: a) geothermal electricity production from the earth's heat; b) direct use of geothermal, which produces heat directly from hot water within the earth; and, c) geothermal heat pumps using the shallow ground to heat and cool buildings. Moreover, this energy can be extracted from several sources: hot water or steam reservoirs deep in the earth that are accessed by drilling; geothermal reservoirs located near the earth's surface; and, the shallow ground near the earth's surface that maintains a relatively constant temperature of 60-70°F. This variety of geothermal resources allows for development on both large and small scales. For example, a utility can use the hot water and steam from reservoirs to drive generators and produce electricity for its customers. Other applications utilize the heat produced from geothermal directly to various uses in buildings, roads, agriculture, and industrial plants. Still others use the heat exchange between the ground and equipment to provide heating and cooling in homes and buildings—the geothermal (or ground source) heat pump [1].

According to the latest report prepared by Benjamin Matek from the Geothermal Energy Association [2], global geothermal energy and operating capacity is at about 13.3GW as of January 2016. Globally, in 2015, eighteen new geothermal power plants were activated, adding about 313 MW to the overall geothermal energy capacity. The Matek report indicates that there was about 3.7 GW of installed capacity and 2.7 GW of net capacity at the end of 2015. The addition of new geothermal power plants require qualified personnel in all phases of GE installation, production, and distribution. Most importantly, the promotion and awareness of GE is needed in order to educate communities about the advantages and challenges of the GE systems. There are a variety of occupations that contribute to GE fields, from building to maintaining. Some of the main occupations are science (environmental, geology, hydrology, and wildlife biology), engineering (civil, electrical, mechanical, and power), drilling, construction (surveyors, estimators, plumbers, and electricians), construction management, and plant operations [3].

According to Lester [4], three of the ten important facts of enhanced geothermal are summarized as part of the *Top Things You Didn't Know about…* series. Presented in the article are the advantages of using natural sustainable heat located in shallow ground and the existence of renewable hot water and rock below the earth's service that can be used to generate electricity. It is also mentioned that the U.S. is a world leader in generating electricity through GE, and the state of California is the leading state in the country, generating 79% of the countries GE. Finally, Lester indicates that electricity through GE is produced when heat, fluid, and natural permeability at depth are available simultaneously [5]. The report entitled the *US Geothermal Education and Training Guide*, by the Geothermal Energy Association (GEA) [6], incorporates lists of a) geothermal educational opportunities, b) institutions and academies that offer geothermal-related programs and trainings, c) research centers, d) potential research and academic-related grant resources, e) industries offering GE-related research and experience, and f) national and international associations.

The majority of alternative energy educational training units are built and sold by companies that offer custom-made systems according to the customers' needs; this increases the cost of the training units. Alternative energy teaching tools help students to fully comprehend complex concepts with interactive educational training equipment, and are very important for the hands-on laboratory sections of energy education. Due to the major costs of educational training units, it becomes a budget concern when purchasing multiple units of training equipment for $30,000 per unit [7-11]. If there are budget concerns for a program, the only option the instructor has is to teach only the associated theory of the course. Taking these issues into consideration, building an energy training unit becomes a smart idea for exposing students to alternative energy fields, at least for demonstration purposes. The training units need to be designed for use in hands-on activities that can provide students with opportunities to engage in experiments that will reinforce the material covered. The construction costs of the training unit should be kept low in order to make the project cost-efficient, especially for multiple-unit projects. In this current project, the outcomes enable the project participants to understand and work with the developed systems. The aim was to design and implement an interactive educational training unit covering fundamentals of GE systems. The unit's mobile nature makes the unit portable, so that the unit can be moved between schools for demonstration purposes.

Theory of Operation

Figure 1 shows the geothermal heat pump (HP) demonstration unit consisting of a small standard geothermal heat pump utilizing a water tank as the ground source. Water in the tank is circulated through the HP using a small electric pump with the flow rate being controlled by a globe valve [12]. The water flow rate is measured using a small electromagnetic flow meter [13]. Important to the operation of this HP unit is the temperature of the water being fed into the HP (i.e., the water tank temperature). The water temperature is measured at two locations—as it leaves the tank and as it leaves the HP unit. The HP is used to condition (change) air temperature. Air temperature is measured entering the HP unit and as it leaves the unit. The unit is controlled using a programmable logic controller (PLC) that acts as a thermostat affected by water temperature. In theory, varying the water flow will change the rate of change in the water tank temperature and affect the change in cooling capacity of the heat pump. In addition to controlling the system, the PLC can be connected to a computer to log the flow and temperature changes taking place. This can be used to analyze the most efficient operating conditions for the heat pump.

Figure 1. Geothermal AC Unit

Industry Collaboration and Design Process

An engineer from Loop Tech, LLC [14] met with the students, who would be working on the project, to discuss the intent of the unit, outline the criteria for its design, and to brainstorm ways to construct the demonstration unit. A lesson in how ground source heat pumps operate and the different types of units was presented to the students. Initial design criteria defined that the unit

- be portable
- fit through a 36-inch-wide classroom door
- have clear sides to view the internal components of the heat pump
- use a water tank as the ground source

The water tank [15] heats up and cools down, so that trainees can feel the heat exchange taking place. The tank also had to be drainable to lighten the weight of the unit for loading/un-loading during transport. The unit would work on a thermostat that senses the water entering the unit rather than sensing the air temperature, in order for the unit to automatically switch between cooling to heating modes. Figure 2 shows a process diagram for identifying the components of the heat pump system. It is important to understand and view the temperature transfer taking place, so a control panel was conceived to allow trainees to monitor those temperatures. A team worked on the instrumentation and control system. A PLC [16] was chosen to perform the thermostatic control and monitor the temperature. The heat pump operated on 240 VAC; however, this power is not available in most classrooms. Since most wall receptacles provide 120 VAC at 15 amps, this became a design criterion for the demonstration unit. A power converter (used to convert between European and U.S. power) was evaluated and selected to operate the heat pump [17].

Proper water flow through the heat exchanger is critical to proper operation of the heat pump, and tank capacity must be evaluated to allow for a reasonable cycle time for the thermostat function. A team evaluated these parameters and began the process of selecting the appropriate pieces of equipment, pricing, purchasing sources, and delivery time to fulfill the criteria. It was determined that a wagon capable of supporting the weight of the equipment and a full tank of water would allow the unit to be portable and still fit through a door. Keeping in mind the equipment to be used, a team began creating designs for support, piping, electrical connections, and air ducting of the system. Table 1 provides a major component list. The component list provides a complete list of materials purchased from various vendors with the support of departmental funds.

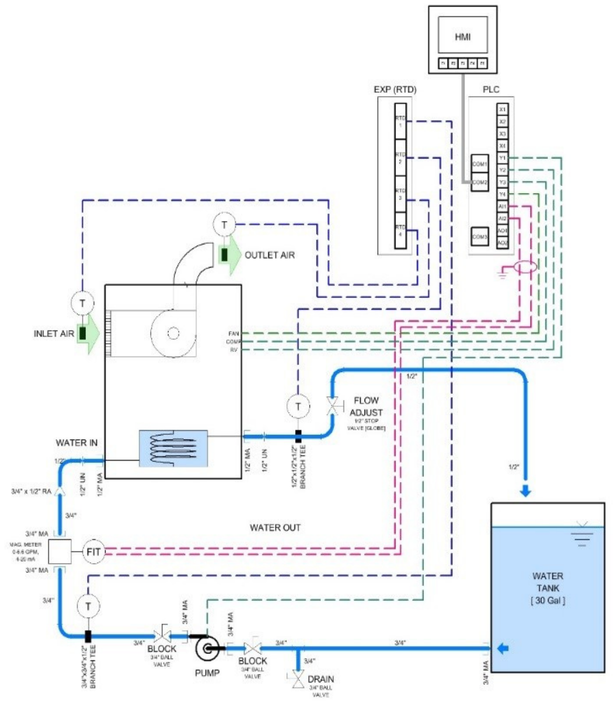


Figure 2. Process Diagram

Table 1. Material List

Item	Description	Source	Part Number	Cost
Heat pump	Water furnace - Versatec water source/geothermal heat pump	LoopTech, LLC	VLV009C000CRT2SSA	2500.00
Tank	RomoTech Poly storage tank, 30-gallon capacity, # 2390	Northern tool	48171	109.00
Pump	TACO 009-F5 pump	SupplyHouse.com	009-F5	231.95
	TACO 110-523BSF 3/4" bronze flange kit	SupplyHouse.com	110-523BSF	27.95
Controls	PLC, RTD module, power supply, relay module, HMI, breakers, fuse holders, terminal blocks	Automation Direct		479.50
Flow meter	ProSense magnetic flow meter w/ accessories	Automation Direct		474.25
Float switch	ProSense float level switch, top-mount	Automation Direct	FLS-VM-100	10.50
RTDs	McMaster Carr #6577T28 (surplus purchase-8pc)	EBAY		86.00
Voltage converter	120/220VAC, 3000VA, 2000W	WW Grainger	30C522	238.75
Plumbing/piping	copper piping	Home Depot		160.28
A/C windows	18" x 24" x .220" acrylic sheet, clear (2 reqd.)	Home Depot	SKU# 241929	41.94
Misc wiring	Power cords and hookup wire	Mouser		50.64
Wagon	Mesh deck steel wagon 2' x 4', 100# capacity	Harbor Freight	38137	79.99
Flat free tires	Northern tool (4 reqd.)	Northern Tool	189386	91.96
Control box	Aluminum bare sheet 6061 O, .063" x 36" x 48"	Online Metals		43.74
A/C outlet	24ga. steel 24" x 36"	Online Metals		17.70
A/C stand	1.25" sq tubing	surplus		35.00
			TOTAL	**4679.15**

Building Process

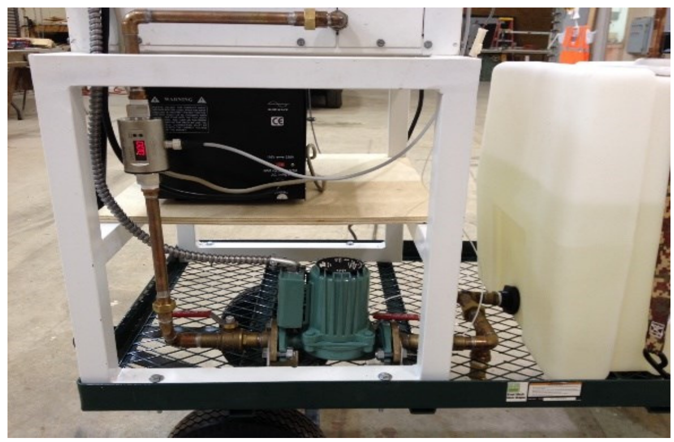
Figure 3 shows the wagon that was acquired. With the wagon, the mechanical design team began fabrication of the heat pump support stand, exhaust duct, and control box. It was determined that, since the demonstration unit was heavy and would have a high center of gravity, it could fall over if the pneumatic tires on the wagon went flat. Therefore "no-flat" tires were purchased to minimize this concern. Copper piping was fabricated to form a ridged and durable piping system. Adapters were fabricated to attach the temperature sensors to the water inlet and outlet copper piping. Temperature sensor brackets were also fabricated for the air inlet and exhaust. A team fabricated the electrical back panel and prepared the PLC program to monitor and control the system. Bench testing was performed to verify its functionality. Once verified, the back panel was installed and wired to the heat pump, water pump, voltage converter, and sensors.

Figure 4 shows an elevation diagram of the complete unit. Each component in the diagram is indicated by the leaders. The diagram gives a clear picture of how the major components were laid out on the mobile unit. The unit was portable and easy to transport for demonstration and teaching purposes.

Commissioning

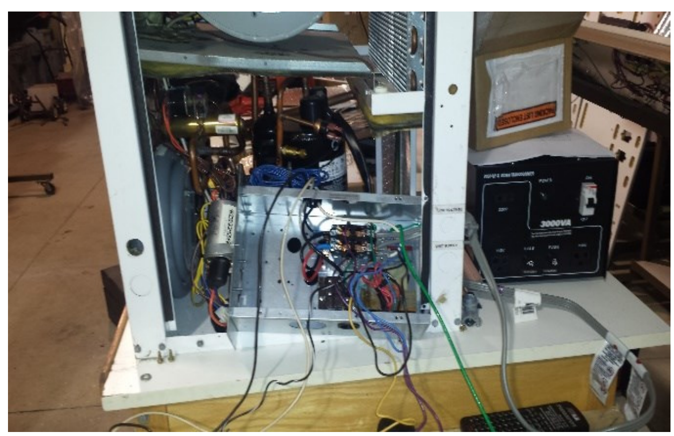
Once the piping was completed, the tank was filled with water to perform a leak test. No leaks were found after the test process. The water pump was used to circulate the water and verify that the piping did not leak. The water flow control valve was varied, and the water flow measurement was monitored to verify it was responding properly. All temperature sensors were monitored to verify that they were responding properly. The voltage converter was activated, and power was applied to the heat pump. The heat pump was placed in the automatic mode, and temperatures were moni-

a) Metal Housing for HP



b) Pump and Flow Meter Installation

c) Piping Installation and Testing



d) HP Installation and Testing

Figure 3. Fabrication and Assembly Process

tored for appropriate responses—the air was cooling and the water was heating. During these operations, the supply voltage and current were monitored to verify that neither was overloading the wall receptacle using a “Kill A Watt” power monitor.

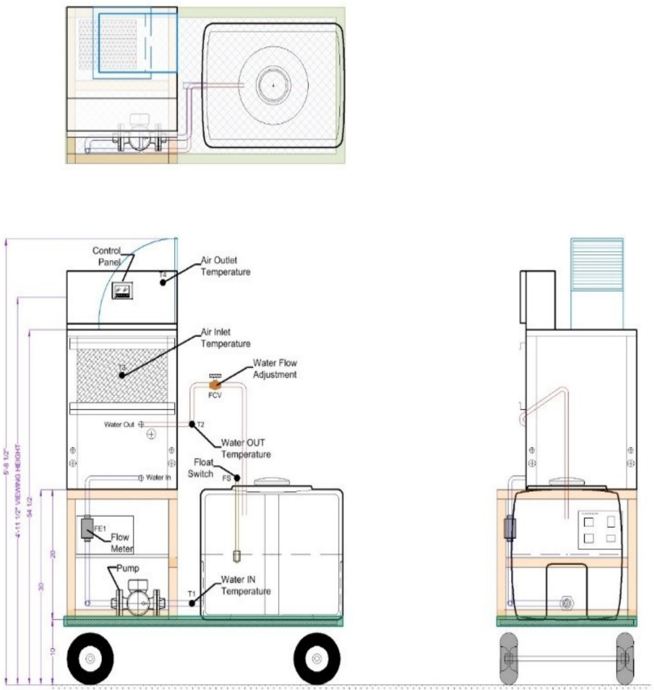


Figure 4. Elevation Diagram

The project team held a meeting to discuss which temperature control approach would be best suited for this system. An investigation was made into the operations of a wall thermostat (both electromechanical and electronic types), its internal switching, and the anticipator circuits. Since the system worked off of the water temperature in the tank rather than operating on ambient air temperature, it was determined that the operating temperature range would work best using high- and low-temperature set points. A PLC contact and timing arrangement was conceived to emulate the conventional wall thermostat for the heat pump. During the commissioning stage, the transition between cooling and heating modes of operation did not operate as anticipated. The heat pump controller board, that monitors operation of the heat pump, had fixed delays that confounded the PLC program. The PLC program was designed to have an adjustable delay between transitions of cooling and heating; however, the controller board also had such a delay. It was determined that the PLC delay could be removed, which would allow the controller board to perform the delay function.

Control Unit and Logic

For the aforementioned process control and instrumentation purposes, Automation Direct (AD) products were preferred, due to costs and an easy programming environment. Most of the sensors and meters were also obtained from AD for compatibility reasons. Figure 5 shows the control and instrumentation unit. The control and monitoring unit is the “brain” of the geothermal unit. This unit has to be expandable in order to handle more sensors, so that the project could be extended. The enclosure of the control and monitoring unit was a custom-made enclosure designed and built in the engineering technology production laboratories. The selected PLC had 24 VDC sourcing discrete and analog I/O. Figure 6 shows the wiring diagram. The diagram shares all of the wiring details with the users. The main purpose of this diagram is to construct other similar units in future energy-related courses and training workshops.

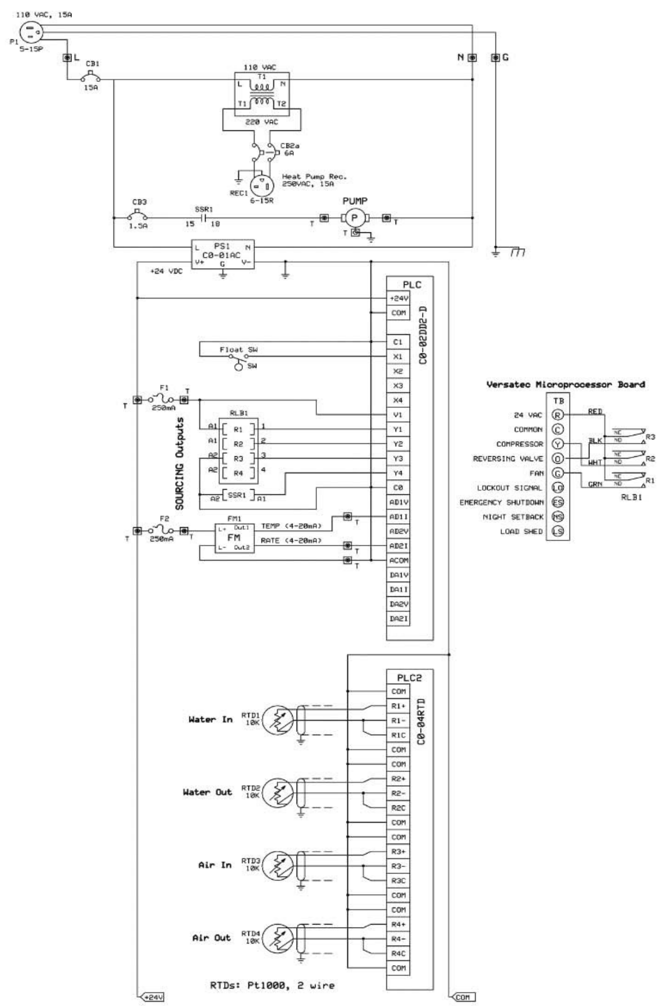


Figure 6. AC and HP Wiring Diagram

a) PLC Control/Monitoring Box—Internal

b) PLC Monitoring Display

c) System Startup/Welcome Screen

e) Temperature Setpoint Control Screen

d) HP Control Screen

f) Process Monitoring Screen

Figure 5. Control and Monitoring Unit

Conclusions

This study gathered students from a variety of disciplines together, merging their creativity and design knowledge to solve a real-world objective by implementing a hands-on experimental project. The project taught the students the value of team cooperation, planning, problem solving, and project management. The outcome of this project was an efficient, easy to build and operate, cost-efficient, portable GE training unit, which works as a standalone mini-lab. The results of this type of project demonstrated that other institutions can develop their own systems and achieve similar success. The project engaged student participation from different disciplines (design and development, electronics and computer engineering technology, and ET electronics). The team leader (a faculty advisor) set up meetings to organize working schedules, progress reports, construction, and commissioning for the project. This fully functional laboratory training unit will augment applied energy education workshops for local community colleges, secondary/high school science/technology teachers, students, and special interest populations not otherwise exposed to state-of-the-art renewable energy technologies.

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Teaching Critical Skills in Robotics Automation: Development and Implementation of an iR-Vision 2D Course in Robotic Vision Systems

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Abstract

Nearly any robot currently used in industry is equipped with a vision system. There has been a rapid development in the use of vision systems, as they increase the robot's performance to identify and track different parts by capturing their location and orientation. The vision system provides the robot "eyes" needed to perform complex manufacturing tasks. To maintain and use robots equipped with vision systems, industry workers need to have the necessary skills and knowledge. It increases the demand for robot specialists and, to meet them, educational institutions have to develop and offer courses relevant to robotics and automation. It is critical that education efforts respond to the demand for robotics specialists by creating and offering courses relevant to robotics and automation. The curriculum and software developed in this research project, conducted at Michigan Tech in collaboration with Bay de Noc Community College, emphasizes skills that are currently needed for robot industry professionals. In this paper, the authors describe the development of an iR-Vision 2D course in robotic vision systems, as part of an NSF-sponsored project that aims to introduce a new approach for industrial robotics in Electrical Engineering Technology (EET) programs at Michigan Technological University and Bay de Noc Community College. The iR-Vision 2D robotics course is designed as a 4-credit-hour course and introduces topics on: safety; basics of optics and image processing; setting up lighting conditions required for the successful vision error proofing and camera calibration; teaching tool, application, and calibration frames; and, performing 2D calibration and 2D single- and multi-view robotic processes. Hands-on training is an integral part of the course and includes various laboratory exercises, with the aim of providing students with the opportunity to execute and troubleshoot different applications that are similar to what they will encounter in industry.

Introduction

Automation is going to transform employment in the next 20 years, and robotics will play a key role in creating jobs over the next five years. These statistics are evident in a study by the market research firm Metra Martech [1] entitled a Positive Impact of Industrial Robots on Employment. Technological advancements have replaced low-skilled jobs and increased the efficiency of production all across industry. Studies have reported that the jobs lost to robots are fewer than the jobs created by them. For example, in 2011, the estimated jobs created by robotics worldwide was about four to six million, and the numbers rise to eight to 10 million counting indirect jobs. International Federation of Robotics (IFR) projects [2] that robotics will generate about 1.9 to 3.5 million jobs in the coming eight years. The rapid growth of robotics and automation, especially during the last few years, and their current positive impact and future projections for impact on the U.S. economy are very promising. According to Metra Martech [1], even by conservative estimates, the number of robots used in industry in the U.S. has almost doubled in recent years.

In the manufacturing sector, recent growth was 41% in just three years. The automotive sector in the U.S. relies heavily on robotics as well. China produces more cars than the U.S., but the number of robots used in vehicle manufacture in China is estimated at 40,000 compared to 65,000 in the U.S. Research by Metra Martech illustrated that, from 2014 to 2016, robot installations were estimated to increase about 6% a year, resulting in an overall 3-year increase of 18%. Likewise, companies that manufacture industrial robots have reported rapid growth of 18-25% per year in their sales and revenue. Even though jobs will be displaced by the increasing use of robots, their growing demand will force the robot manufacturers to rollout more and more jobs. It has been observed that, due to the advancement in robotics, the jobs lost to developing countries are now declining and developed countries are able to create employment in their own lands. For example, Neil Hughes [3] covered in an article that Apple invested $10.5 billion on machines and robots at their manufacturing plant in the U.S. that produces the Mac Pro. In March of 2012, Amazon was able employ 20,000 people in its U.S. fulfillment centers, as they had deployed 1382 kiva robots to automate their warehouses.

These numbers substantiate the alarming rate of increase in the growth of robotic automation throughout different industrial sectors. Industry is in need of a trained workforce to implement, operate, and maintain these robotic systems. Therefore, to realize these demands, it is essential that educational institutions offer appropriate courses in robotics and automation, and certify well-trained robotic specialists. In addition, industrial representatives and workers will need training from certified robotic training centers (CRTCs) to update their skills. In a previous study [4], the authors reported on the development of various robotic-oriented courses for university- and community college-enrolled students, as well as industry representatives. In this current study, the authors focused their attention on iR-Vision 2D Robotics course development and implementation at both Michigan Tech and Bay de Noc Community College.

Current Robotics Curriculum at Michigan Tech and Bay de Noc Community College

In this paper, the authors describe the project undertaken by Bay College and Michigan Tech to update their curricula. The collaboration aimed to develop extensive education materials that would be available between institutions for adaptation. In previous publications [4, 5], the authors described Figure 1 as follows: "It depicts the proposed models in robotics curriculum development which will impact three different educational groups: 1) two- and four-year institutions; 2) students from other universities and community colleges, industry representatives, and displaced workers; and 3) K-12 teachers and high school students." There are several courses in robotics automation for two- and four-year degree institutions, as well as industry representatives that have already been developed via this partnership. These courses are: Real-Time Robotics Systems, Handling Tool Operation and Programming, and Robot Operations. The authors reported on these developments previously [4, 5]; thus, the detailed descriptions of these courses are omitted here. Instead, the authors focus their attention on new courses in robotic vision. One course, Robotic Vision Systems, will be introduced to the students of two- and four-year degree institutions, while the other course, iR-Vision 2D, was designed to address industry needs with certification.

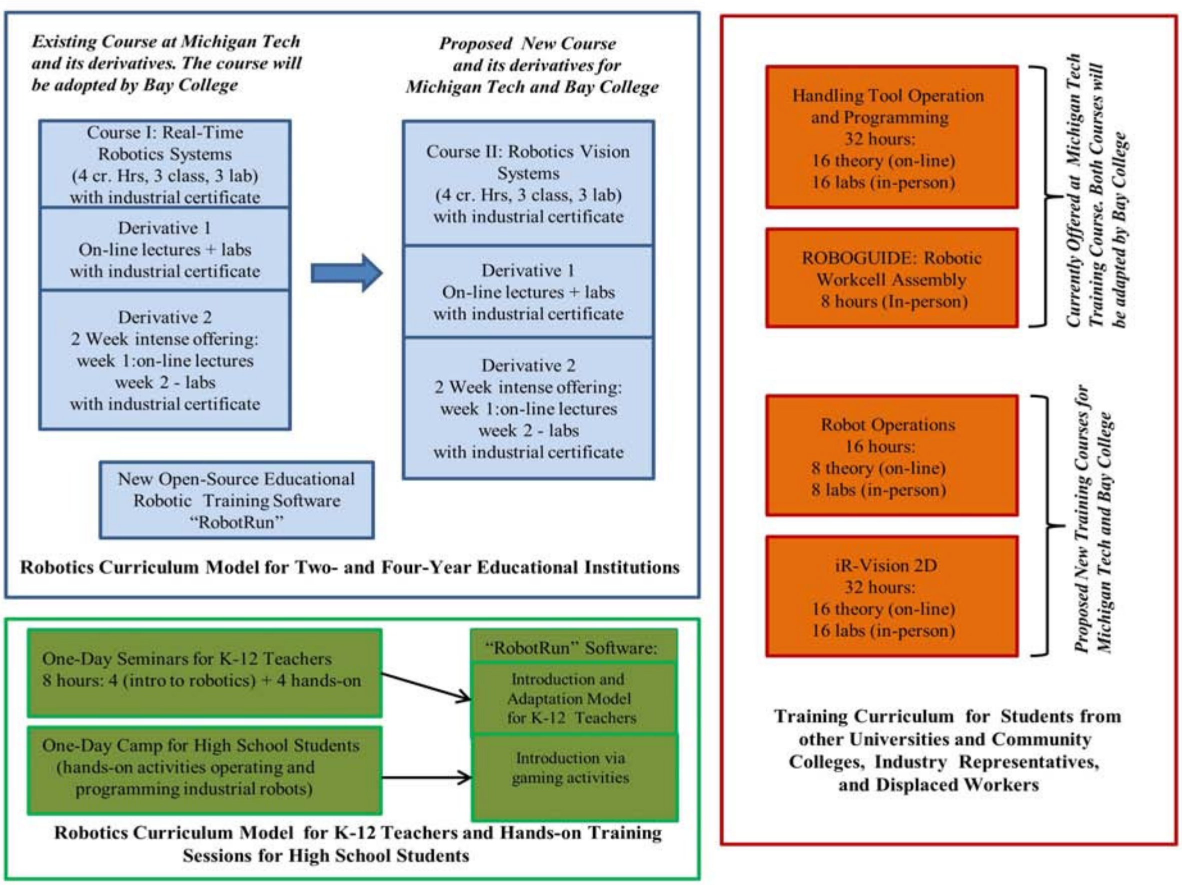


Figure 1. Proposed Robotic Automation Curriculum Development

Robotic Vision Courses at Other Universities

In a recent publication [6], faculty members at the Oregon Institute of Technology proposed the implementation of a course on vision systems with applications in robotics. The principal aim of that proposal was to broaden the interdisciplinary skills of manufacturing and mechanical engineers by providing the students with a software language that has basic functionality and tools that will help them learn the vision systems and implement vision technology in different applications. Another group of researchers at Northern Illinois University [7] restructured their manufacturing automation course by introducing machine vision in their curriculum. The course covers the basic principles of vision, camera systems, lighting, and image acquisition and digitization. In addition, students perform laboratory activities to have hands-on experience in integrating and applying the vision techniques. University of Missouri—Columbia [8] offers the course, "Introduction to Mechatronics and Robotic Vision." The course focuses on: 1) mechatronic systems and their components; 2) the mathematical tools used to model industrial and mobile robots; and 3) vision sensors, their underlying models, and the algorithms that allow us to control and interact with robots.

The laboratory activities consist of MATLAB and C and/or C++ programming to control industrial and mobile robots using sensory information from cameras and guiding them to perform required tasks. At the end of the semester, the students will develop an entire system and compete in a game using vision-guided robotics. Professionals at Robert Morrison University [9] developed a vision-based work-cell for a screw-sorting application. Based on this work-cell, the team developed hands-on laboratory components for the automation and robotics course that will provide practical experience of setup wiring, robot programming, vision integration, and implementation.

iR-Vision 2D Robotics Course Development

Nearly any robot currently used in industry is equipped with a vision system. There has been a rapid development in the use of vision systems, as they increase the robot's performance in identifying and tracking different parts by capturing their location and orientation. Vision systems provide the robot "eyes" needed to perform complex manufacturing tasks. The new iR-Vision 2D Robotics course is designed as a 4-credit-hour course (3 hours of recitation and 3 hours of weekly lab). The course introduces the following topics:

- Safety, including laser safety
- Basics of optics and image processing
- Setting up lighting conditions required for the successful vision error proofing and camera calibration
- Teaching tool, application, and calibration frames
- Performing 2D calibration and 2D single and multi-view robotic processes
- Performing 3D calibration and 3D single view robotic vision processes

Hands-on training is an integral part of any course developed in the School of Technology at Michigan Tech, and this course is no exception. It includes 36 hours of laboratory exercises, providing students the opportunity to configure and execute real-life, industry comparable, robotic vision scenarios. The course has rigorous assessment strategies and culminates in a two-hour certification exam. Students successfully passing the exam receive a certificate in iR-Vision 2D issued by the FANUC-certified instructors. In addition to the traditional offering, two variations (a hybrid and a 2-week intensive version) of the Robotics Vision Systems will be developed and implemented.

iR-Vision 2D Robotics Course for Industry Representatives

In recent times, industry sectors have deployed robots for material handling and other manufacturing and assembly applications. These robots have become a dominant species, replacing the labor involved in unskilled tasks. Robotic automation has been embraced as a way to stay globally competitive, and to reduce the reliance on manual labor to perform redundant tasks. If the U.S. does not want to outsource, it needs to automate. In previous publications [4, 5], the authors stated, "To support the industry, educational institutions have to: 1) develop a training curriculum with industrial certification available to students from institutions where a robotics curriculum is not available; this will make those students more valuable in the job market; 2) provide effective, certified training to industry representatives who need to retool their skills to match rapidly developing technologies, especially in the field of robotics automation; 3) provide displaced workers with the opportunity to enhance, or acquire new, skills in robotics and enter the in-demand robotics job market." Certified curriculum development for all three categories is addressed in this paper.

Certification 1: Handling Tool Operation and Programming (32-hour course)

This course consists of theoretical content and practical training on robots. The course includes a discussion of scholarly and practical robotic topics ranging from kinematics and programming to practical application areas and economic concerns. In recent publications [4, 5], the authors describe the topics included: "the development of industrial robotics; an overview of the mechanical design, control, programming, and intelligence; organizational and economic aspects; robotics in operation and various applications" with 70% of the course focused on offering hands-on experience to the students. The course includes practical laboratory exercises that let participants program and operate the FANUC robots. The first 16 hours of this course offer theoretical lectures that are delivered online, with the remaining 16 hours reserved for extensive hands-on training on the FANUC robots. At the end of the course, students are required to clear the certification exam, where a FANUC-certified instructor tests their understanding of theory along with their practical programming skills. Due to the nature of the course, it can be offered on demand and conducted during weekends, student breaks, or in the summer.

Certification 2: Roboguide—Robotic Workcell Assembly (8-hour course)

FANUC Roboguide software is a powerful tool widely used in industry to design or test a robot's capabilities by simulating it in a virtual environment. The authors developed an 8-hour training course that educates the participants on the software's features. The objective of the course is to train the students to create a virtual robotic workcell consisting of the robot, end-effector, several fixtures, and industrial parts that the robot can manipulate. Students learn to create program files for the robot to perform a simple pick-and-place operation, run the simulation file in step-by-step and production modes, and compile a file that can be further transmitted to the physical FANUC robot for real-time production. This 8-hour certification course is offered on demand along with other certification programs.

Certification 3: Robot Operations (16-hour course)

Industry is in a need for robot operators with minimal amount of skill that is just enough to perform fundamental operation and maintenance of the robots. This 16-hour course teaches students to safely power up and power down robotic arm, jog the robot to predetermined positions, and set up different frames of operation. It also covers a section of basic programming and procedures to reset common robot faults. Unlike the 32-hour Handling Toll Operation and Programming course, the 16-hour course materials do not include advanced programming methods, nor does it concentrate on teaching many software features.

Certification 4: iR-Vision 2D (32-hour course)

This course aims to teach the students all of the basic principles of vision that are required to create and run a scenario using the iR-Vision system. It focuses on setting up cameras and calibrating them to the lighting conditions, establishing communications between robot and computer, learning the features of the vision software and procedures to create with single- and multi-view processes, and programming the robot to complete the operation. Safety procedures are integrated into all exercises. As an integral part of this course, a series of lab exercises was developed to provide hands-on training to reinforce the theory the student has learned. This 32-hour course was designed with a structure similar to the Handling Toll Operation and Programming course: 16 hours of online and 16 hours of hands-on training. The course provides certification for able participants, who successfully demonstrate their knowledge and skill to set up, calibrate, program, and run the FANUC robot with the vision system. A FANUC-certified instructor issues the certificate to participants, who clear the examination. Similar to the other certification courses, it can be offered on demand and conducted during weekends, student breaks, or in the summer.

Hands-On Training

The industrial automation laboratory at Michigan Tech has four FANUC training robotic carts, each containing a FANUC LR Mate 200iC robot, R-30iA Mate Controller, Sony XC-56 camera, air compressor, and a computer. These robots have an option for interchangeable end-effectors, such as suction cups and 2-finger parallel grippers, that are used in developing a variety of applications. The iR-Vision course offered to students at Michigan Tech consists of 12 lab exercises that help them gain hands-on training and experience with the FANUC iR-Vision 2D system. A scaled-down version of the same set of lab exercises is used for the certification program for industry representatives. Following are the topics for the lab exercises:

- Camera and lighting concepts
- Camera setup
- Frames
- 2D calibration
- Error proofing
- 2D single-view process
- 2D single-view process: pill sorting
- 2D single-view process: chips sorting and palletizing
- 2D single-view process: battery picking, orienting and placing

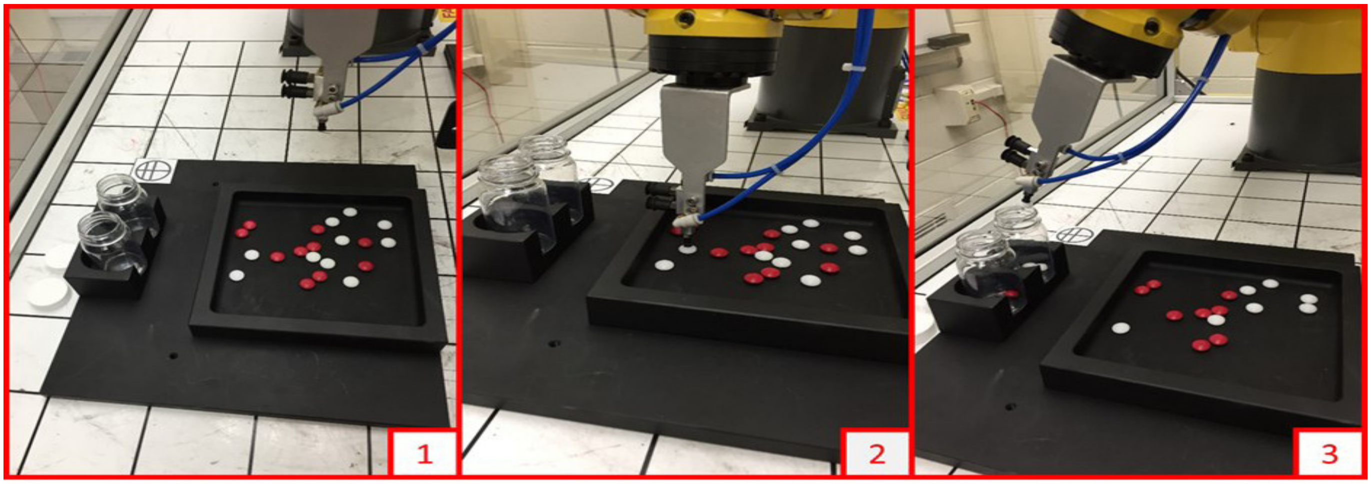
The first few exercises begin with introducing the students to all of the hardware and software components of the setup, consisting of the camera, lights, robot controller, and iR-Vision software. Significant attention is given to explaining the wiring and communication between the camera, robot controller, and the computer. The above also includes the type of camera and connection ports, and explains the procedure to set up the camera. Setting up the camera allows the user to select the exposure time and type of mounting, and to attain different parameters such as image size, aspect ratio, etc. TCP/IP is the protocol used between the controller and the computer to communicate through the software; the hands-on activity is designed to provide a stepwise procedure to achieve successful communication. After the communication is established, the user can access the software and learn the functionality of all the options on the graphical user interface of the software. Objects that will be taught and further recognized by the robotic vision system are placed in the camera's field of view. The camera view is obtained via the robotic vision software and displayed on the computer screen. The clarity of images can be improved by varying the contrast and the exposure time of the camera. These exercises help students to understand how the camera perceives images using pixels under different lighting conditions and to apply this knowledge in the future.

The next stage is to teach students the coordinate systems, referred to as frames, related to the robot's and camera's environment. The three frames that affect the motion of the robot are world, user, and tool frames. Using the teach pendant, a hand-held device used to program and control the motion of the robot, these frames are taught to the robot and used in the procedure for camera calibration. Camera calibration helps in locating the position of the camera with respect to the robot world frame by implementing a calibration grid, a predetermined pattern of black circles drawn in a grid format, that helps determine different parameters such as focal distance and location.

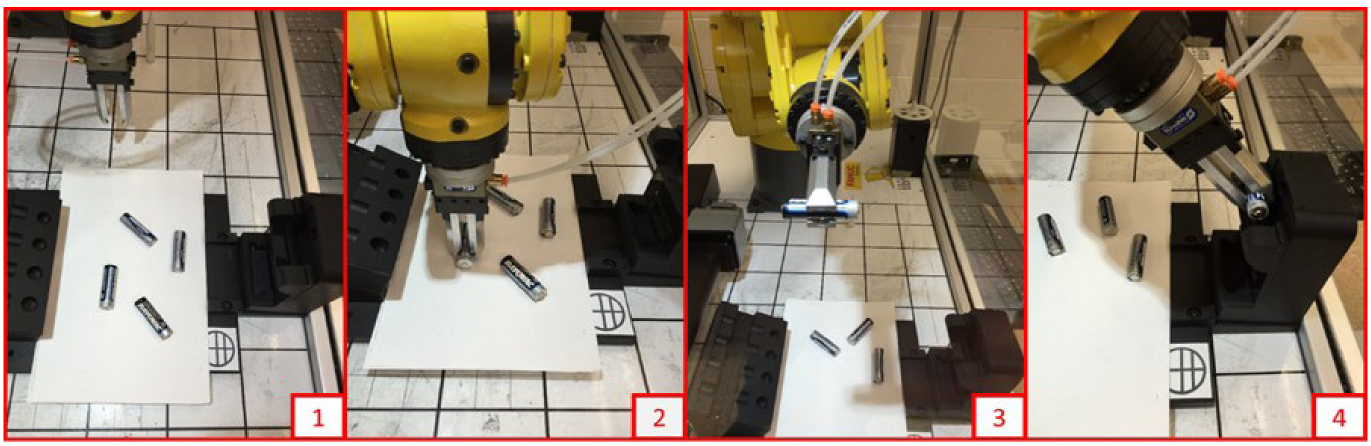
After teaching the basics of setting up and calibrating the vision system, the process of error proofing is introduced in the next session. FANUC Robotics System R-30iA Controller iR-Vision with Error Proofing student manual [10] states, "Error Proofing in automation relates to the ability of a system to either prevent an error in a process or detect it before further operations are performed." It is widely used in industry for various applications and can be performed on manufactured parts in a process, or can be used to monitor critical components of a process. The error proofing technique identifies the presence/absence or orientation of parts and critical areas on a part; it is also an economical way to perform quality checks. The manual also mentions, "The Error Proofing Process requires no calibration and does not return any part offset that can be used to modify robot movement. It does, however, return a pass or fail dependent on criteria set by the user." The process involves a stepwise approach to teaching the location, orientation, and size of different objects to the vision system. It uses the geometric pattern-matching tool to teach the pattern of the object, a tool that includes features like masking and emphasis area, which help in identifying unimportant areas of the image or emphasizing important ones. Image recognition accuracy is expressed by a score threshold, and the target object is successfully found if its score is equal to or higher than this threshold value. Based on the PASS/FAIL results of the error proofing process, the user can use this data to program the robot.

By going through the initial laboratory exercises described above, students obtain hands-on training on the basics of robotic vision, and become well accustomed to the vision system process. The next few sessions involve the use of the 2-D single-view process, with the camera in a fixed mounted position, and different practical applications using the vision system are programmed into the robot. Figure 2(a) shows one of the exercises, a pill-sorting application in which pills of two different colors (red and white) are placed on a black background, and two empty bottles are placed on the side for collecting them. The main objective of this exercise is to recognize the different-colored pills using the vision system, then picking and placing them into their respective bottles. The robot equipped with a vacuum-cup end-effector uses suction for the pick-and-place process. This exercise trains the students in differentiating between objects of the same size but different colors, and improves their programming skills using iR-Vision.

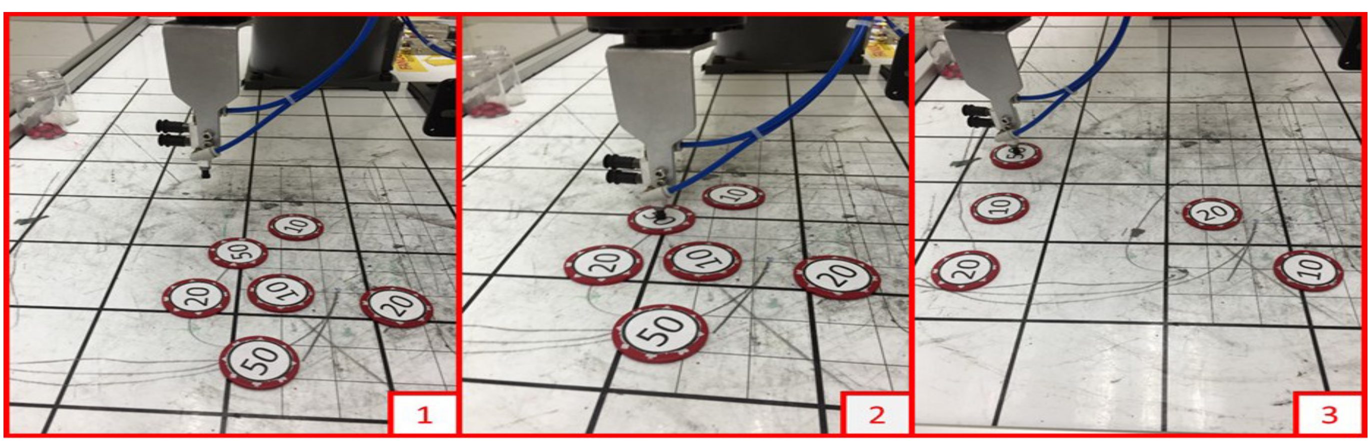
Palletizing is a process of stacking products onto a pallet with a defined pattern of forming the stack. It is a widely used application in industry, and the next lab exercise integrates the vision system techniques with the palletizing option installed on the controller of the robot. Figure 2(b) shows how round chips with different numbers printed on them are placed randomly on the base frame, and each chip is taught as a different object pattern to the vision system. First, the program is written on the teach pendant to locate the position of these chips and pick them up using the suction cups on the robotic end effector. A second program is written using a pre-installed option on the teach pendant called Palletizing EX. This option teaches the approach, pick up, and place points to create a vertical stack of chips in a desired matrix format at pre-defined locations. The students use their programming skills to integrate these programs to execute the desired tasks.



(a) Pills Scenario: 1) randomly placed red and white pills; 2) robot pick-up position; 3) white pills drop position



(b) Batteries Scenario: 1) randomly placed batteries; 2) pick position; 3) orientation check position; 4) drop position



**(c) Chips Scenario: 1) randomly placed numbered chips; 2) robot pick-up position;
3) robot orients and places chips at corresponding positions**

Figure 2. Student Training Activities on the Basics of Robotic Vision

The objective of the next lab is to recognize the position and orientation of a set of randomly placed batteries, pick them up one at a time, show the positive terminal of the battery to the camera to check for orientation of the battery, and drop them into a given slot with the positive terminals of all the batteries on one side. Figure 2(c) shows the setup, with the camera placed above the area, and all of the step-wise functions required to be complete the task.

Conclusion

A collaborative project between Michigan Tech and Bay de Noc Community College to develop courses and offer education in robotics and automation has been described in this paper. Efforts are being made to tackle industry's forthcoming need for highly trained individuals in the field of industrial automation. The project aimed to develop and implement an updated curriculum model, laboratory exercises, and "RobotRun" simulation software suitable for use in both 2- and 4-year EET programs. In addition, reaching out to the K-12 students and teachers will spread awareness and generate interest among students to pursue careers in robotics. Conducting workshops for students at other institutions, or offering programs for industry workers, will broaden the impact. Described in this paper, robotic vision curriculum development is geared towards not only students enrolled in the university program but also provides opportunity for industry representatives to re-tool their skills in robotics and automation. The iR-Vision 2D course and its derivatives was designed to provide significant hands-on training in robotic vision systems and teach the skills that are relevant to current industry needs.

Future Work

In addition to all of the aforementioned hands-on activities aimed at providing in-depth knowledge on the robotic vision systems, their configurations, and programming options, the authors are working towards developing an industrial-like robotic work-cell consisting of three robots, a few photoelectric sensors, one conveyor, a programmable logic controller (PLC), a human machine interface (HMI), and three camera vision systems. Industrial automation applications generally involve all of these devices integrated into a single production or assembly line. The developing work-cell will provide students with an analogous working environment to industry, with the goal of enhancing students' real-time problem-solving abilities and skills. The design of the work-cell is such that all of the three robots are placed in-line and the conveyor is placed in front of them. Sensors and camera positions will be decided based on the applications for the exercises.

The designed 3-robot industrial work-cell will provide students with the opportunity to prototype a wide range of industrial robotic automation scenarios. All of the components of the system, such as the conveyor and robots, will be controlled using the PLC, which will act as the master controller. The initial lab exercises will cover concepts of teaching all connections and wiring of the complete setup. The next several laboratory sessions will be devoted to creating an assembly line, where all of the robots will perform different functions at their respective stations. Vision systems installed above the conveyor will help detect the position and orientation of the parts that are moving from one end to the other. The students will be tasked with creating various programs for all of the robots and running these programs using the master PLC. When the parts arrive at their respective stations, the conveyor will stop and the vision system will guide the robot to pick up the parts and perform its operation. Further plans include designing and incorporating into the robot multi-cup end effectors to pick up multiple objects from the conveyor at once and place them at the desired location. A wide variety of applications can be created using this setup and students will have a wider scope for solving different problem statements as a part of the course project.

Acknowledgments

This work was supported by The National Science Foundation, ATE; Grant number DUE-1501335.

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Biographies

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Real-Time Data Collection and Processing in Open-Loop and Closed-Loop Systems

Jean Jiang, Purdue University Northwest; Li Tan, Purdue University Northwest

Abstract

A new method for teaching real-time data processing using data acquisition (DAQ) boards and the LabVIEW software program is demonstrated in this paper. In the electrical engineering (EE) and electrical engineering technology (EET) curricula, the DAQ board real data collection and LabVIEW program have been used as an effective platform for teaching signal processing and control systems during the junior or senior years. Such courses are offered in both EE and EET programs based on current trends in the signal processing/control industry and student interest regarding career development. The courses place significant emphasis on real-time processing applications. Taking the course, students not only become familiar with the MATLAB and LabVIEW software development tools, but also gain real-time experience in signal processing and data processing. They can design low-pass and band-pass filters and implement them using the MATLAB and LabVIEW programs, and thus can apply the software and hardware interface for real-world applications. Compared to traditional control or signal processing courses, which mainly focus on intensive mathematical derivations with limited opportunity for computer implementations, the real-time projects used in this current study can greatly help students understand how a real-time signal, such as a temperature signal, can be processed and controlled in a closed-loop feedback control system, or how a real speech signal could be enhanced through the following stages: audio amplification, audio digitization and collection by a DAQ board, display by LabVIEW and a spectrum analyzer, digital audio processing by MATLAB and LabVIEW software, and analog audio recovery by an active reconstruction low-pass filter in an open-loop system. Thus, in this paper, the authors present a closed-loop temperature control system that includes a DAQ board interface circuit and LabVIEW software. Next, a DSP (digital signal processing) platform for performing real-time audio data processing is presented. Using these proposed platforms, students can successfully learn LabVIEW and DAQ board interfacing techniques and be able to apply them to real-life applications after completing such projects.

Introduction

Data acquisition and data/signal processing technology have continually impacted electrical, computer, and biomedical programs, because real-time processing plays a key role in many real-time applications of signal processing and control systems. A quick review of the current jobs advertised in technical magazines and on Internet sites reveals a demand for individuals with refined knowledge of real-time processing. Hence, being adequately qualified in operating, maintaining, repairing, evaluating, and helping to specify and design real-time systems allows a student to demonstrate significant competency for employment [1]. In order to prepare engineering/technology students for such an industrial trend, many undergraduate programs in engineering/technology have started to provide not only an introductory course to cover the fundamentals of signal and system analysis, but also an advanced course focusing on real-world applications and relevant current topics such as speech signal processing, adaptive filtering, and closed-loop control systems [2-6].

A control course in the authors' engineering program and a signal processing class in the technology program were designed for junior or senior students to gain experience with real-time data/signal processing and to develop interest in real-world applications. Examples of such projects offered include a closed-loop temperature control system and a real-time acoustic processing project, both of which are presented here. A complete real-time processing system that includes design and testing greatly motivates students and helps them to understand math-related topics much easier, whereas traditional teaching only focuses on heavy math derivations in data collecting and recovering, spectrum analysis, closed-loop system analysis, and IIR or FIR filter design with limited opportunity for computer simulations [5, 6]. The advanced real-time processing courses are offered to students already familiar with the Laplace transform, Fourier analysis, and analog filters from the previous course. In addition, proficiency in MATLAB programming is required, and MultiSIM could be applied to check the filter design results. In offering a wide coverage of projects with a focus on real-world applications, the course can be beneficial to all electrical engineering/technology students.

It may not be appropriate for the program to still follow classical teaching methods using textbooks from a traditional four-year program, as doing so heavily relies on intensive mathematical theory and development [5, 6]. Note that there is a requirement to teach advanced real-time topics at a hands-on level; therefore, in this paper, innovative pedagogies and applications are presented as part of the current engineering/technology curricula.

A Closed-Loop Temperature Control System

In this study, students were asked to create an on/off closed-loop temperature control system that included two SCRs (silicon controlled rectifiers), an LM34DZ temperature sensor, two diodes, and one 10Ω resistor heater. LabVIEW was also used to apply 10V to the heater resistor until its temperature reached 100°F. Then the SCR would turn off its power supply until the resistor cooled below 90°F. The system then turned the power back on for the heater to raise the temperature again. This closed-loop control system kept the temperature between 90°F and 100°F.

System Level Concept

Figure 1 shows the system block diagram, where the design specifications are given and LabVIEW was required for data acquisition and processing.

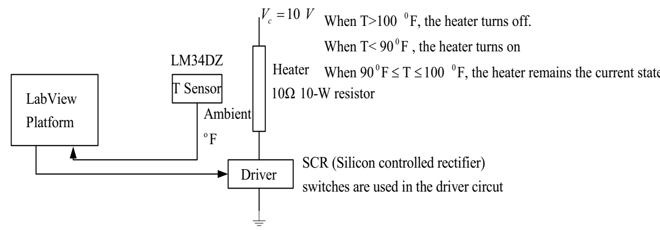


Figure 1. On/Off Closed-Loop Temperature Control

Hardware Design

Figure 2 shows the hardware design and interface with LabVIEW [7] as well as the special elements used in this project, which included an LM34Z temperature sensor, an SCR (often used in power industrial electronics such as automobiles), a diode, and a 4N33 optoisolator.

When the temperature sensor detected that the ambient temperature was lower than 90°F, the LabVIEW DAC channels 0 and 1 would output AO0 = 5V and AO1 = 0V, respectively. This caused SCR1 to turn on and run the heater. Otherwise, the SCR was off. The capacitor was charged to 10V; that is, V21 = V2-V1 = 10V. When the temperature was between 90°F and 100°F, the LabVIEW DAC channels 0 and 1 would output 0V; that is, AO0 = 0V and AO1 = 0V. SCR1 was still on, since the current passing through it was greater than the holding current, and SCR2 remained off. However, when the temperature was above 100°F, LabVIEW ADC channels 0 and 1 would output AO0 = 0V and AO1 = 5V, respectively. This turned on SCR2 and forced SCR1 to be turned off. The capacitor was discharged via the path (current flow) Vcc-V1-V2-K-ground. After the capacitor was fully discharged, it acted like an open circuit. The small holding current could not maintain the current flowing through SCR2. Thus, both SCR1 and SCR2 would be off. When the temperature was below 90°F, this procedure would repeat.

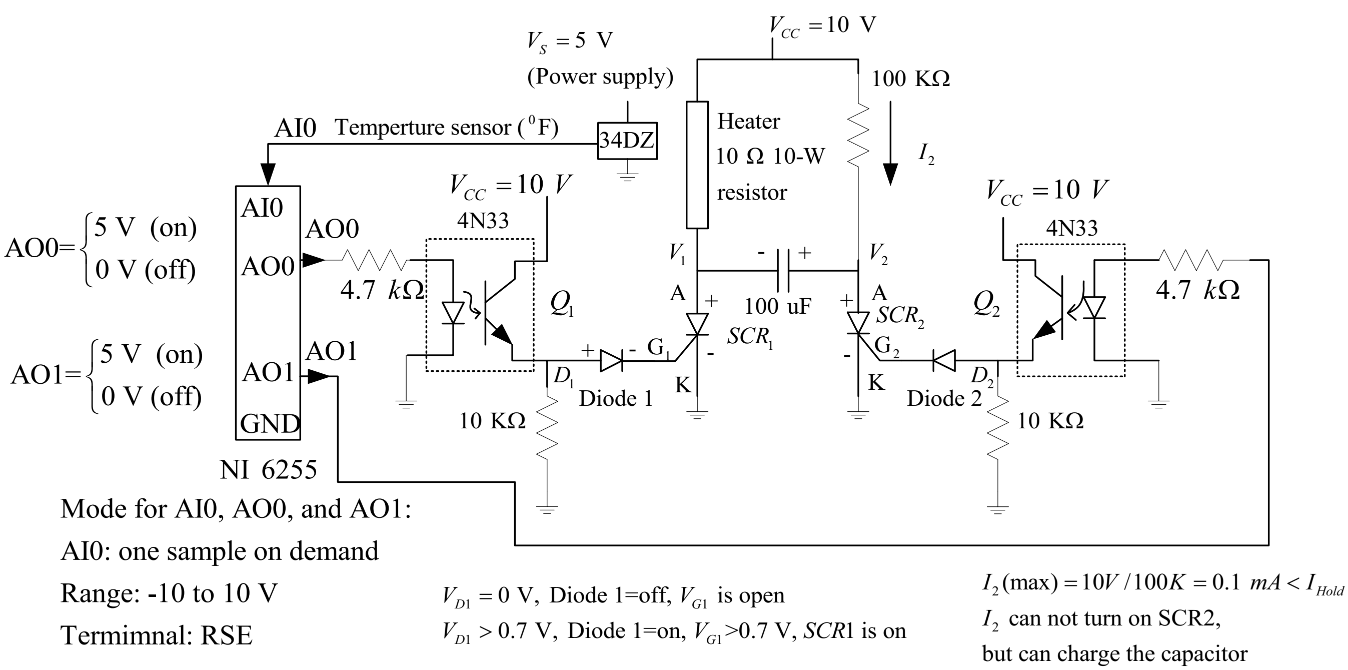


Figure 2. Schematic of an On/Off Closed-Loop Temperature Control System

Software Design and Algorithm

Figure 3 shows the front panel requirement and Figure 4 describes an algorithm for converting the temperature sensor voltage to display temperature in degrees Fahrenheit and degrees Celsius.

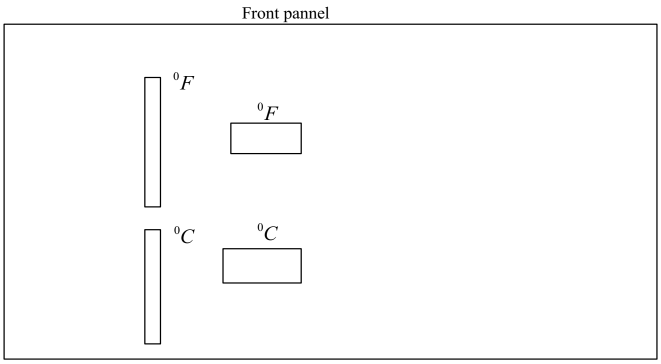


Figure 3. LabVIEW Front Panel

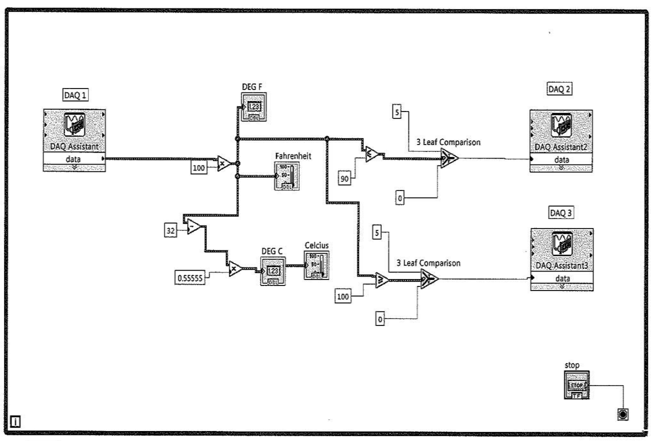


Figure 4. Sample of the LabVIEW Program

In summary, students were asked to design and construct the circuit, utilize LabVIEW to power and control the heater, and display the temperature in degrees Fahrenheit and degrees Celsius. Then, students examined the operation of the circuit by charting the temperature every five seconds in degrees Fahrenheit and drawing the results for two complete cycles of the temperature control for the system.

A Real-Time Speech Processor

The focus of the EET program in which the DSP technique is used was a real-time audio project. The textbook selected was *Digital Signal Processing: Fundamentals and Applications*, by Elsevier, 2013 [1]. The textbook demonstrates clear and easy-to-follow real-world examples, applies many MATLAB programs to present computer implementations, and provides computing examples to motivate students to practice signal processing materials at an adequate theoretical level. In particular, an ample amount of simplified real-time simulations by DSP boards to engineering/technology program(s) is a plus. In particular, MATLAB was chosen to be a main development and design tool in this course after students gained familiarity with it from a previous signal processing course. However, other simulation software was also encouraged, if time permitted.

LabVIEW and a PCI-1200 DAQ board were selected as the main set to practice and test an acoustic processing system. Students gained working knowledge upon completing their projects. Students were asked to construct an audio amplifier, use MATLAB or other software to complete an IIR band-pass filter or an FIR low-pass filter, and then load the filtering results into LabVIEW to process a real speech signal sampled from a microphone. In the meantime, students could also display the original audio spectrum and filtered speech spectrum to compare processing results. Figure 5 shows a simple data capture system for verifying the signal channel and to assist students in obtaining working knowledge of the system. Figure 5 also shows the data acquisition channel. Students can test the signal samples and reconstructions, fully understand the analog-to-digital conversion (ADC) input, and verify the digital-to-analog conversion (DAC) output based on the platform. Students were instructed to build a speech amplifier in the system using an LM386 with a gain of 190. Figure 6 shows the construction of a signal conditioning portion that uses a microphone as the speech input.

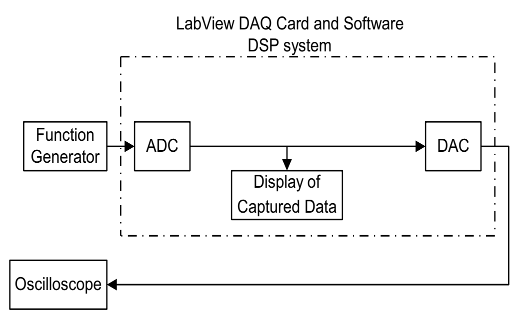


Figure 5. Real-Time Data Capture

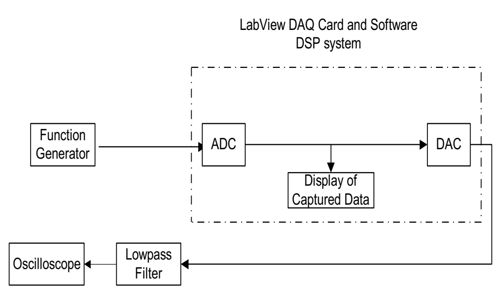


Figure 6. Verification of the Audio Amplifier

Figure 7 shows that students had to design and insert a second-order low-pass Sallen-Key Filter with a cut-off frequency of 3400 Hz in the acoustic system.

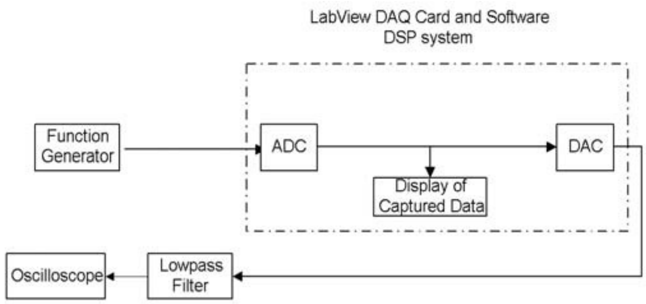
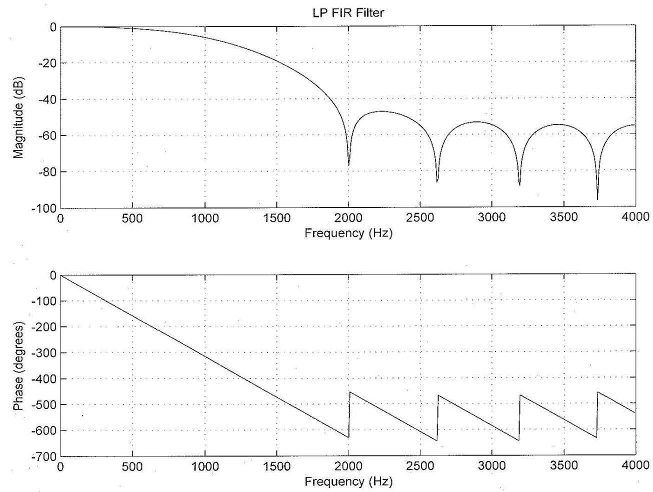


Figure 7. Low-Pass Filter in the Speech Channel

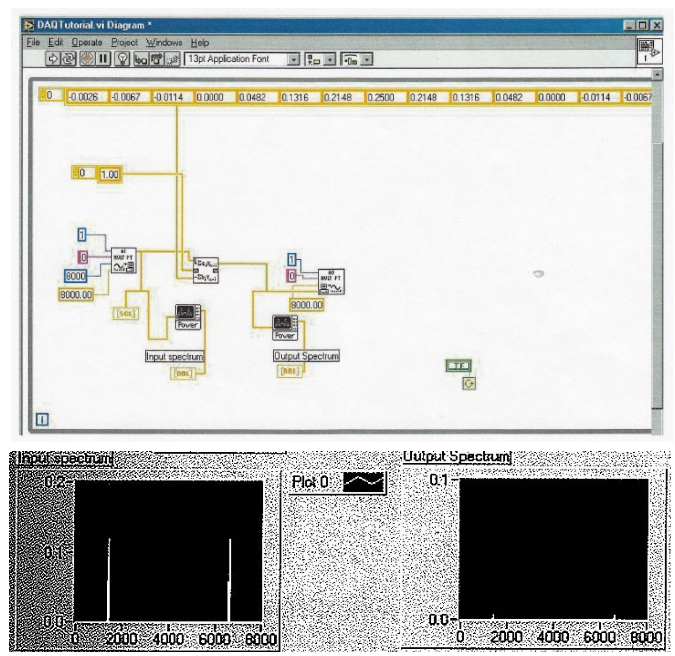
First, students were asked to apply the Hamming window method to design an FIR low-pass filter using MATLAB; Figure 8(a) shows its frequency response. Next, they were asked to load the filter coefficients to an FIR filter generated in LabVIEW from MATLAB; Figure 8(b) displays the filter. The filter had 25 taps, a cut-off frequency of 900 Hz, and a sampling rate of 8000 Hz. Therefore, the high-frequency noise mixed in the audio signal could be easily removed after low-pass filtering in the speech system.

Students were asked to design an IIR band-pass filter using the BT (bilinear-transform) method and MATLAB; Figure 9(a) shows the filter. This is a second-order digital filter passing frequencies in the range of 1100 Hz to 1500 Hz, with a sampling rate of 8000 Hz. Students then loaded the obtained filter coefficients from MATLAB to a digital filter produced in LabVIEW; Figure 9(b) shows the filter. Figure 10 shows that, after the completion of the signal processing, students were asked to construct an entire acoustic system. Figure 11 shows a picture of the hardware board and layout.

In order to test the system's performance, students had to input a voice from a microphone and test the audio output at a speaker. Then they could examine the different filter designs by feeding speech at various frequencies: for example, since a low-pass filter only passes low frequencies but stops high-end frequencies, it makes an audio signal sound muffled; however, a band-pass filter only passes a narrow range of frequencies, so it makes the acoustic signal sound watered down. This real-time hands-on project can be summarized as follows: a) start with a basic speech transmission channel; b) insert a designed audio amplifier to enhance the audio signal; c) design IIR or FIR digital filters using MATLAB; and d) verify the designed low-pass or band-pass filters and spectra of the input and output signals by LabVIEW. Finally, students could compare the calculated spectrum of the original voice to that of the filtered voice, and then compare the calculated spectrum of the original voice to that of the filtered voice. Meanwhile, students examined the filtered speech by listening to the processed sound and comparing it with the original speech.



(a) Magnitude and Phase Response

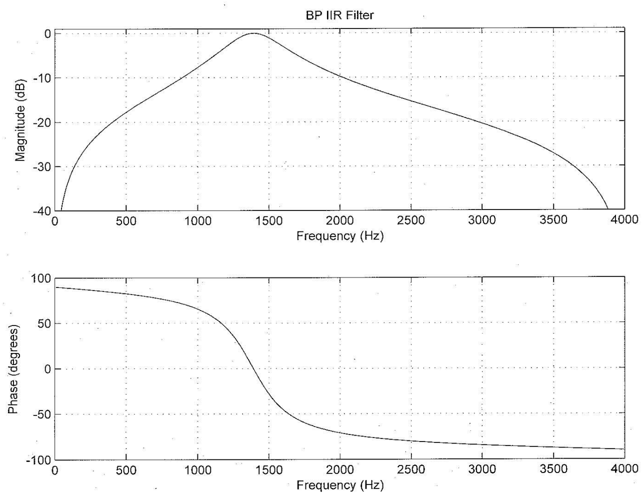


(b) LabVIEW Results

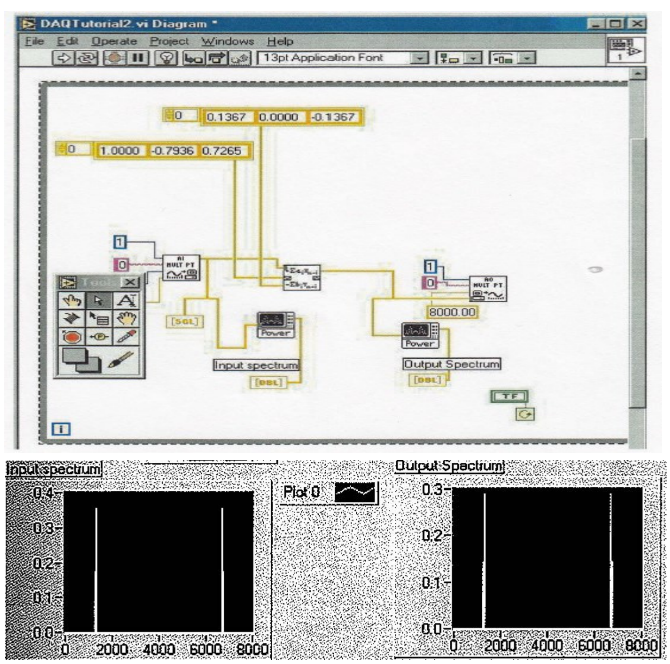
Figure 8. Low-Pass FIR Filter

Possible Improvement

Based on the authors' experience from teaching hands-on courses, all of the class projects containing real-time processing topics—such as closed-loop system analysis, data acquisition and processing, digital spectrum analysis, and FIR and IIR filter simulations—were considered to be adequate. The course materials were well covered and delivered with an emphasis on real-world applications, as opposed to intensive mathematical development. On the other hand, based on current industrial trends, the course could be improved by introducing more real-time systems such as motor control by a sensor, adaptive techniques, sub-band coding applications, and wavelet coding applications. To enhance the lab contents, more advanced data processing platforms with multi-channel ADCs and DACs could be introduced, so that more real-time laboratory projects could be developed.



(a) Magnitude and Phase Response



(b) LabVIEW Results

Figure 9. Band-Pass IIR Filter

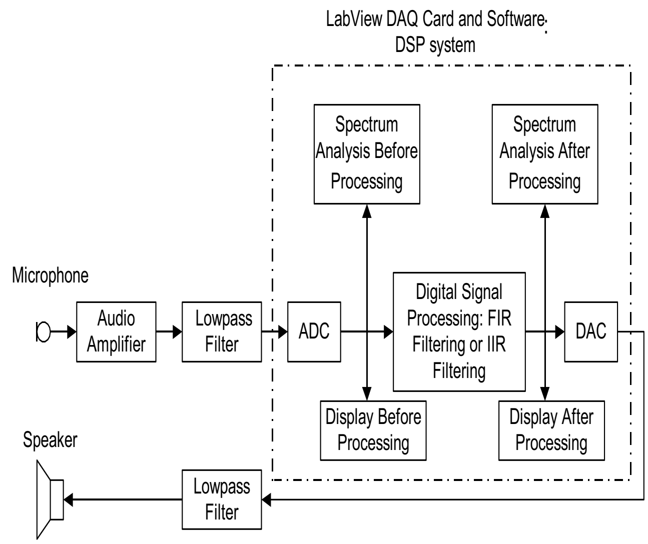


Figure 10. The Complete Audio Processing System

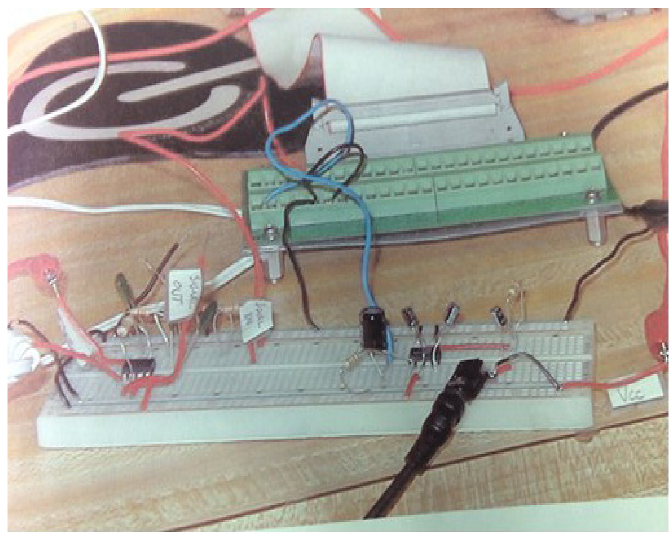


Figure 11. Hardware Layout

Conclusions

The electrical and electronics industry has shown a rapid and consistent demand for engineering/technology students to master advanced and real-time processing techniques. Therefore, the traditional approach of teaching DSP topics using heavy mathematical derivations is no longer appropriate. In this study, an innovative methodology was developed with mathematical simplifications equipped with working examples, LabVIEW and MATLAB simulations, and hands-on projects. Thus, both engineering and technology students were able to master DSP concepts and then apply their obtained knowledge towards their careers and future technical practices.

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STUDENT REFLECTIONS ON AN ENGINEERING TECHNOLOGY CAPSTONE COURSE: TECHNICAL, TEAM FORMATION, AND COMMUNICATION ISSUES DEALING WITH AMBIGUITY

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Abstract

Student input is insightful when reviewing an assignment, project, or otherwise engaging task within the framework of a required course. Most research dissects instructor observations and neglects to consider the student aspect and reflections, as they relate to their experiences navigating the capstone course. An undergraduate engineering technology program at a well-established land grant university in the Midwest requires students to complete a two-semester series capstone course. This course, as well as others in the same genre, works cooperatively with relevant industry to provide students with projects appropriate to their skills and abilities. The course is usually administered with the first part including a proposal or project definition, and the second part is the implementation or solution phase. The intention of capstone courses is to apply knowledge acquired during tenure at college, provide students with an understanding of the industrial workplace, to expose students to the ambiguity and uncertainty of engineering projects, and to hone their problem-solving skills within the context of their chosen career.

Student thoughts and concerns were examined using the lessons learned from an engineering technology capstone course that was provided as part of the final course assignment. Each team provided input that ranged from technical issues to team-formation concerns to dealing with ambiguity. A qualitative content analysis was completed on the essays extracted from the final course assignment and analyzed for content, with the intent of sharing through scholarly work and dissemination. It is the authors' intent to inform practice of the various issues brought forth by the aviation technology students.

Introduction

Participating in a capstone course provides students with the opportunity to gain experience interfacing with the professional world, as it relates to their chosen careers, and to practice using the knowledge and skills acquired while pursuing their degrees [1, 2]. Some may argue that an internship is sufficient for this purpose; however, the capstone experience is guided by faculty and structured to support learning. Further, administration may use the capstone course to assess the degree program's strengths and weaknesses with an amalgamated analysis approach [3]. Participating in capstone courses is also required by many accreditation bodies such as ABET: "Graduates of baccalaureate degree programs must have a capstone or integrating experience that develops and illustrates student competencies in applying both technical and non-technical skills in successfully solving manufacturing problems"[4]. The activities required by the capstone course must provide "assurance that a college or university program meets the quality standards of the profession for which that program prepares graduates" [5].

The authors intend to provide a basic interpretation of student insight into this particular engineering technology capstone yearlong course. While capstone courses are used worldwide, it is best to see what lessons learned exist in one group of students in order to expand future work for other capstone courses. The result of this current study will be disseminated in order to provide insight into the students' experiences at the end of their undergraduate studies and to further understand the students' development in the final states of their studies and if they are prepared for the challenges of the industrial workplace.

Background and Literature Review

Completed research on capstone courses generally goes to great lengths to examine instructor observations or results of assessment [6-8]. Few researchers consider the student aspect and reflections as they relate to their experience in the capstone course [9]. Review of relevant recent and past literature supports this assertion. In the case of Dunlap [9], students were required to complete a journal, take the General Perceived Self-Efficacy Scale [10-14] pre- and post-problem-based learning experience, and include a reflection in the final assignment. The intent of this study was to triangulate the materials that students were generating and synthesize the student experience; findings showed that students experienced increased confidence, but some were also concerned about their lack of experience, which became evident as they progressed through the project. The few other authors, who considered the student perspective, focused on team dynamics and the issues confronted by students having little or no experience working in a team environment [6, 15].

Since work done on the student perspective is limited, and data have been assimilated by observation, summation of reflections, or survey, the current authors chose to use the Content Analysis Method [16]. This method is used to evaluate the Lessons Learned document generated at the end of the two-semester session, as part of the final project document.

Content Analysis Method

The Social Science Research Council's Committee on Linguistics and Psychology sponsored a conference in content analysis in 1955 [16]. At this conference, attending researchers discussed how best to analyze data that are provided via discussion and written word. This means of analyzing written communication is what some consider the "essence of human behavior" [16]. Many refer to this method as content analysis, others use a slightly longer term of qualitative content analysis [17], while yet others refer to this method as quantitative content analysis [18] and refute the use of one singular method for analysis of reflective essays. These were the two most common areas of observation considered important by the researchers at the 1955 conference [19].

The definition of qualitative content analysis by Schrier [17] is three-fold. The three components are a) systematic method, b) flexibility, and c) data reduction for interpretation. Using this interpretation and the information provided by Krippendorff [16], the following pieces were chosen to interpret the Lessons Learned documents from the engineering technology course. The research question from this current study is:

> What do the students in the year-long engineering technology capstone course learn throughout the semesters based upon their projects, interactions with classmates, industry representatives, the instructor, and available resources?

The data were collected and the analysis was done by subjecting the text provided in these sections to a variety of diagnostic means. These means were chosen based upon the material available in the documents, which is the flexibility of the method based upon the available data. Finally, the data were reduced by running the text through word and phrase counters, and looking at frequencies. The data were then used to reduce the smaller words, such as "the," "for," and "like" to further reduce the data per the method. Discussion and conclusions ensued from the findings in the chosen methods.

Methods

Using the content analysis method, all of the data were reviewed. The reflections were reviewed together and separately by student cohort, developing inferences of the authors' intent by finally comparing the groups of reflections by reading, comparing, and then reducing the data.

Research Site and Participants

There were 40 students in each course. The majority of these students were 20-22 years old, with few exceptions of older students, who were in the process of a career change or working towards job advancement. The instructor revealed that around 25% of the students shared that either they transferred from engineering programs because there was too much math, or they had the impression that they had a sedentary career in front of a computer. For the balance of the students in this class, it was not clear why they chose the aviation technology program. Most said it was because "all my friends went to college." Many students in technology are interested in a hands-on approach to education versus theoretical learning. Few of these students were exposed to problem-based learning and even fewer had the opportunity to manage their own time and projects.

Analysis Description

Initially, the aggregate input from two distinct groups of students was examined for word frequency and phrase frequency throughout. It is also worth noting that the students shared the same instructor, who applied the same pedagogical approach with identical course requirements. The data were examined together and then separately by semester. This first step provided guidance to the authors on how to tailor a systematic methodology for examining the material. Use of the Qualitative Content Analysis methods suggest that, through the flexible nature of this kind of analysis, tasks such as these are performed while developing a better idea of the content of the written text. Based on the findings of the word frequency analysis, it was deemed appropriate to perform a phrase frequency analysis, and then finally review the data using computer tools, including NVivo to perform qualitative analysis on text. As with all qualitative analysis approaches, the findings in this study reflected only this particular group of students, as previously described. However, it allows quoting Becker and Geer [20]:

> The most complete form of the sociological datum, after all, is the form in which the participant observer gathers it; an observation of some social event, the events which precede and follow it, and explanations of its meaning by participants and spectators, before, during, and after its occurrence. Such a datum gives us more information about the event under study than data gathered by any other sociological method. Participant observation can thus provide us with a yardstick against which to measure the completeness of data gathered in other ways. (p.28)

Results and Findings

The authors went through the reflective essays by reading, developing inferences, and reducing the data to further understand the students in these two independent courses. The interpretation of what students wrote, as well as how they expressed themselves using technical language, formative terms regarding teams, communication issues, and dealing with ambiguity, is the primary focus of this section. The first section focused on what was found as the reflective essays were read.

Reflective Essays

Reflective essays were reviewed and the path of these essays was deemed to be directed at a few topics. Students were given a very ambiguous assignment, leading to a broad open-ended assignment completion. Overall, students were focused on the team and what they were doing in the capstone course. They focused on time, sometimes defined as such, and in other instances by semester, or other similar terminology. Most of the verbiage was high level, and expressed issues with the project or the team, leading the authors into the stage of developing inferences based on what they read.

Developing Inferences

The essays focused on a few different matters, including an impossible scope, which alluded to student confusion or difficulty with an open-ended or ambiguous topic. While reviewing the first cohort's reflections, students seemed to have issues with planning, purchasing items with differing lead-time, and shipping requirements. These issues lead students to discuss issues with time management and meeting deadlines. Many of the students suggested that if they could do the project over, their greatest focus would be to improve time management or scheduling of their time in project steps and completion. The teams identified communication as an issue with the members, which also led to comments regarding time management. Some teams lamented that their teams developed goals that were too broad and unattainable.

The second semester's reflective essays focused on similar problems and issues, however they stated that they should have begun the project by investigating more means to make the final project instead of choosing one and creating issues with completion, cost, and assembly. They also pointed out that the sponsors were quite busy during the last months of their project, making completion difficult. This group of students mentioned that it would have been helpful had they considered plans for setbacks. Solving some of the problems they ran into was much harder, due to the lack of forward planning. While the inferences are leading, reducing the data into quantifiable observations aids in the interpretation and combination of concepts students found important enough to include in these reflective documents.

Data Reduction

The first step was to use the program available online at www.wordle.net. It graphically represents the content of text providing a word frequency analysis. Figure 1 shows the first available aggregated data from the lessons learned-section of the capstone course final report.

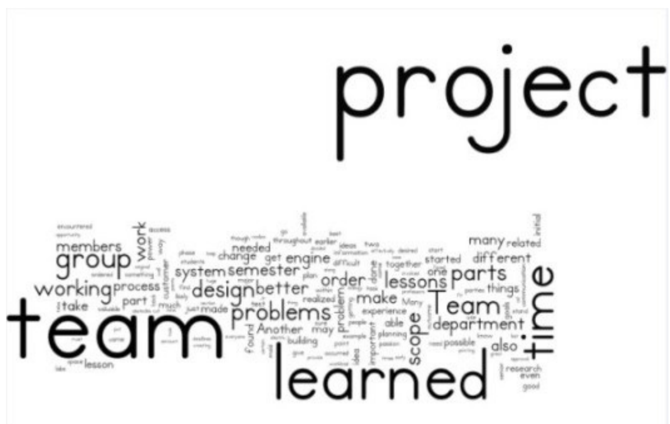

Figure 1. Aggregate Lessons Learned Data

Finding that this, in and of itself, did not indicate much other than project, team, learned, and time were of importance in the text; therefore, individual semester data were analyzed and compared to Figure 1. Figure 2 shows Group 1 of the available data, while Figure 3 shows Group 2.

Figure 2. Group One Lessons Learned Data

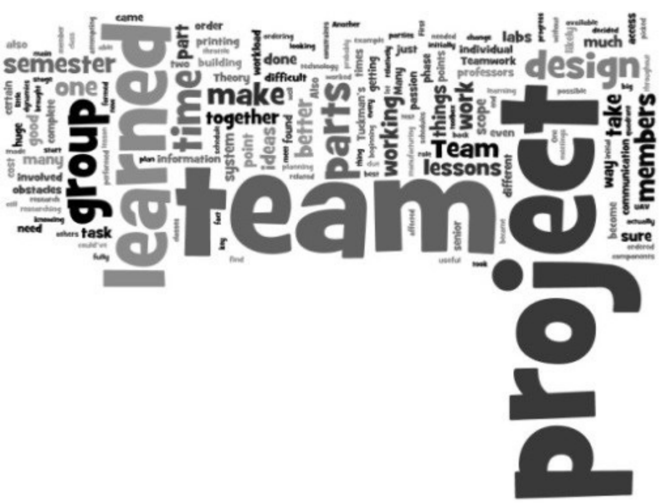

Figure 3. Group Two Lessons Learned Data

Figures 1-3 are based on individual word frequencies. Many of the words, although combined in Figure 1, show that the groups of students considered many of the same things important in their capstone experience. To further the examination of content, via content analysis, a word count was executed to compare the students' word usage independently. Table 1 compares nouns and action words from both semesters. The words shown in this table are those that were the first nine words appearing the most in the word count of all essays.

Table 1. Comparisons of Groups by Word Count

Group 1	Group 2
Project	Team
Team	Project
Learned	Learned
Problems	Group
Engine	Parts
Department	Design
Working	Semester
Scope	members

Further analysis was done to evaluate phrasing that may be helpful in understanding the content of these data. Table 2 was developed to give a generalized comparison of phrasing for 5-word count phrases, and Table 3 for four-word count phrases. A generalization comparing the similarity of five- and four-word phrases, such as "had to do it over" and "to do it over again," can be found in both tables.

Table 2. Comparisons of Groups by Phrases [21]

Group 1	Group 2
the time it takes to	the team learned
we had to do it	we did a good job
the team had to do	to do this project again
the scope of the project	that could be affected by
in order to compensate for	did a good job distributing
it is important	

Table 3. Comparisons of Groups by Phrases (4 word count)

Group 1	Group 2
had to do it	we were able to
to do it over	the team learned that
time it takes to	that could be affected
the team had to	team learned communication
the team also learned	many lessons were learned
the scope of the	good job distributing workload
if the team	do this project again
in order to compensate	

Discussion

Comparing and contrasting graphic representation of the reflection essays provided the authors with an understanding of the groups' differences. The words that were most evident with the aggregated group were *project*, *team*, and *learned*, with the word *project* shown as the largest, and even set off to the side, showing the significant difference of the word. Reviewing the groups separately, both showed the word *project* to be the most pronounced, but not set off to the side. For Group 1, the word *project* was not as differentiated by size or position as in the aggregate and Group 2. The words *team* and *learned*, along with *time*, *problems*, and *department* in Group 1, and *team*, *learned*, and *group* in Group 2 provide the reviewer with a greater understanding of the significance of the project discussion in the essays. It became evident that these student teams found significance in things such as *team*, *learned*, *time*, and *problems*, essentially sharing how the projects affected the teams, how they learned, the lack of time, or time to complete the given problems. When reading the essays, this was what was found, not providing any additional insight other than the significance of the project to the team.

Further review through data reduction using word count and sharing the words side-by-side in Table 1 allows a comparison of word significance in the essays. *Team* and *project* were interchangeable, as far as being the first two words and placed opposite one another in the comparison. The third word of significance was the same—*learned*. After the third word, the words no longer aligned, nor were they able to be easily compared. While reviewing Tables 2 and 3, the reviewers consulted Moon's [22] handbook and found that, for a writer to exhibit deep reflection, they must clearly state what was learned and changed. Using this definition of deep reflection, the statements in the tables, such as "in order to compensate for," "the team learned," "to do this project again," "to do it over," the team also learned," and "to do this project again," demonstrate deep reflection in the examined reflective essays.

The majority of students managed to achieve deep reflection, as evidenced in the reflective essays. However, the question remains regarding what was learned by the students that was technical, was formative from a team standpoint, and communicative. Assessment criteria were developed by Reidsema and Mort [23] that provide guidelines on how to analyze reflective writing. They provide an assessment and demonstrate use in the evaluations and determination of deep meaning in reflective writing.

Usage of Technical Terms

While technical words were used, due to the varying projects done in this capstone course, most were only used one or two times to describe student reflection on the projects, most likely explaining why the most commonly used words included project, team, and learned, as each of those was common to all of the projects. Another reason was that the students concentrated mainly on the project management side of their efforts, relying on drawings, tables, and graphs to communicate other aspects of the projects. The students were comfortable with their technical knowledge, because this is what most programs successfully emphasize. The project management side and ambiguity were less familiar to the students and caused more confusion.

Team Formation

Team formation is critical to the successful completion of any project. In this current case, student reflections said something about "the group" or "the team." General discussion in the essays provided a distinct impression that the team members, while good friends in some cases or people not getting along in other situations, were able to work together and develop a functional team. Review of the essays revealed that the students defined a "sound" or "functional" team, where the members agreed on a project plan and worked towards that end. Another lesson learned was that it is not always easier to work with friends. One team had an issue with meeting more than once a week, resulting in team formation issues. They overcame that by being careful with what they did and when and how they interacted with others. Other teams had issues with becoming teammates with "non-friends" and the issues that arose due to motivation and capabilities. Finally, a couple of teams pointed out issues with low productivity and motivation, due to conflicting priorities as they neared the end of their senior year.

Communication Issues

A review of the essays brought forth the issue of communication, or lack thereof. Many teams had communication issues with team members unknown to one another upon team formation. Their communication style and methods were so different in some cases that rifts in team formation became evident and had to be worked out. Again, the programs concentrated more on technical skills and less on project management, where many tools were available to establish, use, and improve communication. One of the examples could be meeting minutes. The students met on a regular basis, but rarely wrote down their discussions, deadlines, responsibilities, and plans. As a result, many details, as students say, "fell through," were never done, or were finished but with a delay. The project was delayed and caused confusion and anxiety. The results of this study demonstrate that planning and communication are the cruces of successful teamwork. Often, this population of students is neglected or combined with other much larger study populations, so describing the analysis of the capstone reflections provides support that engineering technology students have similar issues to their peers in teamwork. When examining the differences between engineering technology students and other student groups in STEM, this is not always the case.

Conclusion and Future Directions

Overall, the students in this engineering technology capstone course learned that planning and learning how to communicate with one another were critical to the success of a team. These students produced deep reflections and, while not using many technical terms, did share information regarding the formation of their teams and growth in personal interaction, which included modes of communication. While examining the word counts, comparing them from one group of students to another, a common concern regarding communication and collaborative skills emerged. Students did not exhibit these skills and gain an understanding of their importance in teamwork situations.

The end of the semester, senioritis [24] becomes an issue affecting motivation and completion of capstone projects. This revealed that it is imperative that serious project work should take place earlier in the semester to ensure that it is not affected by conflicting priorities and issues caused by the end of the semester for graduating seniors. The study also suggests that learners be exposed to project management methods and tools earlier in their tenure at college. It is crucial to offer more project- and problem-based courses with a greater level of ambiguity to prepare students for the workplace.

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A THERMO-FLUID CURRICULUM FOR ENGINEERING TECHNOLOGY: LEARNING OUTCOMES AND INDUSTRY NEEDS

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Abstract

In this paper, the authors propose a thermodynamics curriculum that is suitable for a mechanical engineering technology program. The proposed curriculum is aimed at striking a balance between accreditation requirements, student expectations, and industry needs. The proposed curriculum also incorporates active student engagement. The assessment of some of the learning outcomes from a junior-level course was used to evaluate student performance in one such course. Active feedback was collected from industry partners in the form of a survey, in order to determine the suitable course content in subject matter pertaining to thermo-fluid areas for an engineering technology program. Results of this survey showed that industry puts less value on theoretical knowledge and more value on useful skills relating to instrumentation and testing, when hiring technology students.

Introduction

Engineering technology programs typically distinguish themselves from engineering by emphasizing hands-on training with a focus on engineering applications. Employers expect (mechanical engineering) technology graduates to be capable of working in such areas as manufacturing, maintenance, production, process, and quality [1]. Technology students are also expected to be suitably prepared for positions related to product and laboratory testing. Thermodynamics, fluid mechanics and heat transfer (thermo-fluid) classes employ mathematics and physics to form a strong theoretical base for the students, but it's up to the student to apply that base to real systems. This theoretical content may not be suitable for an engineering technology curriculum, and does not supply the practical skills expected of a technology graduate. Furthermore, these courses require multiple prerequisites in calculus and calculus-based physics that are typically not included in an engineering technology program [2].

The similarities and distinctions between an "engineering" and an "engineering technology" program have been a frequent topic of discussion for the past few decades [3, 4]. While it is commonly agreed that a technology program should emphasize application and implementation, there is little consensus on the content of the specific curriculum that should be included in a technology program. The added challenge for a thermo-fluid sequence (thermodynamics, heat transfer, fluid dynamics, etc.) is the highly theoretical nature of these courses and the necessary emphasis on mathematics and physics related to the subjects. It is up to the student to translate the theory into practical skills, which is atypical for a technology program. These courses also make extensive use of mathematics and physics associated with the design and analysis of thermo-fluid systems, requiring calculus and calculus-based physics as prerequisites. Since many of these calculus and calculus-based physics courses are not required in an MET curriculum, it is important to deliver a thermo-fluid curriculum that is relevant to an MET program and, at the same time, achieves necessary learning outcomes that meet industry needs and prepare students for career opportunities in these areas.

Project-based learning (PBL) is an established and effective method of teaching that is known to motivate students and enhance their learning of practical skills [5]. PBL incorporates projects into the curriculum that are often without guarantee of success (open-ended). Multiple creative solutions to a problem require students to make mature design decisions. This gives the student multiple opportunities to apply theoretical and practical concepts from the coursework and further teaches incorporation of project requirements and real-world constraints. Other skills not taught in traditional courses, such as oral and written communication, are also often gained through class presentations, project team interaction, and progress reporting. These skills are relevant to both traditional engineering programs as well as technology programs. The current authors argue that, by incorporating PBL, instructors can address several critical aspects of a technology program: application, implementation, and integration.

In this paper, the authors propose a thermodynamics curriculum that will achieve the necessary learning outcomes, while delivering course content that MET students are expected to learn during an undergraduate program. While the specific course title addressed in this current paper is "Thermodynamics and Heat Transfer," the heat-transfer portion, as well as the fluid-mechanics part, will be addressed in later studies. The content of the thermo-fluid curriculum is challenging for students, since they are not able to relate the content to other, more familiar, courses such as mechanics, strength of materials, etc. Some of the key components of the proposed curriculum include relating the content of thermo-fluid subject matter with other courses and emphasizing the relationship between the content and commonly used systems, such as refrigeration systems, augmented by the use of PBL. The proposed curriculum particularly focuses on project-based learning and acquisition of hands-on skills. Industry needs were also analyzed by using a survey instrument.

Proposed Curriculum and Expected Learning Outcomes

This thermo-fluid curriculum was centered around a table-top-size, working demonstration of a thermodynamic cycle. Similar proposals have been made in the literature, but not widely implemented, and not with incorporation of PBL concepts [6, 7]. A refrigeration system was chosen for this study, due to its availability and relatively low cost. Additional emphasis was placed on the measurement and instrumentation of measurable system parameters, such as temperature, pressure, and flow rate. This is because typical technology students are more likely to find these skills more applicable in their employment upon graduation. For the course, a real vapor compression refrigeration system was built and instrumented with pressure transducers and thermocouples. Another system was cut apart to show the internal components of the compressor, expansion valve, heat exchangers, etc. to the students. This exposure was expected to give the students context for the typical piston/cylinder-type thermodynamics problems, the heat-exchanger problems, and flow device problems to a system that they could relate to. This system is shown, diagramed, and discussed on the first day of class with all parts of the system related to the chapters in the book, and the laws of thermodynamics.

It is expected that the first three laws of thermodynamics will be easier to understand when they are related to a real-life system instead of abstract theory. For instance, the first law relates the electrical power needed to compress the Freon to the cooling energy one could get out of the Freon. The zeroth-law allows temperature measurement, etc. The tables and ideal gas equations of state relate pressure and specific volume to temperature and, therefore, energy. Subsequently, in the context of systems and cycles, the second law is introduced showing that heat has to flow from higher to lower temperature, thus demonstrating that a cycle would not run without a hot and a cold reservoir. In addition to this roadmap of the thermodynamics course presented here, students are tasked with assignment problems relating to the refrigeration system, so that they can see what will be necessary to solve these problems. This can be done in a team setting with an emphasis on problem-solving skills.

The fundamentals of heat transfer are covered after wrapping up the thermodynamics content. The basics of heat transfer are then covered with a focus on air-cooled heat sinks, electronics cooling, and instrumentation required for measuring variables associated with heat transfer. Table 1 shows the complete course content. The thermodynamics content was emphasized in the current study, however the heat-transfer content will be taught with a similar methodology. In the short time allocated for the MET students to learn the basics of heat transfer, only the most basic and practical skills can be covered. For example, the topic of conductive heat transfer leads to the guarded heat plate method of conductivity testing, and the concept of a Q-meter (simple device for measuring heat flow). Convection is explained on a very high level; for conduction, convection, and radiative heat transfer, empirical explanations and associated analogies such as thermal resistance are the focus.

Assessment Results and Data Collection

Local industry professionals, with an interest in hiring engineering technology students, responded to the following survey questions. These professionals were members of Western Carolina University's Industrial Advisory Board, which consists of representatives from nine local businesses. Many of these professionals are managers or directors and hire students graduating from the technology program. Seven of the nine advisory board members participated in the survey. The purpose of the survey was introduced with a 5-minute presentation, then participants were given 15 minutes to respond to the following statements and questions.

1. Technology (ET or MET) students should learn practical skills in a thermodynamics course.
2. Technology (ET or MET) students will greatly benefit from learning about instrumentation, equipment and sensors in their program of study. Technology (ET or MET) students will benefit from learning about design of a test setup involving thermo-fluid systems.
3. Technology (ET or MET) students need to learn about data collection and data processing in their undergraduate program.

Table 1. Content for Thermodynamics for Technology Students

	Content	Student Deliverables
Week 1	Demonstration and description of the components of a VC refrigeration unit	Diagram of the system with corresponding book chapters labeled on each component
Week 2	Class meets in teams of 4 to find subsequent assignment problems that relate to the refrigeration system (R-134a compressed in a piston/cylinder). Instruction begins on topics needed to solve the problems, as well as basic concepts and dimensions.	Teams write down what is given in the problems and what needs to be determined. Student-chosen teams work outside of class on assigned problems leading up to solving later chapter problems.
Week 3	Basics of energy, First Law, efficiency	Assignment problems
Week 4	Phases of matter, specifically gasses and liquids	Assignment problems
Week 5	Analysis of closed systems	Assignment including those identified in the first week
Week 6	Analysis of closed systems (continued). Students work in teams for part of the class to solve problems identified in first week.	Assignment including those identified in the first week
Week 7	Class meets in teams of 4, to identify problems in the next chapter on flow work, that pertain to components of the refrigeration system (heat exchangers and expansions).	Teams write down what is given in the problems and what needs to be determined. Student-chosen teams work outside of class on assigned problems.
Week 8	Analysis of control volumes and flow work	Assigned problems
Week 9	Second Law, cycles, and efficiency	Assigned problems
Week 10	Entropy and exergy	Assigned problems
Week 11	Mechanisms of heat transfer	Assigned problems
Week 12	Steady state conduction	Assigned problems
Week 13	Transient conduction	Assigned problems
Week 14	Convection	Assigned problems

4. Usage of thermocouples, RTDs, flow meters, flow channels and wind tunnels should be learnt by technology (ET or MET) students.
5. The focus of thermo-fluid courses for ET or MET students should be on testing and product development instead of analysis.
6. Technology (ET or MET) students should have a theoretical understanding of heat transfer and fluid dynamics.
7. Learning about the application of thermal and fluid systems is important for technology (ET or MET) students.
8. Technology (ET or MET) students should learn practical HVAC skills in their undergraduate program.
9. Technology (ET or MET) students should learn practical power generation skills in their undergraduate program.
10. Technology (ET or MET) students do not need to have a rigorous theoretical background in thermodynamics.

Three open-ended questions were also included in the survey. These questions are as follows:

1. Does your company hire technology graduates in the areas of thermodynamics, thermal systems or fluid systems?
2. What are your expectations from a technology graduate specific to thermodynamics?
3. What are your expectations from a technology graduate specific to fluids and heat transfer?

The purpose of the open-ended questions was to have some qualitative information that could be used to comprehend the responses from the members of the industrial advisory board. Figure 1 illustrates that there was 71% strong agreement among participants (Likert scale 1, “strongly agree”) or agreement (Likert scale 2, “agree”) regarding incorporation of practical skills in a technology-appropriate thermodynamics course.

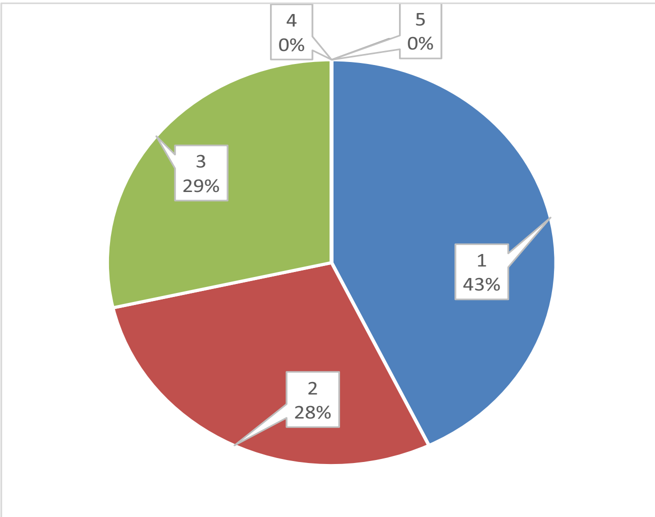

Figure 1. Survey Response – Statement # 1 (*Technology students should learn practical skills in a thermodynamics course*)

The response to Statement # 1 was further supported by the response to Statement #2 in Figure 2, with 86% indicating strong agreement among participants (Likert scale 1, "strongly agree") or agreement (Likert scale 2, "agree") regarding incorporation of instrumentation, equipment, and sensors in the curriculum.

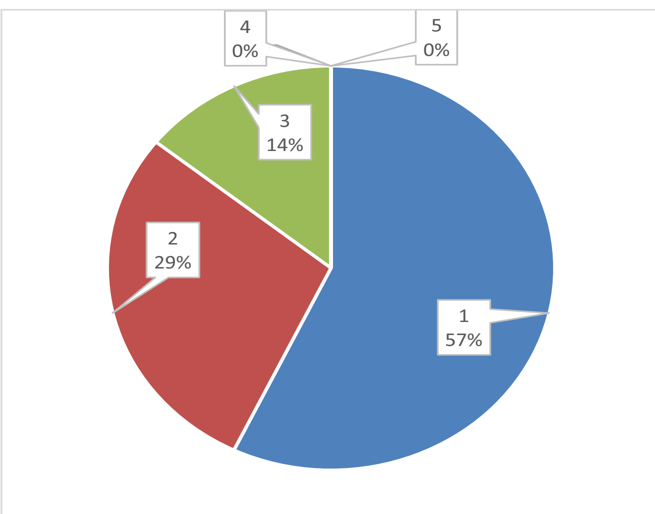

Figure 2. Survey Response – Statement # 2 (*Technology students will greatly benefit from learning about instrumentation, equipment and sensors in their program of study*)

Figure 3 indicates that there was strong agreement among participants (Likert scale 1, "strongly agree") or agreement (Likert scale 2, "agree") with incorporation of thermocouples, flow meters, wind tunnels, etc. in the class (Statement # 5), with 71% of the participants agreeing or agreeing strongly.

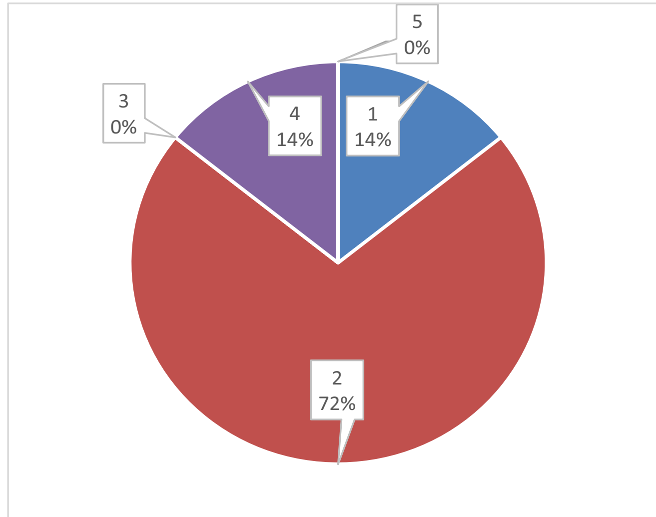

Figure 3. Survey Response – Statement # 5 (*Usage of thermocouples, RTDs, flow meters, flow channels and wind tunnels should be learned by technology—ET or MET—students*)

A large majority of the participants, 86%, felt that technology students do not need to have a rigorous theoretical background in thermodynamics. This can be seen from the response to Statement # 11, shown in Figure 4.

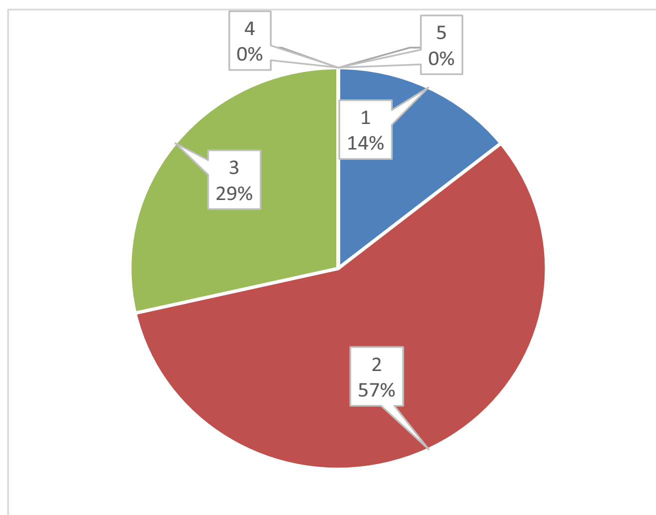

Figure 4. Survey Response – Statement # 11 (*Technology students do not need to have a rigorous theoretical background in thermodynamics*)

In summary, responses to the questionnaire indicated that the members of the advisory board believed that technology students would greatly benefit from the inclusion of content that involves practical skills in instrumentation, sensors, HVAC, general laboratory, and product testing skills appropriate to thermo-fluid industries. The members of the advisory board also seemed to indicate that a rigorous theoretical background in thermodynamics, thermal systems, and fluid systems is not necessary for technology students. Some of the responses to open-ended questions included statements such as: "some familiarity with basic principles of thermal systems is expected," "technology graduates should have an understanding of state transitions, latent heat, fluid flow," "students do not need theoretical rigor but an applied understanding." This is consistent with the curriculum that is being proposed in this paper as a first course in thermo-fluids for technology students.

Discussion and Conclusions

From the survey responses, it is clear that regional industry representatives are looking for more practical skills in graduates from a technology program, and place less value on a theoretical understanding of thermodynamic principles. The responses indicated that technology graduates would be performing functions related to test and measurement rather than design. This not only supports the authors' claim that a technology-centric course in thermodynamics should be based on commonly used and familiar systems, such as HVAC, but also supports inclusion of active learning techniques that develop useable skills. These skills could include instrumentation techniques and test methodologies, which would also give students hands-on insight into components under more theoretical investigation. Future work will include implementation of the curriculum, and assessment by collecting test scores and student assessment data, and comparing them to old curricula.

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Biographies

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Optimization of a Pin-Joint Machining and Assembly Process

Dana Ingalsbe, Jacksonville State University; Chris Marker, Jacksonville State University

Abstract

The manufacturing process for assembling pin joints on fixtures and round parts requires precision machining for critical press or slip fits. The process can be particularly costly when working with metals that do not lend themselves to complex machining and welding. The purpose of this study was to develop new ways to reduce the time and cost of manufacturing these type of joints. There are several ways pin joints can be assembled. These are usually dependent upon the materials used and the tolerance of the joint location. Screw connection, press fit, pinned connection, and retaining compound are the most common methods. Each joint type has its benefits and disadvantages. Screw connections may not be possible in very hard materials, while press-fit joints may loosen in heat-cyclic applications. Pinned joints require many manufacturing steps and can be quite costly. Retaining compounds must be selected properly and require the correct base materials, geometry, preparation, and assembly procedures to function correctly.

In this paper, the authors propose the use of a combination of joint types to create a hybrid physical and chemical bond to evaluate if a joint can be developed with simple manufacturing procedures, thereby reducing the possibility for error in manufacturing and assembly. The end goal is to increase the reliability of the joint, while reducing the cost of production. The joint types explored are applicable to non-weldable, dissimilar precision joints used in a heat-cyclic environment. The obstacles to overcome were expansion and contraction of dissimilar metals, reduction of steps in the manufacturing process, and non-uniform or incorrect compound thickness applications.

Introduction

Press-fit pins are used to locate parts requiring high-precision positioning. Press-fit (also called interference fit) pins may also be used to permanently affix two or more parts together. When a pin is used for location purposes, that pin is permanently affixed to a stationary host on one side of the joint. The other side of the joint consists of a removable member that is attached using a slip-fit joint, which is the hole that accommodates the pin, as shown in Figure 1. This is the common configuration for jigs and fixtures that require accurate placement over repeated use.

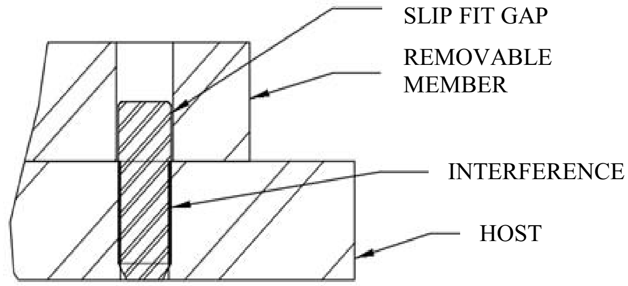


Figure 1. Typical Press-Fit/Slip-Fit Pin Joint

On the slip-fit side (removable half) of the joint, the hole accommodating the pin will be slightly larger than the outer diameter (OD) of the pin itself. This allows the part to slide on and off, while at the same time maintaining the correct location. The slip-fit gap is determined by the size of the pin used in the joint and the level of required precision. Typical slip-fit gap dimensions are on the order of thousandths of an inch, while slip-fit gap tolerances are on the order of ten-thousandths of an inch. Due to these narrow tolerances, the precision machining that is necessary to achieve accurate fit and joint placement increases the cost of producing fixtures and jigs with pin joints. When the joint is exposed to cyclic temperature conditions, the press fit can be compromised, weakening the joint by allowing it to move or pull out. Current practice demands a more complex joint, such as a cross -pinned joint, to maintain joint placement. It is therefore worthwhile to explore alternate methods for the production of joints with reduced manufacturing effort, while maintaining or improving the accuracy of the joint fit.

Literature Review

The focus of the literature regarding press-fit pin joints seems to be upon the optimization of joint strength (axial and torsional) rather than the achievement of precise pin placement. For example, Croccolo et al. [1] explored the use of industrial retaining compound in press-fitted joints (hybrid joints of aluminum and steel). The use of the adhesive was effective in increasing the performance of the joint when the coupling pressure of the joint was within the typical range of 40 MPa. In another study, Sekercioglu [2] used a genetic algorithm approach to determine that many variables, including surface roughness, temperature, and interference fit, among others, independently influence the shear bonding strength in an adhesively bonded, tubular joint. In an investigation examining the static strength of interference -fit hybrid joints, Croccolo et al [3] confirmed that the contribution of adhesive compound is indeed a significant contributor to the strength of the joint. The researchers in this case measured the static strength of interference-fit couplings assembled with and without adhesive compound.

While the focus of this current study was not on the strength properties of the pin joint, per se, the effectiveness of using a retaining compound was of interest to the authors. In this case, application of a retaining compound may help to maintain or improve the integrity of the joint, while at the same time decreasing the cost of joint assembly by reducing the amount of machining necessary.

Motivation/Industry Need

The need for a precision joint with reduced cost and error prevention qualities extends across most manufacturing industries. Pin joints are used primarily for location of removable parts that must maintain their original position after reassembly, eliminating the need for operator adjustment. The pins within the joint are permanently affixed to the host part. The pins then closely slip into the holes on the removable part, maintaining the correct location. This type of joint is commonly found in punch and die blocks used in presses and multi-piece molds used in the manufacturing of plastic parts. The largest application of pin joints, however, is in the manufacturing of machined and welded assemblies, and the assembly of multi-part products. Pins do not necessarily carry a load but are used to correctly locate the removable part with the host part. Pins may wear and become damaged, while functioning in the manufacturing environment. As a result, they must be periodically replaced, and this maintenance function causes downtime. Pins that move or are damaged result in bad parts or damaged equipment, a costly event for a simple part. A faster, lower-cost method for designing and building a secure pin joint is therefore needed to reduce the cost of building fixtures and jigs, as well as to improve the accuracy of positioning and reliability of the joint.

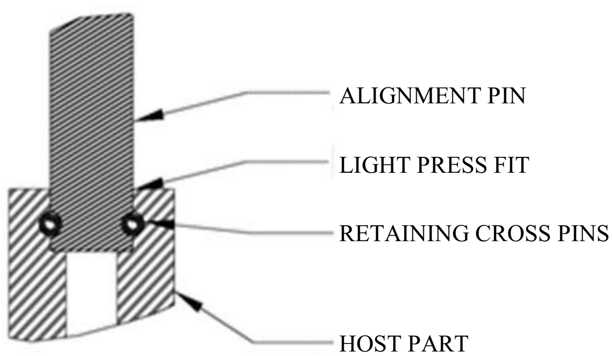
Manufacturing the joint can quickly become a costly operation. By its very nature, the joint is a precision feature, requiring time-consuming processes such as reaming. As punches and dies are often made of high-grade, difficult-to-machine materials, operations like threading become impractical. Many press and mold operations involve assembling the joints under high pressure and temperature. High-temperature operations, such as welding, make a simple press fit inadequate. All of these scenarios demand a more complex joint geometry and drive the cost of manufacturing upwards. Joint complexity determines the amount of time and effort required to replace the pin or pinned parts. There are a number of methods for attaching the pin to the host portion of the joint. Each of these methods can be accomplished in several ways, determined by part geometry and material. Table 1 summarizes the unique benefits and drawbacks of each method.

Table 1. Summary of Joint Connection Types

Joint Connection	Benefits	Drawbacks
Screw	Easily removed/ replaced	Does not withstand temperature cycling Requires more space
Press Fit	Simple machining process Accurate alignment	May not withstand temperature cycling
Retaining Compound	Reduced machining Resists temperature cycling	Ideal gap size necessary Precision alignment difficult
Cross-Pin	Allows accurate alignment Resists temperature cycling	Extensive machining necessary (expensive)

A screw connection may be used in easily accessible and machinable parts. It requires more space on the host than other joint types, and additional features such as countersinks are necessary for accuracy. Using a screw connection requires machining operations for drilling, tapping, and countersinking. Screw connections have a tendency to become loose under vibration and cyclic temperatures; however, screw connections are often used because they are easily removed and replaced. The most common joint connection is the typical press fit, which uses a precision-ground dowel pressed into a smaller precision-bored hole. The pin is held in place via friction caused by the compressive force of the part upon the pin. This is also called an interference fit. The accommodating hole is slightly smaller than the pin. The pin causes the host part to undergo plastic deformation as it is pressed in, greatly increasing the friction on the pin. Interference dimensions are dictated by the size of the joint and the material of the part and pin with a typical interference of 0.0002" for most steels. The location of the hole is critical as well as the tolerance of the hole, which is usually in the ten-thousandths-of-an-inch range. Standard tables, such as those developed by ANSI [4], have been developed that define the press-fit tolerance for most materials. When dissimilar metals are used, a press fit hole may not be sufficient to retain a pin when cyclic temperatures are encountered, or where the pin is subject to repeated tensile forces. Press fits are desirable because the machining process is relatively simple in comparison to other joint types.

Retaining compound joint connections use a chemical bond to hold the pin in place. The joint is a slip-fit joint, with the gap of the joint determined by the retaining compound used. The compound proposed for this current study was Loctite 620 green retaining compound. The retaining compound must be selected based on several factors: component materials, thickness range of the compound (which determines the ideal gap depth), and the operating temperature range of the joint. Helpful information regarding these variables may be obtained from the technical data sheets provided by the manufacturer [5]. A primer may be applied to increase the chemical bond strength, when non-reactive metals such as nickel alloys are used. One benefit of using a retaining compound is its ability to withstand temperature cycling, another is the reduced machining necessary. However, in the case of parts requiring precision press fits, retaining compound does not allow for precision pin alignment.



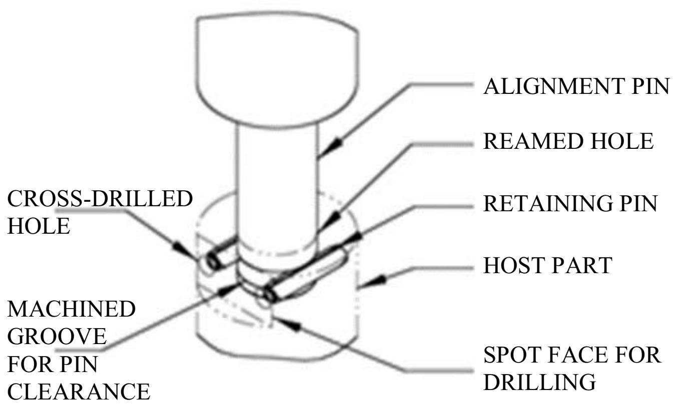


Figure 2. Cross-Pin Joint Construction

Figure 2 shows how a cross-pinned joint connection may be used when the geometry allows the alignment pin to lock in place. This joint style is stable in cyclic temperature environments but is costly to produce, due to the extensive machining that is required. The initial pin hole is drilled as a light press fit or tight slip fit, where the hole's OD and the pin's nominal OD may be of equal dimensions or share a gap of 0.0005". One or two cross-pin holes are then drilled through the part. A corresponding groove is turned on the pin. The alignment pin is seated into the hole, and then a roll pin is pressed into the cross-drilled holes to lock the alignment pin in place. This type of joint is only used when necessary, as the joint requires three pins and multiple fabrication steps. For the purpose of assembling a pin joint in the most accurate yet economical way possible, none of these methods alone provides both accuracy and economy. For this reason, it is necessary to propose a hybrid joint that combines the benefits of different joint connection types.

Proposed Joint Construction

A proposed hybrid press fit and retaining compound (hybrid) joint was anticipated to incorporate the alignment properties of a press-fit joint in conjunction with the retaining compound's ability to resist loosening under cyclic temperature conditions. The joint must incorporate simple, low-cost manufacturing techniques that allow the joint to be used in the same space-constrained areas where a standard press-fit joint can be used. Figure 3 shows how the hybrid joint was designed with standard dowel-pin geometry. A light press fit at each end of the joint is used to maintain true alignment. The OD of the pin will follow standard dowel-pin size and tolerance. The hole is drilled and reamed to standard press-fit dowel-pin dimensions.

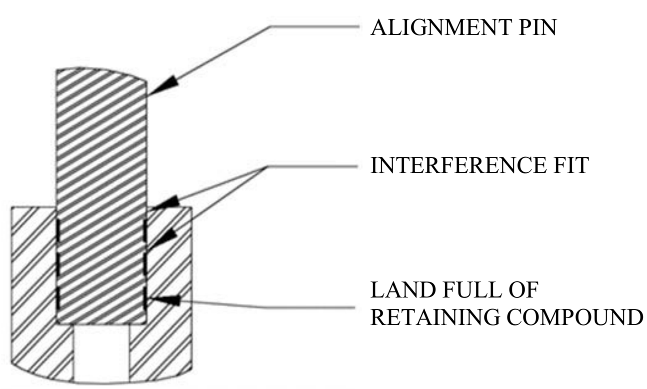


Figure 3. Proposed Hybrid Joint Design

In order to incorporate retaining compound, a series of lands that will act as pockets are added to the alignment pin. The lands are simple, flat-bottomed grooves, turned or ground into the face of the cylindrical surface. The lands are turned to the optimal depth of the retaining compound to be used, as recommended by the manufacturer, and provide for a controlled, even retaining compound thickness. In this case, a retaining compound depth of 0.008" for Loctite 620 was recommended by Loctite's technical data sheet [5]. The hole is drilled as a press fit. The pin is coated with the retaining compound and then pressed into the hole. The retaining compound is then allowed to cure for the time period recommended by the manufacturer.

Conclusion

The proposed hybrid press-fit and retaining-compound (hybrid) joint should exhibit the best traits of both joint types. The hybrid joint should be superior to the standard retaining-compound joint, because it will allow accurate placement of the pin, which is not possible when using retaining compound alone (due to larger dimensions of the hole). The film thickness will be controlled because of the lands on the pin, allowing the retaining compound to have even geometry for more controlled contact. The proposed hybrid joint will be far superior to the screw joint due to its ability to withstand cyclic temperatures and its superior alignment properties.

While the cross-pin joint provides optimal accuracy, its weakness lies in its cost and manufacturability. Manufacturing this joint is difficult under some circumstances, due to the lack of access to cross-drilled features. A hybrid joint will provide greater ease of manufacturing, while maintaining optimal accuracy of pin placement. The cost of the machining process for the proposed hybrid joint will be on the order of that of a press-fit pin joint. One additional turning operation will be required to create the lands on the pin. This is a simple and inexpensive operation, when compared to the machining steps required to create a cross-pinned joint. When comparing the hybrid joint to a cross-pinned joint, the elimination of the roll pins and simplified assembly steps provide additional manufacturing cost savings. The next phase of this study will include a manufacturing cost comparison between the hybrid joint and the other types of joints discussed, particularly the cross-pinned joint, in order to quantify the cost savings experienced due to the proposed hybrid joint.

In order to evaluate the ability of the proposed hybrid joint to maintain its accurate placement during heat cycling conditions, future work will involve exposing hybrid joints to temperature cycling that reflects industrial conditions, while determining if the pin placement remains intact during this testing. Hybrid joints will be evaluated alongside cross-pinned joints to ensure that the accuracy of pin placement is reliable even during robust temperature conditions. Although it is anticipated that the proposed hybrid joint will exhibit the best traits of both cross-pinned joints and retaining-compound joints, future work will involve testing to evaluate the hybrid joint properties. For example, while curing time is greatly affected by the gap size, no information is available that relates gap size to the ultimate strength of the joint [5].

Mechanical testing to be conducted in the next phase of this study will determine if the addition of the lands adversely affects the joints by weakening the pins. Additionally, testing will be used to optimize the land size and geometry for obtaining maximum strength from the joint. A series of pin pullout tests will be performed to evaluate the retaining strength on the stationary side of the joint. A baseline series of tests will be performed using an MTS fatigue tester on a set of pins installed using the standard accepted practices of manufacturing. Comparative baseline tests will be performed on pins installed via press fit, cross-pinned, and seated with retaining compound. These test results will be compared to the results of the same test performed on the new hybrid joint. The changes proposed to mechanical joint design and assembly discussed in this study may have substantial impact in terms of cost savings realized in the forms of increased manufacturability, decreased maintenance-related downtime, and improved product design.

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Using Service Learning to Enrich Knowledge, Training, and Civic Responsibility for Emergency Management Technology Students

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Abstract

It is essential for students to engage in meaningful classroom experiences that ultimately prepare them for their desired careers. Successfully passing a course and obtaining a degree are tremendous assets; nevertheless, students need more opportunities to develop transferable job-related skills, network with workforce professionals, and enhance their awareness of civic responsibility. Promoting such aids in developing well-rounded students makes them favorable to potential employers. In developing job skills and experience, service learning, a form of experiential learning, provides an opportunity to effectively learn through the practical experience of serving the community, based on specific learning objectives and overall direction of the instructor. In this paper, the authors provide a detailed description of the service learning projects implemented in emergency management technology (EMT) courses at an HBCU, and how the service impacted students and recipients of the services.

Introduction

Experiential learning is an active learning process that necessitates initiative and a deliberate willingness to engage in the out-of-classroom experience. As a form of experiential learning, service learning is a concrete method of active engagement that goes beyond the classroom borders to benefit both the learner and the community. Service Learning is an educational method that connects formal instruction with an opportunity to serve the community in order to provide a progressive learning experience. Such experiences help students better comprehend class subject matter, cultivate critical and pragmatic thinking skills, and gain hands-on experiences that may lead to career opportunities and other meaningful scholastic experiences. The service component of experiential learning is an asset in student development.

According to Felicia [1], experiential learning is the process of learning through experience, which involves learning through reflection from engaging in a task. The University of Texas at Austin's Faculty Innovation Center [2] contends that experiential learning is any learning that supports students in applying their knowledge and theoretical understanding to real-world challenges or circumstances in which the instructor guides and facilitates learning. Students are able to actively engage in their learning, become better aware of the course content, and fulfill goals regarding civic engagement and public service matters. According to Itin [3], educational theorist David Kolb suggested that knowledge is increased through personal and environmental experiences. Kolb (as cited in Merriam et al. [4]) further asserted that the learner must be capable of doing the following in order to secure knowledge from the experience:

1. The learner must be willing to be actively involved in the experience.
2. The learner must be able to reflect on the experience.
3. The learner must possess and use analytical skills to conceptualize the experience.
4. The learner must possess decision-making and problem-solving skills in order to use the new ideas gained from the experience.

Student-involved service projects that apply important course objectives are deemed advantageous. Undertakings such as this engage students in strategically designed activities addressing community needs. As Jacoby [5] asserted, this structured opportunity leads to desired service learning outcomes of problem solving, civic responsibility, and more.

Service Learning and Emergency Management Technology

Service learning affords an opportunity for students to take knowledge obtained in the classroom and deliver a meaningful service to the community. According to the National Youth Leadership Counsel, service learning is an approach to teaching and learning in which the students use academic knowledge and skills to address community needs [6]. It is a coordinated effort between an academic institution and community service programs with a targeted community group. As cited in Buck et al. [7], such an initiative inspires lifelong learning and includes structured time for the learner to reflect on the service experience. Moreover, the University of Texas at Austin's Faculty Innovation Center [2] indicated that the location may expand beyond the borders of the university. In these experiences, students participate in an organized service activity that meets identified community needs, and reflect on the service activity to better understand course content and gain a greater appreciation of the discipline. The experience also enhances the students' sense of civic responsibility. As service learning promotes a hands-on, pragmatic, and progressive approach to the learning experience, students in technology programs can greatly benefit and assist the resolution of some community needs.

According to Buck et al, [7], technology also involves advancements, improvement, or management of the natural environment to satisfy the demands of society. To incorporate technology into a program concentration, such as emergency management technology, it is essential in impacting society forecasting and mitigating potential disasters. This further assists in preparedness and response to natural and man-made disasters. Technology can be impactful in emergency management, as its function is charged with creating the framework within which communities reduce vulnerability to hazards and cope with disasters [8]. In 2011, an HBCU instituted an EMT program concentration in which students collaborated with emergency management professionals in the fields of meteorology, law enforcement, fire, and medicine in order to address local community needs. In developing the service learning projects for EMT students and collaboration with emergency management professionals, these activities have afforded the opportunity for students to gain essential career experience and enhance their understanding of the preparation and response to emergency and disasters.

The Webster dictionary [9] provides one definition of disaster as a "sudden or great misfortune or failure." Disasters impact everyone, thereby targeting individuals and communities at large. Therefore, disaster preparedness is essential for proper planning and response. Preparedness consists of awareness of matters and activities undertaken prior to the onset of a disaster, which enhances the response capacity of individuals and households, organizations, and communities. To enhance response capacity, there must exist the ability of social units to accurately assess hazards, rationally predict possible problems in the event of an actual disaster, and appropriately take precautionary measures to reduce impacts and ensure an efficient and effective response [10]. With the increase of both natural and man-made disasters, the demand for highly trained and competent emergency management professionals is vital for those developing and leading initiatives that lessens the impact of disasters.

According to the U. S. Department of Labor's Bureau of Labor Statistics [11], career growth and demand for emergency management directors is projected to increase by 6% between 2014 and 2024—with a median salary of $67,330. With such a demand, it is essential to have post-secondary academic programs and training from which students can develop proper skills to create response plans to protect people and property, and to minimize destruction from incidents. While EMT students are enrolled in academic programs, acquiring hands-on experience is vital to students (future emergency managers) and the overall communities that they will serve. Therefore, service learning projects aid in providing opportunities to acquire valuable experience that can be later applied in the emergency management workforce. This will help students to better understand emergency management functions of mitigation, preparedness, response, and recovery. The overall service learning experience for emergency management technology students guides them in decision making, critical thinking, and reflection on lessons learned for preparedness and response improvement.

Emergency Management/Service Learning Student Project

In the fall of 2015 and the spring of 2016, there were two courses in the EMT concentration designated as official service learning courses at this HBCU (Introduction to Incident Command Systems and Disaster Management, respectively) that provided opportunities for students to apply classroom emergency management theory to help the community. Both courses cover the emergency management practices used by responders during an emergency situation, and explore important functions to be performed before, during, and after disaster strikes. In addition, the service learning course objectives for both courses stated the following:

1. Students will participate in table-top (i.e., hands-on scenarios) exercises to practice skills learned in class and develop a practical knowledge of the incident command system and disaster management.
2. Students will research societal needs, establish a community partnership, and provide service to the community, based on research and classroom training on Incident Command and Emergency/Disaster Management.
3. Students will grow in their knowledge of civic responsibility and reflect on service learning initiatives; thus, identifying how recovery technology can be used to serve the community in the mitigation of problems, preparation, response, and recovery. Such efforts will direct students in developing a project to fulfill the emergency management needs of the local community.

4. Students will collaborate with and learn from professionals in various fields of emergency management to develop a deeper understanding of implementation for emergency management functions, day-to-day operation and proper community preparedness, and response to disasters. Emergency management professionals will also serve as consultants to students on the service learning projects to fulfill needs for preparedness and response for local communities.

Topics such as the definition and function of emergency management, description of man-made and natural disasters, incident command systems and functions, disaster management strategies were discussed. Additionally, students participated in incident scenario discussions, weekly disaster management preparation activities, and completed FEMA's Emergency Management Institute's online independent certificate courses (IS100, IS200, IS700, and IS800). To ensure that objectives were met and each student had successful learning outcomes, students were give bi-weekly quizzes, mid-term and final exams, research reports, and an overall service learning project (with research report, reflection journal, and oral presentation). Students were required to master these assessments with 80% proficiency. If there was an instance in which a student did not master an assessment with 80% proficiency, the designated topics were reviewed, and students were able to demonstrate a higher level of proficiency on subsequent assignments. As activities and assessments were pertinent in reinforcing course content, the collaboration with emergency management professionals helped reinforce subject matter content and better enlighten students on emergency/disaster management careers. This was one of the primary reasons that the EMT professor of these respective courses began collaborations with a local research hospital in which the students performed assigned tasks directed by the medical response team.

This prestigious research hospital partnered with a local health agency to organize a state medical response structure. This structure was implemented to provide medical assistance during disaster incidents. Since the course objectives of the Introduction to Incident Command Systems and Disaster Management courses were to enhance civic responsibility through service learning initiatives by identifying methods to assist communities regarding disaster preparedness and response, collaboration with the medical response team afforded a great learning opportunity. At the beginning of the service learning project, the students signed up for the volunteer community medical assistance unit to learn basic information about medical response protocol and responsibilities. Students participated in an orientation conducted by the medical response team regarding functions for the state and the nation's rapid response after a disaster. Students were charged with tasks to catalog medical supplies on mobile medical stations. These supplies included oxygen tanks and gauges, oxygen filtration systems, basic triage supplies, and other medical supplies. By having these mobile medical stations sufficiently stocked and categorized with medical equipment and supplies, deployment was expected to be faster and more efficient. Students continued this cataloguing project in the spring of 2016, and they also developed plans to modify and further enhance the inventory systems. The project was a great success, and the students earned designated services hours along with passing academic credits. Reporting of the service hours were made to the HBCU's Community and Service Learning Department. Figures 1-3 show student engagement and medical equipment for the project.

Figure 1. The HBCU's EMT Students Learning about Oxygen Gauges in the Medical Response Warehouse

Figure 2. Oxygen Tanks Stored for Emergency Response

Figure 3. Medical Inventory Organized and Stocked by Student, Ready for Immediate Response Initiatives

Regarding the service project, this HBCU's Community and Service Learning Department provided direction for service learning guidelines, hosted service learning orientation with faculty and students, and documented students' service hours. The students were able to earn 15-25 service hours per semester, which aids in meeting the university's service requirements for graduation. Moreover, a memorandum of understanding (MOU) was developed and signed by the research hospital and the EMT professor defining terms and respective responsibilities of the two institutions for the clinical/experiential education of EMT students. With academic coursework merged with civic engagement, the service learning project benefited the students through a hands-on and interactive approach to learning. This interactive approach prompted meaningful reflections that enhanced the learning of the course content, and heightened interest in emergency management careers.

EMT Student Service Learning Reflections

Service learning extends the course content and directs students to personal reflections about their service learning experiences. Effective service learning projects challenge students to reflect on their service experiences through such activities as group discussions and journaling. Service learning reflections establishes the fact that students learn through a combination of thought, theory, application, reflection, and civic engagement [7]. Effective service learning can be achieved, while discussing intellectual, civic, ethical, moral, cross-cultural, career, or personal goals [12]. The EMT students, enrolled in the aforementioned courses, expressed great zeal and appreciation for the project, which was demonstrated from their journaling, online group discussions postings, final service learning project papers, and classroom presentations. Students also conveyed their enlightened understanding of emergency management implementation and career directions. Following are some reflections shared by the students.

Fall 2015

"Growing up, it has always had the passion to help with the community. Volunteering at local agencies as a kid was very exciting, because of joy on the people faces receiving services. It is a great idea that schools enforce service learning for students to complete, because it provide them with the overall experience with their education. Also, service learning give the chance to network with the higher personnel of the project, and it increases the chance on landing a job in the future. The Medical Center provided a great opportunity, because it showed that communication is a key to success in Emergency Management and how to serve the community. After working with classmates, everyone's team work ability improved. As a result, the class developed relationships with each other that could possibly help with a future project. Most of all, skills were learned to help the community in time for disaster and distress."**—Student 1**

"Many people go through college and take various classes and may do well, overall. When placed in the real life situation they can't produce results—they only sit in classrooms to learn. With Service Learning, it actually places you in a work environment. This gives you not only service learning hours, but also work experience that future employers might demand. Service Learning provides a work atmosphere that takes students out of the classroom setting and enables them to put what they've learned to action. The project with this research hospital medical response team helps the community in many different ways. If an incident occurs and an area is affected, these trailers containing medical supplies (that our class helped to inventory and organize) are vital in the response to an incident. If a hospital is affected and isn't able to accept people that are injured, then medical responders and other volunteers are called upon. This not only provides a chance for better survival for the community, but also hope that more people are able to be helped at a faster pace."**—Student 2**

Spring 2016

"This medical unit has an ample medical supply. Having trailers in the warehouse full of medical supplies that are ready to be shipped to places around the world that have been hit with a disaster, this can provide needed assistance in building back up communities. Since Service Learning appeals to the different types of learners, it is so unique—being able to get the needed training before starting a career. Such experiences provide the opportunity to see if one stills desires to work in which a field. Service learning lets and idea of the work field prior to entry." **–Student 3**

"As a future Emergency Manager, Service Learning will guide in hands-on experiences and give me some much needed practice for this field. While doing this project knowledge was obtained to help in career preparation. It is believed that information learned from this project and help in decision making a proficiency. Learning from this project helps in becoming more aware of the steps that Disaster Managers take in preparing for any incident—to better help the community and nation, overall. The tasks were be done while doing project will most definitely enhance the perception for Emergency Management."**—Student 4**

Conclusion

For the purposes of previously discussed project, service learning was described in the following ways: community/ societal need, curricular connections, partnership, student voice, and reflection. Curricular connection is integrating learning into a service project, which is essential in gaining significant experience. Student voice is beyond being actively engaged in the project itself; students had the opportunity to plan and implement their plans to effectively categorize the medical supplies for the medical responders. Reflections provide structured opportunities for students to think, talk, and write about the service experiences. The students provided weekly journal entries in which they stated their respective tasks and how they better understood how to apply the classroom theory. As a culminating reflection component, the students made formal presentations to discuss their experiences, their collaboration efforts with the emergency management professionals, and how the experience helped bring clarity about academic and professional requirements for their anticipated career goals.

EMT students should participate in service learning activities to enhance their awareness of societal needs. As disastrous incidents escalate, it is critical that there are highly trained emergency personnel with knowledge of contemporary technology to greatly impact preparation and response. With this in mind, technology serves as a means that continues improving the quality of life for everyone, thereby leading efforts to help our communities in times of disaster. The experience acquired from these service learning projects, provided EMT students with the ability to develop the exceptional skills needed to obtain and maintain successful emergency management careers.

Acknowledgements

This work was supported in part by U. S. Department of Homeland Security, CCLI-Phase I: Exploratory, under grant number DUE-0948152.

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Biographies

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Career and Technical Education and its Relationship to Engineering Technology Pathways in Marine Mechatronics

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Abstract

Students coming from families with low household incomes often cannot afford to rely on a regular pathway from high school to the university because of college tuition rates. Other students might not seek out available opportunities in their guidance counselors' offices to learn about existing scholarships or learn about different engineering technology or engineering careers. There are also students, who realize that a four-year university degree is not always necessary to find a career that matches their skills and talents. They may also have another educational path to receive a technician, engineering technology, or engineering degree, such as a technical or dual-enrollment program, with the option of returning to college later. Career and technical education (CTE) opportunities can assist students in breaking out of the poverty cycle, as many technical jobs offer salaries higher than minimum wage.

An important factor of technical education success, and filling the technical pipeline to further education, is to provide integration of industry knowledge with traditional, academic training related to the core requirements necessary for further education. Some programs have an embedded mechatronics curriculum in their current courses. Some high schools participate in robotics competitions, which can serve as an excellent pipeline to the STEM workforce, especially in the area of advanced manufacturing, mechatronics, and robotics. In this paper, the authors provide an overview of various opportunities related to engineering technology pathways, more specifically, career-related information related to mechatronics.

Introduction

Certain students find it difficult to seek jobs outside their small towns or counties, or to enroll in technical schools located outside of their school districts [1]. Even if an excellent CTE program exists in their area, they can attend CTE programs only if they live in the city to which that school belongs. Nevertheless, some technical schools might have students from a 600-mile radius. Many technical programs are targeting low-income families, in particular single -parent families, so that the students can reach financial independence [1]. Fifty percent of students coming from high-income families obtain an undergraduate degree by the age of twenty five, while only ten percent of students from low-income families do the same [2, 3]. Many rural students also find it challenging to gain experiences needed for their future jobs because of the lack of opportunities in their counties. Other students have a hard time realizing the relevance of a high school education if it does not provide them with real-life credentials for specific jobs like many of the CTE programs offer, by providing them with a career objective as early as high school, or by providing career and technical exploration opportunities as early as middle school [4-6]. Generally, CTE programs around the nation are on the decline. A decrease of around 11 percent since 1990 has been reported in CTE teacher preparation programs [7]. Only about 17 percent of students enroll in CTE classes [8].

It is also important to match CTE opportunities with career aspirations [9]. Various science, technology, engineering and mathematics (STEM) jobs will be held by CTE graduates [10]. However, some government funding agencies do not necessarily recognize CTE programs as STEM programs for the purpose of obtaining funding [11]. Traditional vocational education does not provide students the academic skills needed to enroll in further post-secondary education [5]. Recent developments in CTE stress the importance of combining hands-on, practical learning with academic learning, which is necessary for qualification for further education [5, 12]. Changing the way these programs are perceived by students, and having role models who went through the entire pathway, is equally important for their enrollment rates [13]. Some studies suggest that integration of more mathematics into CTE curricula will benefit students and their future careers, since they will be more college ready, not just hands-on trained, as only 44 percent of U.S. graduates in 2013 were ready for college-level math courses [10, 14]. Common Core and college readiness need to be integrated with CTE programs for students to have enough requirements to further engage in postsecondary education [12, 15, 16].

Field trips and job shadowing count as graduation requirements in some technical schools for the purpose of providing these students with job-ready skills that are highly sought by industry [1]. Hands-on and work-based experiences that lead to certificates have been reported to decrease student dropout rates [4]. Critical-thinking, problem-solving, communication, and collaboration skills are additional elements related to CTE program success [14, 17]. Furthermore, having multiple opportunities available to students, having a sense of community and business partnerships, having successful leadership related to grant writing and fund raising to sustain the programs, having policies in place, and providing professional training to staff have been reported as key factors for long-term success of CTE programs [4, 13, 18]. Another benefit related to CTE programs is the understanding that students should be prepared to engage in lifelong learning, due to constant changes in today's global market [5].

Career and Technical Education in the Commonwealth of Virginia

The Commonwealth of Virginia has developed strong programs for gifted and talented students through 23 Governor's Schools, as of the 2013-14 school year [19]. However, there is still a gap related to the general student population, in regards to a lack of core skills and abilities among high school graduates. CTE education is noted as a promising avenue for improvement of their STEM literacy and other applied learning related twenty-first-century skills, as defined by NGA Center for Best Practices [20]. CTE programs are integrating academics and career and technical education, work-based learning, and a focus on the development of transition agreements to postsecondary education through career pathways. They have embedded Standards of Learning (SOLs) and Virginia's Workplace Readiness Skills in their competencies. A current trend is that students enrolled in CTE programs obtain a degree, certificate, or a credential, and that they have more options that would enable them to be eligible for high-demand, high-wage jobs.

The Technical Diploma option was recently approved to replace the Standard Diploma and provide an appropriate CTE sequence. Career and Technical Education in Virginia has the following career clusters: Agriculture, Food & Natural Resources; Architecture and Construction; Arts, A/V Technology and Communications; Business Management and Administration; Education and Training; Finance; Government and Public Administration; Health Science; Hospitality and Tourism; Human Services; Information Technology; Law, Public Safety, Corrections and Security; Manufacturing; Marketing; Science, Technology, Engineering and Mathematics; and Transportation, Distribution & Logistics [21]. These career clusters are aligned with the National Career Clusters Framework.

Virginia also offers 350 different programs for industry credentials, which are available to students as part of the Virginia's Credentialing Initiative. These credentials can be full industry certification, recognized by industry, trade, or professional organizations, such as Project Lead the Way–STEM, or National Automotive Technicians Education Foundation (NATEF). They can also be stackable credentials that will lead to future full industry certification. CTE also provides a national standardized assessment of knowledge related to the specific career pathway through the Occupational Competency Skills Assessment. It also enables students to acquire necessary State License or Workplace Readiness Skills for Commonwealth Certification, which is recognized by the employers in the Commonwealth of Virginia. The growth of the total number of CTE completions is a result of this initiative [22].

Mechatronics Level 1 Assessment

Mechatronics has recently been added to the list of required skills in the different career clusters, such as in the manufacturing career pathway: Maintenance, Installation and Repair. The demand for employees in the field of mechatronics is predicted to grow by nearly 21 percent in the next ten-year period [20]. A related certification is the Mechatronics Assessment, Level 1, which was developed by the National Occupational Competency Testing Institute (NOCTI) [23, 24]. Related occupations for this pathway include communication system installers/repairers; instrument control technicians; security system installers/repairers; electrical/electronic installer; shop mechanic; auto repair mechanic; and, auto service technician [25].

Career and Technical Education in Virginia Beach

Even middle schools in the advanced public school system, such as one in the Virginia Beach Public Schools system, offers courses under the Technical and Career group (elective courses) Technology Education, 6 (Introduction to Technology), 7 (Inventions and Innovations), and 8 (Technological Systems), which are nine-week courses for grades 6 to 8 that introduce students to basics of technology systems, tools, machinery, energy sources, and technology systems, such as transportation or communication, then teach them the engineering design process and provide them with hands-on problem-based activities. By the end of this group of courses, students work in teams to solve problems, construct models, and learn to operate machines and use computers to describe or control systems. Middle school also offers computer skills and keyboarding classes that cover basic operational skills, word processing, multimedia, spreadsheets, and desktop publishing.

The high school curriculum is more diverse and offers a wide range of choices for students, including engineering-related courses. Virginia Beach Public Schools, for example, offers a set of technically oriented courses grouped as Experiential Learning courses. There is an articulation agreement between the public school district and Old Dominion University (ODU), and students that take a certification exam in courses from these programs can get college credit in engineering technology or engineering education programs at ODU. These programs are offered by regular high schools and include: basic technical drawing engineering drawing; communication and information technology; control technology; pre-engineering; principles of technology; production technology; and, technical design and illustration.

Courses offered by the advanced technology center include: engineering design and architectural design; engineering technology I and II; and modeling and simulation, with 1 year of basic technical drawing [26]. Virginia Beach Public schools include these among their high schools and STEM Academy, which has a curriculum designed for careers related to STEM engineering technology, information, and entrepreneurship technology. In this particular school, students can select one strand and complete a comprehensive pathway towards a corresponding associate industry certification.

Dual-Enrollment Courses in High School

Dual enrollments are collaborations between high schools and colleges, where juniors and seniors are permitted to enroll in actual college courses on college campuses, advanced placement courses, or international baccalaureate program courses [27]. Nineteen percent of high school students were taking college-level coursework in 2006, compared with seventeen percent in 2005, due to the increase in the number of students taking advanced placement, dual enrollment, and international baccalaureate programs [20]. One of the programs developed to strengthen the pathways to postsecondary education is the International Baccalaureate (IB) program. It has been reported that four-year graduation rates for students enrolled in this program are 79 percent, compared to 39 percent of students not enrolled in this program [5].

Dual-Enrollment Courses and Mechatronics Pathways

Virginia Beach Public Schools offer dual-enrollment courses at the Advanced Technology Center in Electronic Systems I & II, Electricity I & II and Electronic and Robotics Technology, which can be transferred to the mechatronics program at Tidewater Community College, Chesapeake, VA, starting in the spring of 2015. The Advanced Technology Center in Virginia Beach is a STEM education facility that offers students a college-like experience and a comprehensive technical education. Students may be registered at their home high school, while taking half-day classes at the ATC. They can also prepare for national certifications and get college credit upon satisfying the specific requirements. If students do not continue with community college or university education, they can directly enter the job market with the knowledge and certifications required by employers today. The classes and programs offered at the ATC are aligned with the demands in today's industry, especially with those in the Hampton Roads area.

Another dual-enrollment course that focuses on CNC programming and mechatronics was developed for Portsmouth Public Schools, Portsmouth, Virginia, with Tidewater Community College, Chesapeake, Virginia, and Old Dominion University. This project was funded by the Workforce Investment Act Incentive Grant program for the partnership between Opportunity Inc., Workforce Development Board of Hampton Roads, Tidewater Community College and Old Dominion University Department of Engineering Technology, and STEM Education and Professional Studies. Two grants were awarded: the Development of Foundation of Mechatronic Course in 2013 and the Mechatronics Teacher Camp: Foundations of Mechatronics Professional Development Workshop for Career and Technical Education Teachers in 2014. A short course, Foundations of Mechatronics, was developed and disseminated to career and technical education teachers from the Hampton Roads region in the summer of 2013 at the ATC in Virginia Beach in the summer of 2013.

There were ten CTE teachers, who participated in the workshop and received CTU credit. They all received the Spark Fun Inventor Kit with Arduino Uno microprocessor. Learning modules that would be designed as a result of this grant were: 1) Introduction to Mechatronics and Mechatronic Systems; 2) Electric Circuits and Components; 3) Electrical Energy Sources; 4) Electrical Power Considerations; 5) Semiconductor Electronics; 6) System Response; 7) Analog Signal Processing - Op Amps; 8) Digital Circuits; 9) Microcontrollers; 10) Sensors; and 11) Applications of Mechatronics. Teachers were given teaching slideshows for these lectures, assignment activities, and additional handouts and reference lists. It was also suggested that they use labs that come with the Spark Fun Inventor Kit.

Mechatronics in Career and Technical Education in Hampton Roads

Tidewater Community College, in collaboration with ODU, is developing and implementing a set of standards and building an educational pathway from an Associate of Applied Science degree (A.A.S.) to a Bachelor of Science degree (B.S.) in Engineering Technology with an emphasis on mechatronics. The project, funded by the Office of Naval Research, has integrated pathway components starting from high school education, moving to the community college, and then to undergraduate engineering technology education. The first effort will reach out to high school students by exposure to possible mechatronics careers through dual-enrollment courses that introduce students to mechatronics educational pathways. The second effort will focus on mapping out needed competencies for maritime mechatronics technicians and maritime mechatronic engineering technologists. Students in high school are competing at various levels of mechatronics-related activities, ranging from building autonomous robots and programing them, to understanding how electromechanical systems are built. Figures 1 and 2 show examples of such activities.

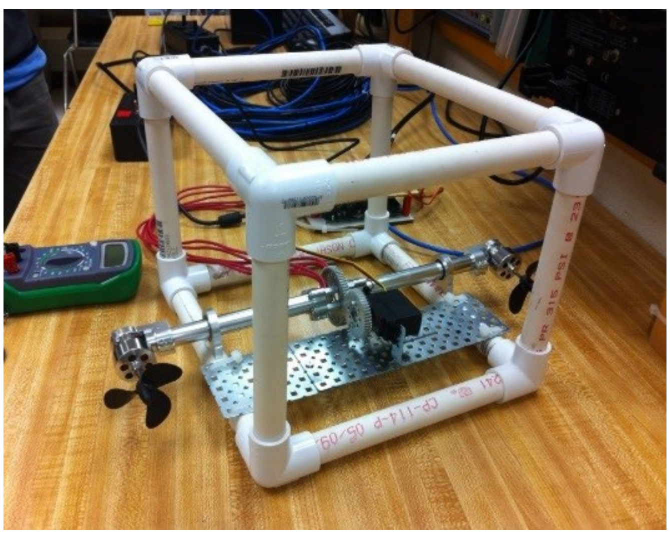

Figure 1. Mechatronics-Related Activity at Granby High School, Norfolk, Virginia

Granby High School has three courses with embedded mechatronics and robotics in the Student Learning Outcomes: Principles of Technology 1, Principles of Technology 2, Engineering Exploration I, Engineering Analysis and Applications II. Engineering Concepts and Processes III will be the third course of a three-course sequence that will enable students to solve real-world problems. This course focuses on building an engineering team, working with case studies, managing projects, applying logic and problem-solving skills, delivering formal proposals and presentations, and examining product and process trends. In addition, students continue to apply their engineering skills to determine whether they are good candidates for postsecondary educational opportunities in engineering. Students will participate in STEM-based, hands-on projects as they communicate information through team-based presentations, proposals, and technical reports. Students will take the NOCTI pre-engineering certification test at the completion of this course.

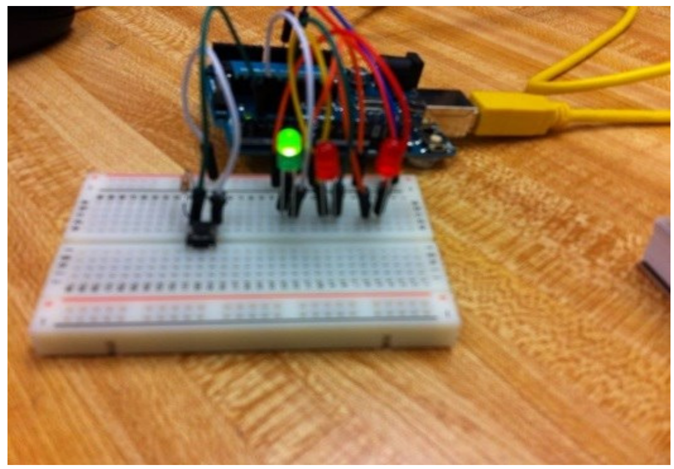

Figure 2. Mechatronics-Related Activity at Granby High School, Norfolk, Virginia

Marine Mechatronics Pathway

This project of embedding marine mechatronics as one of the available pathways for CTE students, community college students, and engineering technology students is in its first year. The curriculum will be developed in response to the needs of the maritime industry, which will be analyzed using the Developing A Curriculum method (DACUM) and a modified Delphi method [28]. In the first year, a modified Delphi panel was conducted with industry practitioners to gauge the most important elements of future marine mechatronics curricula on three levels. During year one, Round I of the modified Delphi method began with the development of a questionnaire to identify the quality indicators for the mechatronics curriculum. The questionnaire gave directions and definitions that were critical to the participant as well as to the study, so that every panel member was using the correct format when completing the questionnaire. It also used the same definitions of key terms used in the instrument.

Examples of related indicators from the review of literature were presented to aid the participants in format for typing a new indicator or modifying an existing one, as well as to start the brainstorming process. Participants remained anonymous to each other, avoiding influences of reputation, authority, or affiliation. Mechatronics activities described in this paper were embedded in the 2015-16 school year in Granby High School. After the curriculum is developed, various data will be collected to measure the project's success. It will take years after its implementation to collect longitudinal data related to the how many students completed each level of marine mechatronics education and determine what types of jobs they got, how many of them landed a job in the area of their training. For this project, a comprehensive evaluation plan was a central feature of this project and was based on the project's goals, objectives, and activities. The evaluation takes into consideration the resources, techniques, procedures, and strategies employed to accomplish the goals and objectives of the project (which is mainly curriculum development), as well as the outcomes of the activities and their impact on the participants. The evaluation plan will examine accountability, effectiveness, and impact.

Many schools are presently offering or are planning to offer courses or programs in mechatronics [29]. The need has been identified for development of new programs for mechatronics certificates [29, 30], mechatronics technicians [31], and mechatronics engineering technologists [32] at various community colleges [31] and mechatronics courses at universities across the country [29, 32-36] and worldwide [37-40]. At the university level, the first engineering technology program that offered a mechatronics education degree was Purdue University Calumet in Hammond, Indiana, as a result of NSF ATE program funding [32].

Moreover, the shift towards integrating mechatronics education as one of the STEM academic areas can be seen in various NSF ATE awards funded from 1995 until now. Some examples are: project "Shaping High-Quality Integrated Nebraska Education (SHINE)" at Central Community College, Grand Island [41]; "Meeting Workforce Needs for Mechatronics Technicians" at Purdue University Calumet, Hammond, IN [42]; "Learning Product Design through Hands-on Mechatronic Projects" is a partnership among Carnegie Mellon University and Polytechnic Institute of New York University (NYU Poly) [43]; "The Technician of the Future: Mechatronics as a Statewide Transferable Skill Set Supporting Green Industry" project at Linn Benton Community College, Albany, OR [44]; "The Discover STEM-Generation Innovation project" at Owensboro Community & Technical College (OCTC) [45]; "Mechatronics and Innovation for Rural Technicians" [46]; and, "The Engineering of Engineering Technicians (E2T)" at Virginia Western Community College [47].

Therefore, developing mechatronics curricula became one of the important topics in various states in the U.S., mainly driven by industry, since many international companies already have mechatronics training programs in place. Some of these programs mimic European models of engineering education, such as the German dual system that already has CTE education as a core of future formation of engineering [48]. Some of the main principles that form the basis of such dual methodology are based on the "Leonardo concept" that sees engineering as a multifaceted profession, ranging from skills and craft-based competencies to the advanced-math applied engineering skills [49]. In many European countries, there are two main types of CTE, one track that is more vocational with lower levels of math and science, and other track more technical with high-level math and science courses and which is seen more as a preparation for engineering and technology careers. It is very typical to have students obtain a technician degree while still in high school, and then moving on to a higher education pathway. That curriculum integrates industry-based competencies with academic skills, which are needed for success at university level. In that sense, Virginia is following a trend which is seen recently as a result of various efforts across the country to strengthen the advanced manufacturing workforce by having more pathway-based approaches when it comes to technical education.

Conclusion

Many high schools across the country have a wide range of career and technical education courses that can be selected from among electives from the STEM cluster that are related to engineering technology, ranging from pre-engineering to power and transportation technology, materials technology, technical drawing, and electronics. Some of these courses can be considered for credit for corresponding community college courses. However, not all schools have CTE courses that are from these career clusters. Students are still bound to attending high school only in their school attendance zones. Additionally, there is a limitation in terms of credit hours that a student can take, as all of these courses will fall under an elective category of courses, and students can only take a limited number of elective credits. If students have academies in their high schools and they are enrolled under specific academy programs, they have to register for academy-related courses, and thus will have even less flexibility in selecting a CTE course. Counseling is crucial in this respect, in order to guide a student towards a particular engineering-related pathway, and to identify the sequence of courses that must be taken. There is still a lot of work to be done for other cities that do not have STEM academies, governor's academies, or advanced technology centers. In these other cities, students are limited to taking CTE courses in other career clusters, not necessarily the ones related to mechatronics or other areas of STEM, such as engineering or technology.

Acknowledgements

The authors wish to acknowledge support from the Office of Naval Research for the "Higher Education Pathways for Maritime Mechatronics Technicians (MechTech)" grant, Agency Proposal Number N00014-15-1-2422.

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WRITING FOR PUBLICATION

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Abstract

Academicians publish for a number of reasons including personal satisfaction and the opportunity to share research or successful pedagogical techniques. One of the more significant reasons, however, is to meet requirements for promotion and tenure. Although higher education institutions may vary in expectations, all require a certain degree of professional development for faculty to attain tenure and advance through the professorial ranks. In this paper, the author offers advice for publishing, based on the author's considerable experience serving in various editorial positions for a number of technical publications. Specifically, the author examines appropriate content, writing quality, ethical considerations, and interactions with editors.

Introduction

Why write? Professional educators have a long history of pragmatic writing: in college, as evidence of knowledge and a demonstration of research skills; in graduate school, as proof of original thought and advanced skills; and professionally, as a pathway to tenure, promotion, and recognition. While writing does involve a certain level of creativity, it does not require innate talent. Interestingly, noted fiction writers, who do have an innate talent, view writing as a type of problem solving. Novelist F. Scott Fitzgerald once suggested, "You don't write because you wantto say something; you write because you've got something to say." Likewise, journalist and novelist Joan Didion explained, "I write entirely to find out what I'm thinking, what I'm looking at, what I see and what it means" [1]. In this sense, professional writers are engaged in the same activity as professional engineers: using creativity to develop an elegant and robust solution to a problem.

In an industrial setting, engineers write to convey technical information to a wide constituency: peers, management, shareholders, and the general public. In academia, however, engineers primarily write for professional advancement, especially at the onset of their careers, since professional development is a criterion for promotion and tenure. As they advance through the academic ranks, however, the quality of writing may change, with a focus on identifying and developing the knowledge of the field itself. Dubbed the "body of knowledge" (BOK) by the ASCE [2], many other professional organizations, such as the ACM's Special Interest Group on Computer-Human Interaction [3] and the ASQ [4], have been striving to define and classify the knowledge peculiar to their fields. The NSPE offers a broader definition: "A profession's BOK is its common intellectual ground—it is shared by everyone in the profession regardless of employment or engineering discipline" [5]. To that end, academic publications can provide invaluable contributions by serving as outlets to a wide professional audience.

Appropriate Content

All journals tailor their content to examining specific areas within particular disciplines. ASEE's *Journal of Engineering Education*, for example, is the society's archival publication and publishes original work that contributes to the BOK of engineering education. IEEE publishes a wide array of journals on various topics related to electrical engineering as well as journals that focus on other areas of interest to that primary audience: for example, *Transactions on Professional Communication* or *Technology and Society*. Authors should be realistic about considering content as well as a publication outlet. Submitting the results of a not-so-original research project to a journal with a 20% acceptance rate is self-defeating. Instead, think smaller, as Slagell [6] suggests: "Your first publication doesn't have to be an earth-shattering research study." It does, however, need to be harmonious with the journal's general direction and editorial policy; to ensure this, examining a few issues of the journal is important. Even a cursory perusal will reveal the typical content, length, and style of articles appropriate for publication in that journal.

In addition to reviewing potential publication outlets, conducting a thorough literature review is essential for content originality. Journals will probably not publish an article that repeats information available elsewhere, and research studies need to fit an unoccupied niche. According to Epstein et al. [7] regarding Sage Publications' guidelines, publishable articles typically exhibit the following characteristics:

- They present new knowledge, either in the form of substantive research findings, theoretical developments, new insights into existing debates, new analyses of existing knowledge, or a synthesis of the literature.
- They are grounded in the relevant literature, demonstrating familiarity and engagement in an on-going academic conversation.

- They address new or familiar issues pertinent to the discipline or field.
- They ask or attempt to answer provocative questions in a persuasive manner.
- They are well written, with carefully crafted and sustained arguments.

Writing Quality

In addition to original content, the writing itself needs to engage an audience. Resources available to authors are numerous. In fact, many publishing houses and journals offer very helpful, free materials for potential authors. The ASME website, for example, includes an article that details manuscript specifications as well as a number of helpful hints, such as explaining the various sections required, examples of reference format with a table indicating journal abbreviations to use in citations, and other items of interest regarding writing for ASME publications [8]. Similarly, Wiley [9] devotes a section of its website to advice for authors: finding a journal, preparing the manuscript, submitting the paper, and publication. And sometimes editors will use their columns to dispense advice. For example, Steve McConnell [10], editor of *IEEE Software*, once spent three pages detailing what makes an article publishable—statistically significant research findings, a focus on one topic, a clear writing style—and what does not—fuzzy focus, overgeneralizing, too much background, padding for length, and inappropriate content. New authors, in particular, are encouraged to consult these types of resources as well as traditional articles offering advice.

Publication in a professional journal requires that authors be keenly alert to issues of language usage and follow conventional grammar standards. Articles with numerous writing errors, especially those that impede the reader's understanding, will probably be rejected or returned to the author for substantial revisions. A number of studies over the past 30 years have examined the reasons for article rejection, and they have remained relatively stable over time. For example, in 1985, Davis [11] surveyed 87 editors of engineering and science journals and reported that "ineffective expression" was chief among rejection rationales [11]. Eleven years later, Henderson and Reichenstein [12], in a similar survey, concluded that "poor organization, poor writing" resulted in rejection. And in 2010, Miller et al. [13] identified "poor paper organization and presentation" as a major reason for rejection, as ranked by 40 engineering journal editors. Non-native speakers writing for English-language publications need to be especially conscious of language usage. The following excerpt is a passage from a manuscript that was returned to the author for language issues:

Although the technological development in the industry is to develop a synchronized and integrated with technologies from other industries, but the technology developed by the industry as part of other technologies are used. Therefore, in order to access and use of technologies and companies in other industries and use their knowledge of technology and other industries are forced to organize broad strategic relationships with another industries. So there's strategic relationships and exchange knowledge and technology in the innovation process and is not a choice but to develop new technologies is one of the requirements. As this example illustrates, the author may have a viable idea, but substandard English obscures meaning. The excerpt displays issues with punctuation; inappropriate use of articles (or complete lack thereof), especially "the"; stand-alone adjectives, unconnected to nouns; and generally awkward sentence structure. All of this results in an unclear message regarding the purpose of the paper, vital information that should appear in the beginning for reader orientation.

Peer-review literature also identifies questionable writing as a frequent reason for article rejection. Pearson [14], discussing articles rejected for a medical journal, notes that the direct approach in composition is preferable to affectatious phrasing, overuse of acronyms, and excessive technical jargon: "say what you mean, mean what you say, and don't use big words." Thrower [15], editor-in-chief of a technical journal, writes in Elsevier's "Publishing Tips" that language is often a reason for returning papers to authors before the peer-review stage: "The language, structure, or figures are so poor that the merit can't be assessed. Have a native English speaker read the paper. Even if you ARE a native English speaker."

Indeed, non-native speakers of English are at a distinct disadvantage when writing for English-language publications: not only do they have to contend with intricate technical matters but also the onerous task of communicating that information in a foreign language. Finnish educator Norris [16] offers several useful tips:

1. Avoid the temptation to directly translate sentences written in the author's native tongue to English, as "the result will be awkward, unclear, and full of errors."
2. Strive for clarity and accept responsibility for it; readers should be able to grasp meaning on a first reading.
3. Avoid ambiguity by using precise diction.
4. Edit text for clarity and hence a better opportunity for acceptance.
5. Read text aloud, as this practice will acclimate authors to the nuances of language and help them to identify awkward phrases.

6. Accept the fact that "English is not logical" and adapt accordingly.

Ethical Considerations

Adherence to established principles of academic integrity is essential to the publishing enterprise. Items such as trust—between editors and authors, authors and source materials—are crucial in establishing credibility of individual authors and their written work. To this end, authors should familiarize themselves with policies regarding copyright and academic integrity, typically located on the journal's website.

Copyright

When a journal editor accepts a manuscript, a condition for publication typically involves a copyright transfer, by which the author gives ownership of the manuscript to the publisher. ASEE's copyright transfer, for example, states, "The undersigned, desiring to publish the above paper in a publication of ASEE or cosponsored by ASEE, hereby transfers their copyrights in the above paper to the American Society for Engineering Education, known as ASEE" [17]. An author desiring to use small portions of that paper in another context should treat it as any other source material, using quotation marks, if repeating material verbatim, and citing the source.

Authors seeking to republish an entire article in another journal or submit a published conference paper to a journal must first obtain permissions from the original publisher. Not doing so may constitute copyright infringement. At the very least, it is duplicate publication, a practice generally frowned upon. In addition to violating copyright, duplicate publication constitutes an ethical transgression because, as Das [18] notes, it "could distort empirical evidence," waste editorial time and resources, occupy "limited/competitive journal space," and signify "poor scholarship." This includes translations of articles into other languages.

Experienced authors should note that this marks a change from past practice. Prior to 1990 [19], it was common to "tidy up" a conference paper for submission to a professional journal. Since then, republishing conference papers is considered as "self-plagiarism," or text recycling, and is a cause of significant concern among journal editors [20] and professional organizations. In fact, several now include warnings about self-plagiarism [21]; IEEE, for example, flatly states that it is unacceptable [22]. The same is true of publishing several similar articles based on the same study, a practice known as "salami slicing" [23]. Both of these techniques are recognized by plagiarism detection software, now in use by more than 250 publishers; numerous positive matches will probably result in article rejection [24] or a return to the author for significant revision.

All printed or recorded works in the U.S. are automatically protected by copyright law, including Internet items. Scholars may use a portion of written material without seeking permissions. For example, quoting short passages from a published book is allowable under copyright law, but if an author quotes a chapter or an entire work, permission is required [25]. Copyright also protects graphic images, both printed and online, and allowable usage differs from text. According to U.S. copyright law, images include "two-dimensional and three-dimensional works of fine, graphic, and applied art, photographs, prints and art reproductions, maps, globes, charts, diagrams, models, and technical drawings, including architectural plans" [25]. Using complete or adapted images requires permissions, since, unlike text, the entire image is typically reprinted. Citations must include words similar to "reprinted with permission from [copyright holder]."

Authors who are uncertain whether to pursue permissions should err on the side of caution and contact the appropriate persons or entities. Works in the public domain are no longer protected by copyright and do not require permissions.

Academic Integrity

Journal editors expect originality in content and, as mentioned above, many publishers currently use detection software to ensure that submitted manuscripts adhere to academic integrity standards. This type of software searches large databases for matching text. While these programs are certainly not foolproof and require an editorial eye, a finding of 70% matching text could indicate that the submission has already been published elsewhere or that the author is engaging in professionally undesirable behavior. At the very least, an editor will require a significant revision.

For academic integrity policies, authors should consult the websites of professional journals or the societies responsible for publications. IEEE, for example, has a very detailed policy that includes variable sanctions, depending on the severity of the infraction. For an article containing fabricated data or 50% or more matching text, which includes materials re-used from an author's prior publications, sanctions include publishing a notice that the author has violated IEEE's Publication Principles, expunging the article from the database and not considering manuscripts from the author for a period of three to five years, as per committee recommendation [26].

Interactions with Editors

Correspondence between authors and members of the editorial staff—manuscript, associate, section, or technical editors—is common throughout the publication process, which, depending on the number of review iterations, may be rather lengthy.

Understanding the Review Process

Authors may become impatient with the amount of time involved in the peer-review process. It is important for authors to recognize that the process is iterative and may take some time, depending on the number of revisions required. Correspondence with editorial staff may occur at any stage. Upon receipt of a submission, the manuscript editor usually performs a desk review, checking for appropriate content and adherence to journal style. In addition, this editor may perform an originality check for matching text. Depending on the outcome, the editor will either return the manuscript to the author or send it to content reviewers for peer commentary. Although the number of reviewers varies from journal to journal, three is common. Peer reviewers usually have three to four weeks to perform their reviews; they may comment freely or follow a format prescribed by the journal. Several decisions are possible: accept as is (rare), return to author for minor or major revisions (most common), or reject. A "return to author" finding means that the writer has a chance to improve the article by incorporating the reviewers' suggestions. A finding of reject, however, is usually final, although some journals have an appeal process [27]. As a noteworthy aside, some open access, online journals—those deemed as "predatory"—promise very quick turnaround times, in some cases just a few days from submission to publication. While they claim to peer review submissions, many do not [28]. Real peer review takes time.

Responding to Rejection

Receiving a rejection notice is always a disappointment, whether authors are new to the publishing enterprise or are seasoned professionals. In addition to the decision, editors will forward reviewers' comments, which are intended as constructive criticism, to help the author refashion the manuscript into a publishable article. New authors, whose papers have been rejected, should seriously consider not appealing but instead focus energies on revising the manuscript according to the reviewers' comments [29]. Avoiding the temptation to bombard editors with excessive emails is essential, as this behavior can result in being labeled a "nuisance author." A 2010 ethics case reported by the Committee on Publication Ethics provides an apt example: An international author, whose paper was rejected, resorted to using email as a weapon, spamming the journal editor, researchers in his field, and governmental officials with abusive emails. In addition, he kept re-submitting his paper, changing his name and using different accounts.

As a final coup de grâce, he sent out a counterfeit email, under the journal editor's name and address, saying, "If all Chinese authors are as impolite and narrow-minded as you, any contribution from China will be automatically rejected. So please stop this." Responding to the mountain of emails that the editor received in response was very time-consuming. Finally, the editor decided to simply ignore the author, resulting in a number of manuscripts sitting in the system and "messing with [the] journal's statistics" [30]. While this may sound far-fetched, this author has received curious emails from some, whose articles have been rejected. In one case, the writer, who had sent his manuscript to the wrong person during semester break, contacted the entire editorial board one week after submission to request the reviewers' comments. The board responded that the review process takes several weeks and to please be patient. The author continued writing, addressing his very long and colorful emails to the whole board—89 in all. Finally, the editor wrote a definitive rejection letter because reviewers noted that the content of the article was not appropriate for the journal. Undaunted, the author's response indicated his disagreement with that judgment: "I believe that I have a great paper as result and 100% sure that most of the researcher will refer this paper as base paper for their future research. In future it's citation will be very high." Obviously, this is not an appropriate mode of interacting with journal editors. And, while it may be psychologically cleansing for the author, such emails do not influence the editorial staff's decision to reject the manuscript. If anything, the reverse occurs.

Conclusions

Like other professional duties, writing a publishable article requires time on task and due diligence in ensuring accuracy and originality. And even with the most carefully written article, an author may face rejection. However, remember that the craft of writing is similar to learning a musical instrument: each takes practice and practice results in improvement. Overholser [31] noted, "To remain productive in scholarly works, authors should gain a sense of meaning, enjoyment, accomplishment, and satisfy professional curiosity through the process." Ultimately, publishing in professional journals involves more than meeting requirements for promotion and tenure: it is a creative and intellectually fulfilling exercise, one that contributes to a sense of personal satisfaction and helps to create the knowledge of a profession.

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Biography

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TECHNOLOGY MANAGEMENT: ADAPTING TO A RAPIDLY CHANGING WORLD

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Abstract

Technology management, or the strategic management of technology to provide an economic, political, and technological edge over peers or competitors, has been a concern of the U.S. since at least the end of World War II. Now, several emerging megatrends have been recognized, including the increased urbanization of the world's population, interconnectedness among economies and economic power shifts, and climate change, impacting the need for more efficient and effective technology diffusion and technology transfer. Several key areas, ranging from mobile Internet and pervasive social media to advanced robotics, artificial intelligence, next-generation genomics, and biotechnology, are influencing the occurrence of these trends. As a result, the capabilities of individual humans, and humanity in general, are changing rapidly and profoundly. Technology diffusion has seldom aligned with the speed at which innovation occurs. With the exponential rate at which technological change is happening now, the issue of technology diffusion and transfer is exacerbated. Organizations and governments are often strained, and particularly in developing countries. As a result, higher education has attempted to respond to rapidly developing needs by creating academic programs, albeit slowly, aimed at producing professionals with appropriate backgrounds to "navigate these unchartered waters," but these efforts have not typically involved global, or even national, input from expert practitioners. In the U.S., there are at least four dozen technology management-related programs. But does the current perspective of what is meant by technology management align with these megatrends, and is the need for technology diffusion and technology transfer vital to the U.S. and other countries?

The objectives of this paper are several fold. First, for background purposes, technology management, technology diffusion, and technology transfer are defined. Second, the recently emerging broad technological trends are described, and the current perspective and competencies aligned to academic programs in technology management in the U.S. are identified. Third, the authors describe approaches to technology management programs in Europe and Asia. Finally, insights are shared regarding whether academic technology management programs align to emerging world trends, and direction for further study is identified. This paper will be of interest to the academies, nations, societies, industries, and businesses throughout the world.

Introduction

The concept of technology management (TM) has been around at least since World War II. Its significance has been linked to the economic, social, and political well-being and livelihood of not only individuals, but of nations, too. Emphasis on TM increased after World War II and with the escalation of tensions during the Cold War [1]. The U.S. viewed the management of technology not only as a political, economic, and industrial imperative for the U.S., but for its allies including Japan, Canada, and Great Britain, in response to the military build-up of the USSR. It was difficult afterward not to note how the increasing use of technology impacted social institutions, the organization of work, the development of human-built environments, and worldwide economics [2]. Notable contributors to the development of TM as a concept, and then the academic discipline and industrial pursuits of it, include Frederick Winslow Taylor, Henri Fayol, Walther Ratheneau, Henry Ford, and James Burnham, among others.

Academic TM programs worldwide now have acknowledged that effective management of technology impacts nations' research and development capabilities, technology transfer, development of technological skills, capabilities, and knowledge. In this paper, the authors discuss technology, technology management, and concepts critical to technology management as well as the critical importance of technology management, because of the exponentially increasing rate of technological change and the aforementioned megatrends. The direction and aspects of TM programs in the U.S., Asia, and Europe were investigated to help determine how effectively they address these emerging trends.

Technology

Noori [3] suggested technology contains three major components. The *hardware* component of technology includes the physical or logical plant (machines, equipment, and their contrivance together) for carrying out tasks to achieve goals and objectives. It includes *software* or sets of rules, guidelines, and algorithms for using the hardware to achieve goals and objectives. Further, technology includes *brainware*. The brainware component implies a purpose to the objectives, goals, and application of the hardware, and the software of technology including the know-how and knowing-why portion of technology use. Orlikowski [4] stated that technology is defined according to *scope* and by the *role* of its usage. In using scope to define technology according to the aspects comprising technology, the word role implies the interactions resulting from technology usage. Wright [5], a technology educator, described technology as being products, processes, or organizations that define technology in the following manner:

> *Technology is humans using objects (tools, machines, systems, and materials) to change the natural and human-made (built) environment. Technology is conscious, purposeful actions by people designed to extend human ability or potential to do work. Technology increases human capabilities.… It is changing. It causes change.* (pp. 14-15)

Regarding the impact of technology on the future, The World Economic Forum [6] recently stated:

> *Technology is understood as a broad concept covering not only products such as machinery, equipment, and material, but also processes and organization methods, all linked by the common factor of enhancing efficiency in production. In addition, technology adoption contributes to a conducive innovation ecosystem.* (No page number; refer to the website related to reference [6].)

In noting how technology is changing the world of work, Levin [7] cited three trends impacting work. One impact is the ability to carry around sophisticated computational devices known as cellphones to communicate virtually immediately anywhere in the world with virtually anyone using the technology. Another trend is increased connectivity to the world-wide-web. A third trend is the increasing development of cloud-delivered enterprise applications, accessible over the Web, and not requiring virtual private network (VPN) access to use it. These three trends are influencing the emergence of work into knowledge-work. This transition to knowledge-work promotes a worldwide, mobile-knowledge workforce. Levin further noted that the change management of technology, or simply technology management, is vital to humanity's future. With this consideration, the authors of this current paper recommend using a more contemporary definition for technology, relative to technology management and its impact on humanity: "Technology is the amalgamation of infinite ideas manifesting into the physical objects and structures, including organizations, policies, laws, norms, and the devices, humans use to maintain their existence or to further their wants, needs, or desires. It includes any human-made single purposes tools, multiple purpose devices, or complex systems and accompanying techniques for lessening human toil. Technology magnifies human abilities to exceed physical, biological, or cognitive limitations. It causes stratification in humanity through the specialization of tasks and processes, while lessening or creating disparity where none before existed."

Technology Management

Technology management (TM) or management of technology (MoT) links engineering, science, and management disciplines to plan, develop, and implement technological capabilities in order to shape and accomplish the strategic and operational goals of the organization [8]. Thamhain [9] stated that MoT is the art and science of creating value by using technology with other resources of the organization. Gaynor [10] viewed technology management as linking the disciples of engineering, science, and management to plan, develop, and implement technological capabilities for shaping and accomplishing an organization's strategic and operational objectives.

The International Technology and Engineering Educators Association (ITEEA) defines a technology manager as one possessing a minimum level of technical knowledge, with skills in one or more contextual areas, and applied abilities in system design, application, products, or processes [11]. Thamhain [12] also defined management of technology as being both an art and a science for creating value, using technology together with other resources in an organization. A review of the literature suggests several concepts important to effective TM. These concepts include, but are not limited to, technology diffusion, technology transfer, absorptive capacity, desorptive capacity, and the social spheres of influence upon the use of technology.

Concepts of Technology Management

Borgo et al. [13] suggested that technology is more than simply tools, technique, actions, and systems. They provided the term technical artifact to describe technology as the intentional acts, agents, and attributions of human activity, using tools and developing them into processes, and suggesting a philosophical nature for the use of technology. It is a term applicable to virtually any human endeavor and to the resulting effects of technological use. Aspects and characteristics of diffusion of innovation provide for the concept known as technology diffusion. As diffusion of innovation is key to technology transfer, Rogers [14] stated that an innovation is an idea, practice, or object that is new to an individual or a unit of adoption, and its transfer is dependent on being communicated, over time, through certain channels and among members of a social system. This techno-socio connection is important to the context in which a technology is ultimately used. Relative to communication channels, over time, through certain channels and social systems, cost is a primary motivator, regarding innovation and technology diffusion [15]. Underdeveloped countries are at a disadvantage, regarding the adoption of outside advanced technologies. A certain threshold of technological development must be met in order to be able to accept outside technologies. A term that has been associated with this concept is technology acceptance. The wider the gap between a country's existing level of technical development and the technology available to be introduced from a more developed nation, the longer and more difficult technology adoption becomes. Diffusion of technology through technology transfer accounts for a large portion of income disparity across countries [16]. Several metrics have been pointed out as being useful for accessing the technological capabilities of nations useful toward technology management [17].

Technology excellence is key to technology management. Technology excellence involves three phases: 1) shaping, which is the acquiring, developing, and enriching of technological knowledge resources; 2) melding, which involves the blending of knowledge resources to create new processes, capabilities, expertise, and skills; and, 3) leveraging, which is the application of technological knowledge resources to exploit new opportunities and to reveal new knowledge resources to cycle back to the shaping phase. Japan was extremely successful in the utilization of these phases in rebuilding after World War II [18].

Technology transfer describes the process or actions through which tools, technological capability, technological know-how, and experience move from outside sources to a single entity or multiple organizations. The first association of the term technology transfer is to economic development, due to technological advancements. Reddy [19] noted from Soundararajan that economic growth, due to technological advancement based upon the transfer of technology from developed countries to lesser developed countries of the world, provided the basis for terminology such as first-world (developed), second-world (developing), and third-world (underdeveloped) countries. Technology transfer associated with innovation and economic principles often occurs directionally from developed countries to lesser developed countries. Technology policy and decision making are guiding factors as to the extent to which technology transfer takes place [20]. Technology transfer is often multifaceted. It involves opportunity, desire or need, search for appropriateness, comparison, selection, acquisition, implementation, and term of use. The extent of technology transfer may be tacit, implied, non-specific, or specific. Technology transfer can occur as a single instantaneous event or as a multi-stage process of events. Critical points to understanding technology transfer are suggested as follows:

1. Technology transfer is non-linear and may have varied associations. Aspects of technology transfer transactions do not always occur on a one-to-one basis. Often, the aspects of the transfer occur on a one-to-many or a many-to-one basis.
2. Integration is key to technology transfer. As technology itself is a multi-dimensional commodity, the components of technology transfer often occur through a variety of sources or suppliers in order for a technology to become an end-use, turnkey, complex system.
3. Technology transfer is dynamic. As technology does not remain static over a period of time, the aspects of technology transfer also change and evolve over time.
4. Technology transfer implies technology diffusion.
5. Technology transfer requires industrial and community technology opinion leaders to leverage successful transfer.
6. Emerging technological developments, patterns, and trajectories define for organizations which technology transfers to purse to remain competitive.
7. Awareness gaps exist, communicating available technology for transfer from country to country, region to region, or locality to locality.
8. Technology transfer can minimize disparity and cause disparity.
9. User-producer interactions are often underestimated during the process of innovation during technology transfer.
10. Possession of a technological resource does not necessarily imply its use or effective transfer.
11. Policy measures must be flexible among potential technology users in order to address a wide variety of needs.
12. There is often a strong cultural dynamic embedded within technologies. Understanding the cultural dynamic is critical to technological adoption for successful technology transfer to occur. The impacts of technology transfer need be considered prior to the action of technology transfer occurring.
13. Managerial capability is essential to technology transfer between industry and countries accepting technology transfer [21].

In recent years, the complexity of the transfer process has been examined by a growing number of researchers whose findings are beginning to impact technology policy decision making. Metrics similar to the *Technology Achievement*

Index are used as a verification of technological development due to and through technology transfer [22]. Two measures important to technology transfer are absorptive and desorptive capacity. The ability to acquire and utilize external knowledge by an organization is known as absorptive capacity. The ability of an organization to transfer technology outward from it to other entities is known as desorptive capacity [23].

Technology road mapping, a concept originating with Motorola in the 1970s, is a robust technology management tool. The goal of developing the tool was to align product development with investment to address future market needs [24]. Business and industry use technology road mapping to effectively manage technology and innovation in order to maintain and gain competitive advantage [25]. Technology road mapping is also utilized at an industry level through collectives of interested stakeholders in a given industry. These stakeholders span small and large, public and private organizations, including industry consultants and government officials. Industry roadmaps are developed to stimulate industrial collaborations and focus and accelerate technology advancement in an industrial sector [26].

Evidence of Rapid Technology Change Regarding the Need for Technology Management

As suggested by technology contemporaries, including James Burke, Kevin Kelly, Ray Kurzweil, and through application of Moore's Law, the management of technology is now essential, due to the exponential rate of change occurring in the world today as a result of technology use [27-30]. Technology is transitioning work from what were once primarily labor-intensive activities to primarily knowledge-intensive activities [31]. In the manufacturing sector alone it has been reported that knowledge workers, or workers relying primarily on data and information to accomplished their work, currently represent about 40% of the manufacturing workforce [32]. Research suggests that 47% of existing American jobs are at risk of elimination, due to computerization and automation. Frey and Osborne [33] found that computerization is especially likely to impact fields such as transportation and logistics, production labor, and administrative support occupations. The losses will likely occur in stages. Services, sales, and construction positions will likely be the first to be impacted. The rate of dislocation of management, science, and engineering jobs is likely less pronounced, since activities in these career fields are more difficult to automate, but this is dependent upon the rate at which artificial intelligence will develop. Understanding the historical connections between innovation, urbanization, and transportation is important for technology management. These connections play a part in technology development, innovation, patenting, and diffusion of technology [34].

Workers with creativity and social skills in services, sales, and construction areas will be less susceptible to computerization and automation displacement [35]. By 2020, it has been suggested that there will be an additional 5.9 million Americans without high school degrees and up to 1.5 million fewer college graduates to meet America's employment demands [36]. Forty percent of the executives whose companies intended to hire new workers in the coming years, have noted skills gaps in work applicants, leading to positions being open for six months or longer. Healthcare, business services, leisure and hospitality, construction, manufacturing, and retailing will account for as much as 85 percent of all new jobs. Twelve emerging disruptive technologies have been identified as influencing life, business, and the global economy [37]. These emerging disruptive technologies include:

1. Mobile Internet
2. Automation of knowledge work
3. Development of the Internet of Things (IoT)
4. Cloud technology
5. Advanced robotics
6. Autonomous and near-autonomous vehicles
7. Next-generation genomics
8. Energy storage
9. 3D printing
10. Advanced materials
11. Advances in oil and gas exploration and recovery
12. Advances in renewable energy

Berger and Frey [38] investigated work employment opportunities in new industries first appearing only between 2000 and 2010. They concluded that skilled workers are more readily capable of accepting technological change than workers lacking technical skills. Furthermore, they noted that the need for skilled work within existing industries, prior to the year 2000, has decreased. Workers in new industries were found to be young and better educated, "due to skill-based technological change," than previous-era workers. They found that individuals with STEM degrees were more likely to select new industries for work while professional degreed individuals were less likely to work in new industries. The new industries are more likely to occur in cities given a historical advantage through hosting land-grant colleges, with a better educated population and higher concentration of skilled workers. The implication is that "places that are plentiful in educated people benefit from the diffusion of technological knowledge across companies and industries." They noted a geographical correlation to new industry development. The highest fraction of new industry workers are particularly located in the Northeast and Western states in America, and particularly in the cities of, in order, San Jose, CA; Santa Fe, NM; Washington, D.C.; San Francisco, CA; and Provo, UT.

The Future of Jobs report published by the World Economic Forum poses that a fourth industrial revolution is occurring [39]. Disruptions driving this industrial revolution include climate concerns and natural resources constraints, the changing flexibility of work and work environments, the development of energy supplies technology, robotics and autonomous transportation, longevity and the aging of societies, and the rapid urbanization of populations.

Spheres of Influence upon Technology Management

Social, political, and economic spheres of society influence the management and use of technology [40]. Design and implementation of technology are patterned after a wide range of social and economic factors, and based upon technical considerations [41]. Rogers stated how technology clusters impact human interactions [42], while many philosophers, including Feenberg, Marcuse, Borgmann, Ihde, and Latour, have provided abstract theorizations concerning technology's influence upon society, and impacts of human technology usage on humanity [43]. Orlikowski [44] noted several important concepts toward understanding technology management. First, there are shared "interpretations of interventions" concerning the use of technology. Structural models describe technological and sociological interactions relative to how technology is a product and medium of human actions. This can be considered deterministic. The Forces of Change model is useful for recognizing the challenges and opportunities facing technology management education [45]. This model lists challenges and opportunities to technology management, including:

- Environmental issues
- National defense and homeland security
- Health issues
- Demographic trends
- Cultural and economic division
- Deregulation and instability of global financial industry

Other models have been suggested for conceptualizing management of technology [46, 47]. In Figure 1, the authors suggest using a "Social Spheres of Influence upon Technology" model for conceptualizing strategies to ensure successful technology management abstraction.

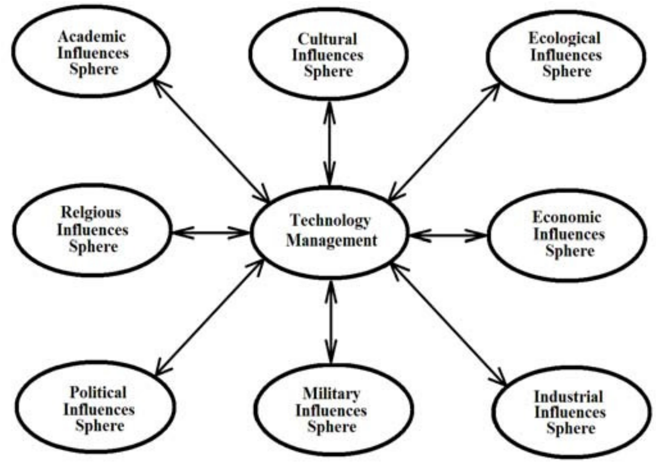

Figure 1. The Social Spheres of Influence upon Technology

Aspects of Technology Management Important to Industry

As technology management (TM) initially came about as an academic discipline after World War II aimed at enhancing nation-state capabilities, it has been suggested that value creation is imperative for not only business and industry, but for academic technology management programs. In doing so, TM becomes an engine for progress and economic health, regarding development of advanced economies throughout the world. Whereas traditional management is valuable for understanding, assimilating, integrating, and directing technology and technology-facilitated innovation for the benefit of enterprise and customers, technology management enhances competencies for creating and improving products, processes, and services in the marketplace. But modern TM programs are quite diverse in nature.

The academic fields of engineering and technology management evolved into academic disciples at opposite ends of a spectrum, with the technology management programs constantly being added, remade, evolved, and retired. The varied focus of the many TM programs includes entrepreneurship, technology commercialization, operations and project management, information technology management, societal implications and awareness of technology, and technology strategy. The discipline of technology management, defined within a contextual setting of engineering and technology management (ETM), falls in-between engineering at one end of the spectrum, with masters of business of business administration (MBA) and public policy at the other end. The academic discipline of technology management is noted as containing knowledge areas including knowledge of technology, knowledge of technology-linked management topics, knowledge of general management topics, and knowledge of supporting disciplines [48-50].

Aspects of Technology Management Programs in the U.S.

There have been varying perceptions regarding the competencies and skills of technologists and technology managers. Doggett et al. [51] conducted two surveys to establish a technology management competency model. The following questions were asked in order to narrow the perception: 1) What is the core body of knowledge for an entry-level technology manager? and 2) What are the core competencies for an entry-level technology manager? Two contexts arise from the core competency model. The applied context defines technology management according to process, project, systems, and operations. Within the management context, self-management, people management, quality management, and risk management are criteria defining the competencies.

Concerning process and self-management, identified competencies included responsibility, integrity, knowledge, self-monitoring, discipline, and values. Concerning project and people management, the criteria leading, listening, organizing, mentoring, planning, knowledge of group dynamics, respect, decision-making, empowerment, and staffing emerged. Concerning systems and quality management standards, improvement, quality frameworks, and customer-focused reliability. Concerning operations and risk management: analysis of risk, risk tools and techniques, risk tolerance/appetite for risk, risk prioritization, and risk culture and context were defining characteristics of technology management. This model, with three levels, defines a body of knowledge useful for the academic discipline of technology management in the U.S.

Technology Management Programs in the U.S.

Through a search of the Internet and survey of the membership of the Association of Technology, Management, and Applied Engineering (ATMAE), academic programs using technology and management in their title were found. A list of these programs is provided below:

1. Bemidji State University—Technology Management (BAS)
2. Boston University—Operations & Technology Management (BS, PhD)
3. Bowling Green State University Construction Management, and Technology (BS)
4. Central Connecticut State University—Industrial Technology—Technology Management (MS)
5. Central Michigan University—Industrial Technology Management (BAA, BA, BS)
6. Columbia University—Technology Management (MS)
7. Davenport University—Technology Management (MS)
8. Eastern Illinois University—Technology Management (MS)
9. Eastern Michigan University—Technology Management (BS)
10. East Carolina University—Technology Management (PhD)
11. Georgetown University—Technology Management (MS)
12. George Mason University—Technology Management Leadership (MS)
13. Georgia Institute of Technology—Management of Technology, Information Technology Management (MBA-MOT and PhD)
14. Herzing University—Technology Management (BS)
15. Indiana State University—Technology Management (BS, MS, PhD)
16. Jackson State University Technology Management (BS, MS)
17. Marshall University—Technology Management (MS)
18. Massachusetts Institute of Technology—Technology, Management, and Policy Program (MS, PhD)
19. Millersville University of Pennsylvania—Applied Engineering & Technology Management (BS)
20. Neumont University—Technology Management (BS)
21. New York University—Polytechnic School of Engineering—Business and Technology Management (BS); Management of Technology (MS); Technology Management (PhD)
22. North Carolina Agriculture &Technology University—Technology Management (PhD)
23. Northern Illinois University—Industrial Management & Technology Emphasis (BS)
24. Ohio Northern University Manufacturing Technology with Management (BS)
25. Ohio University—Engineering Technology and Management (BS) and Technical Operations Management (BS)
26. Portland State University—Engineering and Technology Management (MS); Technology Management (PhD)
27. Southeast Missouri State University—Technology Management (BS, MS)
28. Stanford University—Technology Management Center—Science, Technology and Society (BS)
29. Stevenson University—Business and Technology Management (MS)

30. Texas A&M Commerce—Technology Management (MS)
31. Texas AM University—Technology Management (BS)
32. Texas A&M University Kingsville—Industrial Management and Technology (BS)
33. Texas State University—Technology Management (MS)
34. University of Bridgeport—Technology Management (MS, PhD)
35. University of California at Santa Barbara—Technology Management (MS)
36. University of Central Missouri—Technology Management (PhD)
37. University of Idaho—Technology Management (MS)
38. University of Illinois—Technology Management (MS)
39. University of Northern Iowa—Technology Management (BA)
40. University of Pennsylvania—Technology Management (MS)
41. University of Southern Maine—Technology Management (BS)
42. University of St. Thomas Minnesota—Technology Management (MS)
43. University of Wisconsin—Platteville—Manufacturing Technology Management (BS)
44. Utah Valley University—Technology Management (AAS, BS)
45. Washington State University—Engineering Technology Management (MS)
46. Western Kentucky University—Engineering Technology Management (MS)
47. Wichita State University—Engineering Technology Management (BS)

Aspects of Technology Management Programs in Asia

Japan, after World War II, is an example of effective and productive technology management and technological excellence. Japan has always been a country with very few natural resources. After being devastated during WWII, Japan set about to rebuild their country. Technology management was imperative in making Japan a leading economic power in the world. Core values include engendering a homogeneous culture, reinforcing productivity norms, being receptive to absorptive technology development, human resources development, and an intense focus on operations management to promote effective technology management. Being mindful of market and customer concerns, innovation and research and development were high national priorities after WWII. Identifying technology of generic significance, but with high potential growth, was key. Leaders participated in technology forecasting and road mapping, with commercialization of technological capabilities in mind. Ideation and diffusion of technology were paramount to their becoming a worldwide techno-industrial economic power after WWII. Because of Japan's close proximity to other Asian countries, including South Korea and Taiwan, technology transfer easily occurred [52].

Undergraduate management of technology (MoT) programs provided in Malaysia adhere to the 2003 established International Association of Technology Management (IAMOT) credo for providing technology management programs. Goals by industry and education leaders for this country include shifting from a labor-intensive economy to a knowledge-intensive economy, and for the country to become a technology provider rather than a technology user type of country. Five knowledge groups define MoT in Malaysia, according to the credo [53]. These knowledge groups include:

- Management of Technology (MoT) Centered Knowledge
- Knowledge of Corporate Functions
- Technology-Centered Knowledge
- Special Requirements/Assignments
- Knowledge of Supporting Disciplines

The five MoT programs in Malaysia, according to this credo, include:

- Bachelor Degree in Management (Technology)
- Bachelor in Technology Management (Production and Operation)
- Bachelor in Industrial Technology Management
- Bachelor in Technology Management (Innovation Technology)
- Bachelor in Technology Management (High Technology Marketing)

Malaysia, being a wealthy, yet developing, natural resource country in Asia, has identified sustainable technology management as vital toward development of its country [54]. As a hub, the capital Singapore, when initially attracting multinational high technology, value added companies, recognized difficulty in bringing Western technologists and engineers to the country to manage their high-technology companies. In response, research was conducted for establishing the MSc/MoT degree at the National University of Singapore (NUS). They benchmarked NUS, Stanford University, University of Waterloo, and Eindhoven University, master's MoT programs [55].

Aspects of Technology Management Programs in Europe

Leaders from higher education, the corporate sector, and the public sectors in Europe were interviewed to determine whether graduate and post-graduate technology management (TM) programs in Europe were adequately addressing the emerging needs of business and academia in Europe. First, interviews were conducted of technology leaders there and covering a range of topics. Addressed during the interviews were the pedagogical approach and content provided in current technology management programs, whether the programs were delivered on-site or off-site, how the content was provided (i.e., either via in-house presentation or by consultants and business school faculty), the topical focus of the TM programs, and the expected outcomes of the TM programs. From these initial interviews, it was determined that TM education in Europe had evolved in different ways since the 1990s. Two emerging trends were determined. Demand for specific skills development was occurring. Second, an anticipation of outcomes toward organizational renewal, and venture entrepreneurship was occurring. Based on these findings, a typological view of specific skills versus generic skills development, and job efficiency and career focus versus company renewal and venture focus was developed [56].

The following conclusions from the interviews and the topology were then reached. The first trend noted was the need for the development of generic technology skills for the retention and recruitment of employees in the workforce in Europe. The second trend toward European companies was in providing specialized, on-the-job training in companies provided by consultants. It was noted that universities and institutions of higher education were not well suited for transferring the specific skills and tacit knowledge of companies to potential workers.

It was further noted that consultants were more adept at providing specific skills with consideration of different industry sectors and cultures and that boot-camp-type educational programs were preferred for attaining company-focused objectives. A clear trend was noted toward embedding generic skills into technology-specific programs to emphasize industry-specific needs in Europe. Gleaned from the article was the fact that TM programs in Europe are contextually different from those in the U.S., with the European programs having a strong business and entrepreneur component, while the emphasis of the U.S. programs was technical competency [56]. A primary concern regarding technology management in the EU educational systems is toward respecting cultural values across countries, businesses, and industries [57].

Conclusions

Since World War II, technology management has been of great concern, and is of exceptional relevance now. Technological megatrends are deterministically driving life, business, and the global economy. Twelve, emerging disruptive technologies noted in the paper are pushing various facets of modern life. These megatrends have major implications toward the concept of technology management and providing technology management-related education. Work is transitioning from what was once predominantly labor-intensive activities to knowledge-intensive activities. This phenomenon is causing worker displacement. Geographic areas already experiencing technological advantages hosting high-technology business and industry will further their technological advantages. As various facets of society influence technology management, technology and society have reciprocal effects upon each other. As noted by Berger and Frey [38], STEM-degreed graduates, such as those produced from technology management programs, are in high demand and likely more easily transition to other emerging technology occupations than those graduates without STEM degrees. Providing basic technology skills seems more germane to undergraduate applied science and applied engineering programs. Concepts like technical artifact, technology transfer, technology road-mapping, are important for understanding technology management and providing technology management-related education. Academic technology management programs exist worldwide not only to provide technology skills but to provide technology management skills.

Technology management not only has evolved in a variety of ways in the U.S., but in Asia and Europe as well, toward addressing emerging economic, political, and socio-technological needs. Companies, at least in Europe, have come to realize that academic TM programs can only provide basic technology skills and conceptual knowledge regarding technology management. Although European companies find the level of basic technical skills and TM concepts provided by higher education institutions acceptable, they utilize outside sources including specialists and consultants to address their specific technology and TM needs. It is essential that technology management programs provide business and industry, along with consideration of society in general, not only with the necessary skills and competencies but the proper balance of various skills, in order to meet workforce needs. What is the appropriate balance of theoretical and practical development necessary to produce graduates, who make the most impact when entering the workforce? Consideration of both the Asian and European technology management approaches discussed in the paper, in contrast to American technology management approaches for benchmarking purposes, may very well provide an answer to this question.

With the rapid pace of technological change and the influences of globalization occurring, industry-influenced instructional design very well may be used as a starting point for filling gaps between what academia provides educationally and what industry practitioners and society needs and requires. Finally, using an industry-influenced starting point can help determine when TM programs, regardless of geographic region where provided, undergo revision or continuous improvement efforts toward remaining current and appropriate. Additional investigation into the similarities and differences between technology management programs for benchmarking purposes, and technology management needs relative to industry and society, both in the U.S. and abroad, provides avenues for additional research. These types of opportunities help ensure TM program currency and should be explored further.

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STEM OUTREACH EFFORTS FOR URBAN STUDENTS

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Abstract

Four-year universities and community colleges rely on outreach efforts to bring the awareness of STEM-related careers to students, who might be interested in joining their student body in the future. These events are of utmost importance for students, who do not have all of the necessary role models to engage them in conversation about their future careers. Some students might not perceive a STEM career as valuable and feasible in their future career paths, even if their own schools offer information and resources related to STEM career pathways. Hence, various outreach efforts at different levels of education have to be integrated to make sure that students learn about engineering careers early enough for them to consider this choice and to adjust their high school curricula to align with their future careers. In this paper, the authors present four outreach efforts for four levels of K-12 education: pre-school, elementary school, middle school, and high school. The activities used to implement these outreach events are also discussed. Activities related to robotics, for example, have the advantage of engaging young students and, at the same time, offer the opportunity to discuss different engineering branches, such as electrical or mechanical engineering, electronics, wireless devices, or underwater robots. Location of the outreach event is also important, since STEM information needs to reach both students and their families. As such, the authors discuss the placement of the STEM events in schools, in the community, or in job-related places such as a Navy base.

Introduction

The current generation of students growing up in a highly technological society of the twenty-first century faces advanced technologies in every aspect of their daily lives, with computers, smartphones, tablets, and other high-tech gadgets being ubiquitous from very young ages [1, 2]. This level of technology in society is due to engineering advancements, and there is a high demand for engineering-educated people at all levels [3]. But in order to bring more people into engineering, the first thing to do is to create awareness of the importance of engineering, both for young students in grades K-12 and for their parents [4, 5]. Lately, a plethora of STEM-related programs are being offered at all levels, starting with very young kids in elementary and even preschool, ranging from summer camps, workshops, participation in conferences promoting specific careers, or even professional development events focused on K-12 teachers, both in the U.S. and globally [6-9]. Other programs are sponsored by government agencies such as the National Aeronautics and Space Administration (NASA) and the National Science Foundation (NSF), and they provide summer programs related to engineering for K-12 students [10].

The programs may address students as well as their teachers, and they may include workshops and summer camps, in-school or out-of-school programs, robotics clubs in schools, or outside school grounds offered by other organizations [11]. Some of these programs are spread over a few days or possibly one week, but shorter programs may be only one day and may take the form of field trips or STEM fair events. All of these programs are important and they have specific goals. While a summer camp is more focused on a specific STEM area, which might be robotics or rapid prototyping, for example, or some other science or engineering topic, a STEM fair would have the goal of exposing the participants to a broad selection of STEM-related opportunities in the region, through displays and hands-on activities to stimulate the curiosity of young students for science and engineering [12]. Before a student starts looking for a summer camp in engineering, he/she should learn about such opportunities and understand the benefits of such a camp; and here is where a STEM fair event can provide the necessary information. Even though these days there is a multitude of STEM programs, all of them have their limitations, and there is a large group of students that still do not have access to them. A school might offer a robotics club, but there is always a limited number of students that can be part of it; and, if a student does not have a clear idea about that club early enough at the beginning of a school year, the club capacity might be filled before he/she learns about it or decides to participate [13]. A summer camp that runs for a week is very often not an affordable option for a lot of students and, again, the spots usually are filled by the time a family learns about the opportunity or has the chance to register for it [14]. Thus, even with increasingly larger numbers of science and engineering-related programs, a lot of students still do not get access to them, and they might even be intimidated by this and get the impression that STEM education is something that a lot of people get access to but not them. This is where community-oriented STEM events can increase awareness and inform students and their families about engineering careers and educational pathways to be pursued in the K-12 curriculum to enable successful STEM careers.

Old Dominion University College of Engineering Engagement in Outreach Events

Old Dominion University is fully engaged in reaching out to the community for science, technology, and engineering careers; and the range of programs vary from funded to volunteer-based programs, in close collaboration with local schools to develop programs in those schools, in the university, or at community locations that facilitate the participation of everyone interested, either student or parent. In this paper, the authors discuss some of the volunteer-based outreach activities organized at different locations outside of the university. The location of the event is crucial in reaching out to specific groups in the community, especially in areas of large groups of underrepresented students, rural areas, or poor communities. Some of these activities are STEM fairs organized at different locations, such as a Navy base (Norfolk) or a high school in a community with a large group of underrepresented students (Portsmouth HS). For such events, the participants come with displays and demos and very often with hands-on activities that introduce young students to the basic concepts of science, technology, and engineering, and to current issues in the community, where STEM solutions are needed. Successful students in different STEM-related programs have the chance to show their projects (very often robotics-related projects) and to be role models for other students, to inspire them and give them information on how to get involved in such programs.

Different organizations have the opportunity to distribute information about their offers in terms of STEM-related programs or products (such as educational materials). Universities and colleges provide information about education pathways towards different careers in STEM-related fields. The downside of such events is that, most of the time, they are overcrowded and a student can spend only a short amount of time at each boot, especially when he/she is part of a group and has to go along with the group. The amount of information might also be overwhelming, and young students might find themselves lost in front of all the exciting displays of which they do not have much of an understanding. That is why the fair event is very important for distributing information, creating awareness, and helping people of different organizations establish contacts, but they need to be followed by more specific events that involve smaller groups of students and are placed in different environments. Faculty and students from ODU's College of Engineering and Technology participate frequently in STEM programs and activities on school grounds in the local community. These events are in collaboration with teachers and local school districts, and they may materialize as engineering days organized for groups of students at different grade levels, or programs that go year-round, or for a period of time in conjunction with engineering classes or clubs that run in the schools. Faculty also get involved at the individual level, as they may volunteer time as tutors in the areas of math and science for K-12 kids, or they may get involved in senior projects in specific high school programs that are required for graduation.

An Engineering Program for Pre-School Children

In the 2012-2013 academic year, the 3-5 year-old multi-aged classrooms at the Children's Learning and Research Center (CLRC) at Old Dominion University (ODU) implemented a teacher-led engineering unit that spanned approximately three weeks. Students were exposed to many areas of engineering including, but not limited to, mechanical, aerospace, civil, chemical, and genetic engineering. This experience included fieldtrips around the campus, where the students made magnetically levitated train cars and were exposed to balloon-powered cars printed on a 3D printer. During the 2014-2015 academic year, the CLRC expanded the engineering unit and implemented project-based learning into its curriculum. The activities related to the 3D-printed balloon-powered cars were expanded. The students were brought into an engineering design lab with a 3D printer, and they were presented with different 3D-printed balloon-powered cars. They discussed the process of engineering design, how cars are built out of various parts, and how these parts were different in the models presented. Based on team analysis of the different models, the students voted on which car they thought was the best—the measure being which car would go the farthest. Then, with the help of their teachers, they brainstormed ideas of how a car should be redesigned for better performance. Each of the four classes met with two engineering faculty members to turn their ideas into a new car designed in the computer-aided design software, Autodesk Inventor. The kids had the chance to design their cars to look like sharks, for example, or to have parts of the cars remodeled in different shapes, such as a star, an octagon, or a triangle. They discussed the influence of the car total weight, the size of the wheels, and the overall car shape on the car's speed performance. Figure 1 presents one car design and the 3D-printed parts designed by preschoolers for this project.

From all the cars that were designed according to the specifications, four cars voted by the kids were selected for printing. These final designs were tested by the children in a competition. The main design objective was to build the fastest car. After the competition, each model was discussed based on its performance. This way, young students were involved in the iterative process of engineering design and testing, and in discussions related to different geometrical shapes and properties of solid dynamics, speed, and acceleration. The 3D-printed cars from this project would continue to be used in STEM/STEAM outreach events, where students from elementary schools would be asked to visually inspect the cars and estimate which one would go father; then to swap wheel sizes and determine how the wheels affect the distance the car will travel; and finally to investigate how the balloon affects the motion of the car. This way, students are exposed to various facets of engineering, such as aerodynamics, rigid body dynamics, reconfigurable design, and testing.

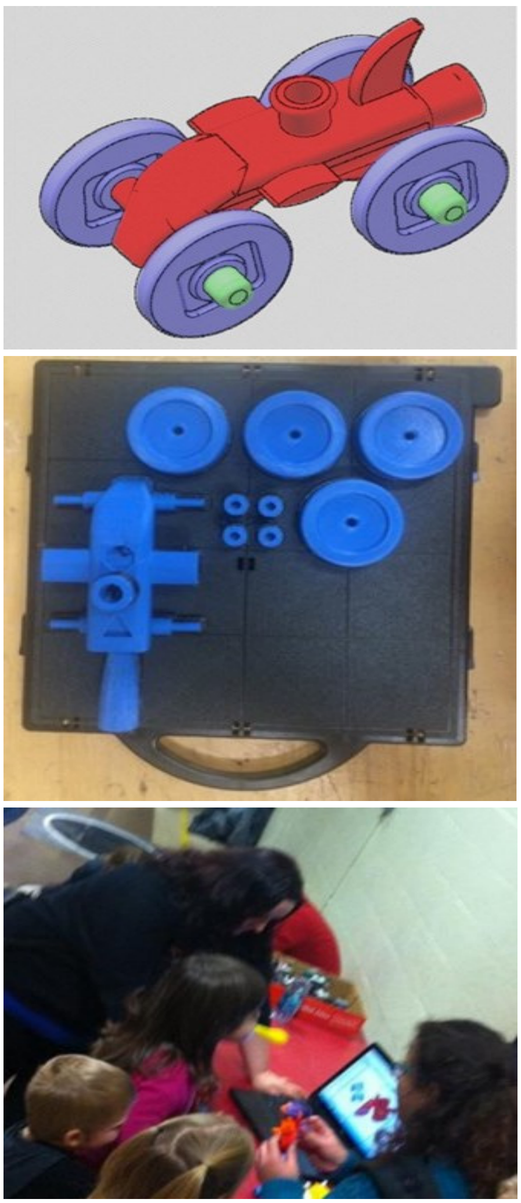

Figure 1. Balloon Cars Designed by the Preschoolers

In-School Engineering Day for Fifth Grade Students

This event was organized within an elementary school and addressed only one group of students, the fifth graders, who are at the point of making their choice for middle school. Virginia Beach has few choices for middle schoolers, including gifted and IB programs, but even if a student choses to pursue the neighborhood middle school, this is a time when a student starts thinking about career and curricular choices, which are important for creating the basis for success in those careers. For this event, two faculty members and several students from ODU participated. The event spanned over half of the school day. There were roughly 100 students participating, along with the fifth grade team of teachers. The engineering day consisted of two presentations made by the faculty, demos, and hands-on activities. One of the presentations introduced the students to the field of engineering, its importance over time, and its omnipresence in our everyday lives. The presentation made the distinction between engineering and science, and among the wide range of engineering fields. It was emphasized that engineers are curious and creative people, and their work targets specific needs in local communities and society as a whole.

Students were encouraged to identify areas of engineering that they felt more attracted to, that they liked, and were particularly curious about. The idea transmitted was that one should not think of engineering as a very narrow and specialized field that only some people are fit for, but that it is a wide range of specializations and each student can find his/her own identity within engineering and bring personal contributions to the development of the field. Students received the presentation very well. They were familiar with a lot of the information presented, and this eliminated the initial timidity of the students in front of college faculty and students, and towards a field perceived as very difficult. Since the familiar information was presented in a new context, or was pointing to aspects they were not aware of, the presentation had the added benefit of inspiring the students, and to fire up their curiosity and their desire to learn more about engineering in general and specific areas in particular. A second presentation was more specific and introduced the students to the aspects of mechatronics, its interconnections with various other fields of engineering, its history, and presence these days in areas ranging from community jobs such as cleaning polluted areas or helping people with special physical conditions, to space exploration and advanced manufacturing processes. The engineering day for fifth graders included presentation demos with robots and small engineering projects, featuring electrical and mechanical laws or properties.

The setup of this event offered more time than a fair-type event for every student to get a chance to try the demo projects and ask questions about them. After the engineering day, the teachers continued the discussions in class with the students on the topics presented, and students were asked to write about their learning through this event. Since a large number of students approached the faculty members and expressed their desire to become engineers after learning of the wide variety of engineering alternatives, and to talk about how learning about the importance of engineering in society sparked their interest, it became apparent that targeting smaller and more homogeneous groups has the potential of being more successful in reaching the students.

STEM Event for Middle School Students Organized on a Navy Base

The Hampton Roads area is home to a large concentration of military populations, either living there permanently or being stationed for several years. A lot of the adult military population is often interested in furthering their education and getting a degree, while staying in the area. In this context, ODU has a lot of programs to accommodate military students, and a large portion of the student body is either active or retired military personnel or coming from military families. Among the young population enrolled in the K-12 education system, there is a large number of students that are either coming from military families or that aspire to become part of the military forces later in life. For these students, it is very important to introduce them to STEM and to the opportunities for engineering and science-trained individuals in military-related fields. In support of these ideas, a science, technology, art, and math fair was organized in the spring of 2016 at the Mid-Atlantic Regional Maintenance Center (MARMC) at Naval Norfolk Station. Interactive booths celebrating current and emerging technologies were presented by ODU in conjunction with U.S. Naval agencies and regional shipbuilding industry partners. Over two hundred students from three middle schools in Hampton Roads engaged in STEAM activities through tabletop displays and hands-on activities, all organized by academic, private industrial, and government participants to introduce students to the concepts and the outcomes of STEAM. Students had also the opportunity to talk directly with professionals in these fields. ODU engineering faculty and students were present at the event with some original projects built by college students; they introduced the middle school students to these projects and explained to them how the ideas, developed while working on college projects, are shaping the Navy and the related industry today. The demos presented on this occasion were related to areas such as naval and maritime, robotics and mechatronics, and electronics and circuits.

An autonomous boat, for competing in the Roboboat Competition sponsored by Office of Naval Research (ONR), was designed and built by a multi-disciplinary team of ODU undergraduate engineering students from the Engineering Technology, Mechanical and Aerospace Engineering, and Electrical and Computer Engineering Departments. Figure 2 shows how the Roboboat Autonomous Surface Vessel was set up as a static display with posters to explain the vessel's design and competition details.

Figure 2. Roboboat Autonomous Surface Vessel

Another stand had ODU students teaching ship design terminology and concepts of buoyancy and stability through hands-on activities. They also helped middle schoolers to build boats out of aluminum foil and let them use the different designs to compete in order to determine which ones would hold the most weight before sinking. Navy personnel and ODU faculty and students also explained to the middle schoolers about unmanned underwater vessels used to respond to oil-spill disasters. Figure 3 shows how middle-schoolers had the opportunity to remotely operate small submersibles to respond to a simulated oil spill in a small pool. Another group of displays was related to car building and intelligent machines. The ODU Motor Sports Club's Baja Car was set up as a static display, with ODU students on-hand to explain the design and competition details. This car was designed and built by a multi-disciplinary team of ODU undergraduate engineering students from the Engineering Technology, Mechanical and Aerospace Engineering, and Electrical and Computer Engineering Departments.

Students from the Computer Science department designed and built intelligent land vehicles to sense and respond to different obstacles, as part of their academic requirements in ODU's Intelligent Machines Course. This project integrated robotic design and programming skills, and visiting students were introduced to the importance of hardware/software-integrated design needs in a wide range of industries. A last group of displays from ODU introduced students to electronics and circuits through reconfigurable circuit boards that are commercially available. These boards may be found at affordable prices in toy department stores but they can be invaluable teaching tools for students at all levels, and can be used to introduce them to different circuit components and the laws that govern them through hands-on experiments that are easy to put together, test, and modify, without the need of soldering. Next to the circuits' stand, students were also introduced to mechatronics and robotics through the use of the SumoBots robots, in such a way that they could see how learning the basic principles through simple designs can lead them to more complex applications, such as robotics.

Figure 3. Oil-Spill Response Using Unmanned Underwater Vessels

Since the event was hosted on Naval Station Norfolk inside the MARMC facilities, students saw first-hand the technical equipment and the type of engineering-related work that sailors and civilians do on a daily basis. Students were able to see the U.S. Navy's ships up-close and understand the engineering activities required to keep the ships afloat; ships full of advanced technology that keep the sailors safe and prepared to carry out the country's missions. The entire event had the goal of getting students excited about engineering and helping them see the opportunity of achieving an engineering degree in their communities, at ODU, and, upon its completion, the fortuity of pursuing an engineering career with the Navy in the proximity of their home. For some students, being able to get the required qualifications and find jobs in their home areas is crucial, especially when affordability of higher education becomes a priority for the younger generation.

STEM Fair in High Schools or Local Colleges

STEM fairs, or science and engineering fairs as they are sometimes called, are nothing new these days; but it is important for them to reach the population that is most in need of the information that they provide. For students in local communities that struggle with poverty and associated social issues, it is crucial to bring to their attention not only the opportunities that are around them in terms of education or career, but the very fact that those opportunities are within their reach, that there is a chance for everyone to be successful, and that chance might be closer than they think. Sometimes teenagers might not be so open to discussing their potential and choices for future careers with a family member or a guidance counselor in school. Even though the schools' guidance offices have plenty of information about local opportunities, some students still do not take advantage of this information. The benefit of a STEM fair organized in the community, eventually in one's own school, is that it reaches both students and their families, bringing the information directly to them. Hand-on demos and activities for all ages make a fair fun and brings people together; but along with these activities, local colleges and universities also come with information and points of contact for the variety of programs that they offer, the career opportunities related to those programs, and the pathways to reach and succeed in these programs.

An example of such an event is the annual STEM fair day organized on public high school grounds in the Portsmouth city of Hampton Roads. It is a daylong event for neighborhood families and students of all grades. On this occasion, local students from different grades have the chance to present the projects they built during the previous year's science classes, strengthening the confidence in their own potential, raising their self-esteem, as well as inspiring other students, possibly even their own classmates. Local industries and organizations also come with displays and science/engineering-related demos and products that spark the imagination of young students and inspire them to pursue careers in engineering and science. Another example is the STEM fair organized annually by Christopher Newport University in Newport News City, also in Hampton Roads. To these fairs, ODU's college of Engineering and Technology participates with demos supported by college students, such as SumoBot robots, and young students are always very excited about these demos, as shown in Figure 4.

Faculty members are always present at these events, and they get the chance to reach out to high school students, who are preparing to choose their college pathways. Not only are the different programs discussed with the prospective students, but with students entering high school. Also discussed are the curricular choices in high school that will lead to a successful college experience.

Figure 4. STEM Fair Day at Wilson High School in 2015 and 2016, Organized by the Portsmouth Public Schools

Conclusion

With the need for highly trained engineers and scientists in today's society comes the need of informing students and their families about the wide variety of options available, and to make this information especially available to those students having little or no exposure to higher education and pathways to reach it. The Hampton Roads area, home of Old Dominion University, includes low-income communities, large groups of minority populations, and a very large group of military families. ODU is dedicated to reaching out to all members of this community and helping them achieve their educational and career goals. In this paper, the authors discussed the need for variety among STEM outreach events, from fairs to in-school programs, their benefits and the importance of their location and the population to which they reach out. Also presented were four representative events in which ODU faculty and students participated, ranging from programs for preschoolers to in-school programs for students entering middle school, and fairs for middle and high school students.

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COST ESTIMATION FOR IMPLEMENTATION OF A B.S. PROGRAM IN MECHATRONICS ENGINEERING TECHNOLOGY

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Abstract

The purpose of this paper is to provide a chronicle of the implementation cost estimation for a multidisciplinary BS in Mechatronics Engineering Technology program, based on the needs of regional industry in Northern Kentucky and Southern Ohio. The new mechatronics programs are intended for students, who are prepared to be hired by industry as multi-disciplinary professionals. Colleges and universities currently offering electronics technology, electrical systems, mechanical and manufacturing engineering technology, electromechanical engineering technology, industrial engineering, robotics, and computerized control systems are in an advantageous position to implement those programs, as some of the required resources may already been in place. This program is a 2+2 degree program between Cincinnati State Technical and Community College (CSTCC) and the bachelor degree programs at Northern Kentucky University (NKU). The courses in the curriculum were selected from among existing courses in the associate degree programs at CSTCC and the bachelor degree programs at NKU. New courses will be added to meet educational and/or industry needs. A pathway to B.S. degree completion for graduates from CSTCC was also envisioned in the form of a transfer agreement.

Introduction

Founded in 1968, Northern Kentucky University (NKU) is a metropolitan university with approximately 16,000 students, located in Highland Heights, KY, in the greater Cincinnati area. NKU currently offers Bachelor of Science degrees in Engineering Technology (electronics—EET, and mechanical and manufacturing—MMET), with the support of local industry, which provides most of the students with co-op opportunities. The MMET and the EET are long-standing programs at NKU. These programs have catered to the manufacturing industry in Northern Kentucky and Southern Ohio areas for more than two decades. CSTCC is a technical and community college located in Cincinnati, Ohio; it was chartered by the Ohio Board of Regents in 1969. The college offers over 75 associate degree programs and majors, and over 40 certificate programs, being one of the ten largest co-op education programs in the nation, as measured by the number of student placements. Recently, Cincinnati State created a new division, named the Center for Innovative Technologies (CIT), which combines the Engineering Technology and Information Technology divisions.

Processes of continuous improvement and assessment of course outcomes as well as student learning outcomes will be embedded in the program in order to address the extent to which the programs meet applicable ABET criteria and policies for accreditation. Recruiting of non-traditional and underrepresented students will have precedence, in order to address the challenges posed by workforce requirements in this geographic region. Northern Kentucky and Southern Ohio host many advanced manufacturing companies, producing high-value-added products. Companies such as Mazak, ZF Steering Systems, General Electric, Procter & Gamble, Fives, Johnson Controls, Toyota, and others play a significant role in the region's economy. The availability of adequately trained individuals is paramount to fulfilling their human resources needs, as has been repeatedly expressed to the local institutions' faculty and administrators [1]. A 4-year plan to satisfy the requirements for the Associate of Applied Science in Electromechanical Engineering Technology degree at CSTCC, leading to the Bachelor of Science in Mechatronics Engineering Technology degree at NKU, will be implemented in the form of a transfer agreement. By completing the Associate of Applied Science degree at CSTCC with a satisfactory GPA, students will receive credit for as many courses in the bachelor's degree program as possible. Transfer credits will be based on approved course equivalencies to be defined.

Mechatronics

The term mechatronics was first used in the late 1960s by a Japanese Electric Company to describe the engineering integration between mechanical and electrical systems. It is an integrated comprehensive study of electromechanical systems, integrating electrical, mechanical, and computer engineering areas [2]. ASME describes mechatronics as "where electronics meets mechanical engineering, computing, optics, actuators, sensors, digital controls, and robotics." From its inception in computer-controlled machining and factory automation, mechatronics has incorporated these engineering disciplines and more, plus bioengineering and nanotechnology. Examples of mechatronic systems include aircraft flight control and navigation systems; automotive electronic fuel injection and anti-lock brake systems; automated manufacturing systems including robots, numerical control machining centers, packaging systems, and plastic injection-molding systems; artificial organs; health monitoring and surgical systems; copy machines; and many more. A common element of all these systems is the integration of analog and digital circuits, microprocessors and computers, mechanical devices, sensors, actuators, and controls [3].

Project Plan

Curricula at NKU and CSTCC follow the general guidelines for accreditation defined by the Accreditation Board for Engineering and Technology (ABET) [4]. Mechatronics curriculum design includes development of goals and objectives, programs of study and curriculum guides, courses, laboratories, textbooks, instructional materials, experiments, instructional sequences, and the supplemental materials focusing to accomplish a wide range of educational goals [2]. The cross-curricular approach is reflected at the level of the targeted goals and the targeted contents; the use of new technologies and of the computer as a working tool will determine the student's educational course [5].

The mechatronics courses are intended to develop a comprehensive understanding and the ability to apply theoretical and experimental concepts in design, optimization, and implementation of electromechanical systems posing different levels of complexity. These objectives are achieved by the delivery of electromechanical systems theory, as well as fundamentals of engineering programing and software. A balanced coverage can be assured by a careful blend of courses, chosen from the ones offered by NKU and CSTCC. This project includes the development of one new program, the improvement and adaptation of existing facilities, as well as faculty development. An NSF Advanced Technological Education (ATE) grant proposal was submitted for funding of the curriculum development, faculty professional development, and acquisition of new and upgrades to existing laboratory equipment and, therefore, the budget is organized accordingly.

Faculty

A new cross-disciplinary faculty member will be needed in the MET program. This position will keep the new program current in the areas of automation and industrial controls, while incorporating aspects of electromechanical systems into the curriculum. Also, for accreditation purposes, ABET requires the programs to have full-time dedicated faculty member(s) [6]. Table 1 shows the current faculty composition, where the full-time faculty are able to offer a total load of 84 credit hours (including a prospective new faculty member). The remaining credit hours are distributed among part-time faculty members. An increase in enrolled students is expected in the EGT programs as the new MET program is in place; some migration is also expected of students from the current programs (EET and MMET) to the MET program. An industry-needs survey indicated that 84.7% of respondents anticipate the hiring (each one) of 1 to 15 mechatronics professionals and 7.7% will hire 16 to 50 in the next five years. Additional pressure on the faculty body can be anticipated, in order to meet the demand from constituents.

As shown in Table 2 the engineering technology (EGT) programs offered 37 courses during the fall of 2015-2016, with a total enrollment of 665 seats. The required credit hours to be taught are 111. Table 3 shows an exceptional growth in EGT enrollment during the last five years, mostly due to the increase in numbers of international students and also due to organic growth resulting from the rebound of the U.S. economy. The above facts and Tables 1-3 fully support the creation of a new faculty line to be fulfilled by a new faculty member with an annual salary (according to CUPA [7]) of $66,289.00. The total yearly cost for this position can be estimated by applying 13.85% for employment taxes and adding the amount of $4,000.00 for benefits [8]. Therefore, the total estimated payroll cost for the new faculty position will be $79,470.00.

Faculty Professional Development

Faculty currency in the subject matter that they teach involves continuing scholarly activities and/or professional interactions that strengthen the faculty member's knowledge of his/her field and its interdisciplinary advancements, best business practices, newest technology developments, best learning theory implementations, and most effective teaching practices and innovations [9]. Due to the rapid evolution in electromechanical and electronic systems, and the ever-changing aspects involved in modern industry, the maintenance of professional and academic currency is absolutely essential. An annual faculty professional development plan is proposed in a rotation schedule, in order to provide opportunities to faculty members to stay current. Table 4 shows how the plan follows the framework proposed by Odden et al. [10] (where applicable).

Table 1. NKU EGT Program Faculty Qualifications and Status

Faculty Name	Highest Degree Earned Field and Year	Rank [1]	Type of Academic Appointment [2] T, TT, NTT	FT or PT [4]	Years of Experience			Professional Registration/ Certification	Level of Activity H, M, L		Expected teaching Load (per semester, except Summer, (CH)
					Govt./Ind. Practice	Teaching	This Institution		Professional Development	Consulting/ summer work in industry	
NKU											
Fac. 1	PhD 1989 Iowa State University	ASC	T	FT	5+	19+	13		M	M	12
Fac. 2	PhD 1998 Ohio State University	ASC	T	FT .875 in MMET	6	9	9		H	M	12
Fac. 3	MS 1966 University of Cincinnati	ASC	T	FT .875 in MET	32	19	16	PE	M	L	12
Fac. 4	PhD 2011, Florida International University	AST	TT	FT .875 in MMET	30	4	2		M	M	12
New Faculty Member	PhD - TBD	AST	TT	FT 1.0 in MET	TBD	TBD	TBD		M	M	12
Fac. 5	PhD University of Massachusetts	AST	TT	FT .125 in MMET	15	7	2		M	M	12
Fac. 6	MS North Carolina A&T State University	I	NTT	FT .875 in the program	2	8	1		M	M	12
										Total credit hours taught by FT faculty per semester	**84**
Fac. 7	PhD Aerospace	A		PT	19+	3	3				TBD
Fac. 8	PhD, ME, 2004 Eastern Mediterranean University	A		PT	2	6	1		H	M	TBD
Fac. 9	MSCE 1988	A		PT	33	22	22	PE Ohio, RCO, MPE	20 cr hrs/ yr in tech. legal & manage	Several hrs/Month	TBD
Fac. 10	MS	A		PT							TBD
Fac.11	BSIE 1983, MED 1993	A		PT							TBD
Fac.12	BS	A		PT							TBD
Fac.13	MBA Communications	A		PT	15	15	1		M	M	TBD
CSTCC											
Faculty 1	BS 1991 Electrical Engineering	ASC	T	FT		15	15		H	M	
Faculty 2	MS 2011 Electrical Engineering	AST	TT	FT		5	5		H	M	

(1) Code: P = Professor ASC = Associate Professor AST = Assistant Professor I = Instructor A = Adjunct O = Other
(2) Code: TT = Tenure Track T = Tenured NTT = Non Tenure Track
(3) The level of activity, high, medium or low, should reflect an average over the year prior to the visit plus the two previous years.
(4) At the institution
MMET - Mechanical & Manufacturing Engineering Technology; EET - Electronic Engineering Technology; MET - Mechatronics Engineering Technology

Table 2. EGT Classes Required Credit Hours

	2015-2016 Fall	2014-2015 Su	2014-2015 Sp	2014-2015 Fall
Enrollments (seats)	665	167	753	839
Classes	37	12	46	47
Required credit hours per semester	111	36	138	141

Table 3. EGT Classes Enrollment (source: Institutional Research Office – NKU)

Credit Hour Production by Course Discipline	Fall 2009	Fall 2010	Fall 2011	Fall 2012	Fall 2013	Fall 2014	1 Year % Change	5 Year % Change
EGT	654	801	1050	1914	2913	2553	-12.4%	290.4%
Lower Division	291	312	489	759	1014	765	-24.6%	162.9%
Upper Division	363	489	561	1155	1899	1788	-5.8%	392.6%

First Major by Discipline	Fall 2009	Fall 2010	Fall 2011	Fall 2012	Fall 2013	Fall 2014	1 Year % Change	5 Year % Change
Electronics Engineering Tech Major	29	42	58	91	116	109	-6.0%	275.9%
Mech. & Manuf. Engineering Tech Major	70	83	125	197	246	210	-14.6%	200.0%

NKU Facilities

Engineering technology programs occupy nine rooms on the second floor of the Business Center to accommodate the faculty and program secretary offices. All laboratory classes are taught in the following rooms, all located on the first floor: BC108, 115, 117, 121, 125. EGT also uses some conventional classrooms on an as-needed basis. Figure 1 shows the Business Center Building floor plan (first floor), as well as its location on the campus.

CSTCC Facilities

Over the past few years, the EMET program at Cincinnati State has been retooling to reflect advanced manufacturing and automation needs in the area. One major piece to the retooling is the upgrade to the robotics laboratory, which needs to be complemented with the following robotic equipment:

- FANUC LR Mate w/Vision (quantity of three)
- FANUC Touch Screen iPendant for RoboGuide (quantity of 12)
- FANUC M-1iA w/Vision (quantity of one)

The CSTCC equipment requested for this grant will be housed on the main campus, 3520 Central Parkway, Cincinnati, OH 45223. The three FANUC LR Mate robots and the one FANUC M 1iA robot will be located in room Main 148. Main 148 will require no upgrade for these robots, which has been completed with a third-party donation valued at over $10,000. The FANUC Touch Screen iPendants will be located in Main 150 and will use existing computers.

Laboratory Implementation and Improvement Guidelines

A solid understanding of multi-domain dynamic systems with accompanying modeling and analysis techniques is the key technical skill that mechatronics engineers should master [11]. To support the classes in mechatronics systems, and to emphasize the correlation between different subjects (applied engineering and pure sciences), the implementation of new and/or improvement of existing facilities will follow the procedure adopted by Yu et al. [12] in designing each specific laboratory, as depicted in Figure 2.

Table 4. Cost Structure for Professional Development

Provision for 2 faculty members per year in a rotation schedule, to be assigned by the program administration					
Cost Element	Ingredient	How Cost is Calculated		Per Faculty	For 2 Faculty Members
Materials, equipment and facilities used for professional development	Materials	Materials for PD, including the cost of classroom and supplies.	Office materials, clerical supplies.	300.00	600.00
	Equipment	Equipment needed for PD Activities	TI hardware, sampling equipment, lab kits	500.00	1,000.00
	Publications	Articles, books, subscriptions		300.00	600.00
	Facilities	Rental or other costs for facilities used for PD	Conference rooms, teaching aids	N/A	N/A
			Sub-total (Materials, Supplies and Publications for PD)	**1,100.00**	**2,200.00**
Travel and transportation for professional development	Travel	Costs of travel to off-site PD activities	Subsistence (4 days NKU rate, 3 trips)	432.00	864.00
			Lodging (4 nights, approx. rate, major metro area, 2 trips)	1,120.00	2,240.00
			Transportation (air ticket, taxi, rental car, 2 trips)	2,000.00	4,000.00
	Transportation	Costs of Transportation within the district for PD	200 miles @ $0.47 - NKU reimbursement rate	94.00	188.00
			Sub-total (Travel)	**3,646.00**	**7,292.00**
Tuition and Conference Fees	Tuition	Tuition payments or reimbursement for university-based PD	1 Conference fee	800.00	1,600.00
			1 Trade show admission + conference	430.00	860.00
			1 technical training fee	2,000.00	4,000.00
			Sub-total (PD)	**3,230.00**	**6,460.00**

The NKU existing facilities offer support for the current engineering technology programs (MMET and EET); however, a dedicated mechatronics laboratory is necessary, not only to support the new program, but also to improve the classes that will become part of the new program. Tables 5 and 6 show the proposed list of new and updated equipment.

Recruitment and Dissemination Initiatives

NSF statistics on the state of education in the U.S. indicate a decreasing tendency in domestic students enrolling in and successfully concluding degrees in science and engineering [13]. There is a gap between the number of vacant positions in industry and the number of graduates with the right qualifications to fulfill those positions. To reverse that trend, initiatives are being proposed to increase high school students' awareness of STEM disciplines, as well as to attract students from minority groups to the new program within the NKY and Southern Ohio areas. Table 7 shows the initiatives and respective budgets.

Principal Investigators' Compensation

Table 8 shows how the principal investigators (P.I.s) will be compensated.

Evaluation and Assessment

A qualified external evaluator will be responsible for the evaluations and will submit a written final report at the end of each project year. Measurable data will be used to describe project accomplishments in reports sent to the National Science Foundation. Following a general guideline provided by NSF [14], 5% of the project costs for evaluation will be allocated, including compensation and travel expenses for the evaluator and team members. This allocation will be distributed equally along the 4-year period.

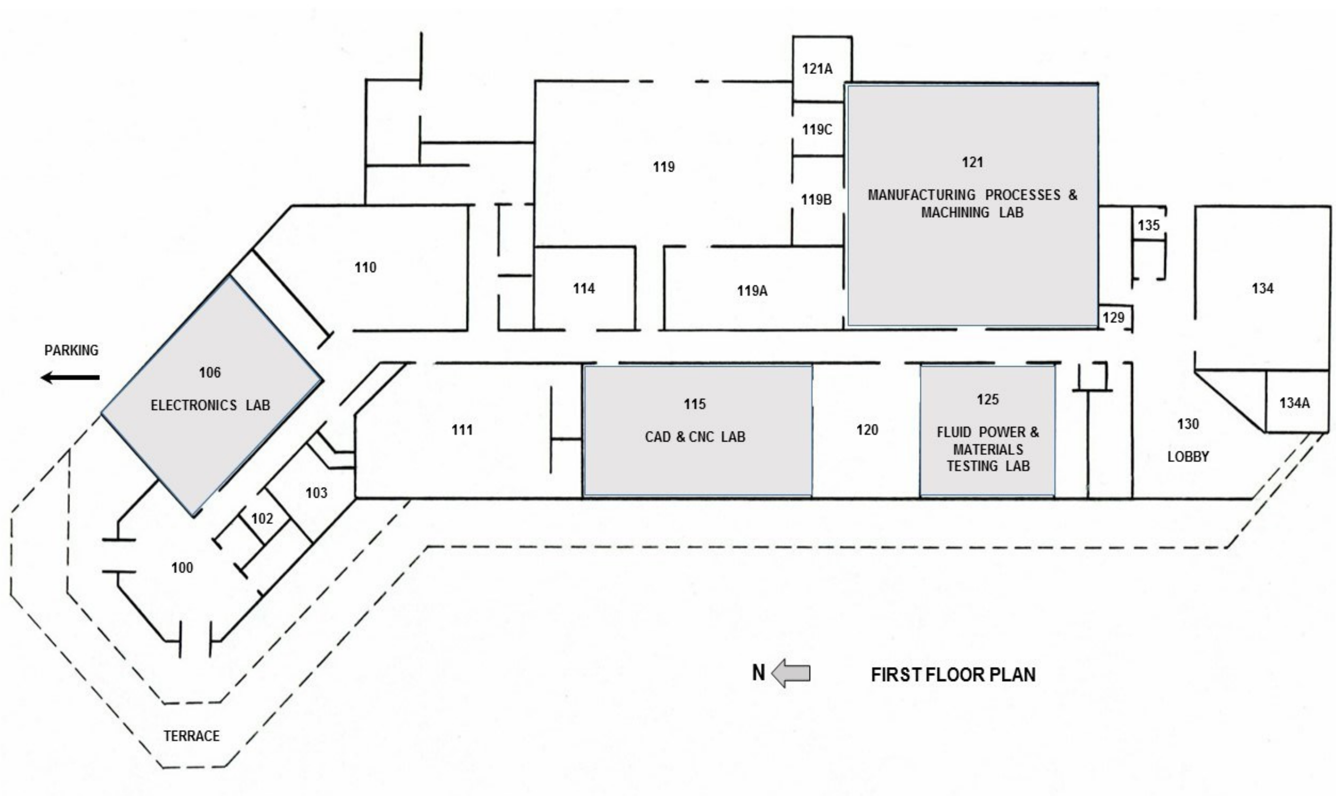

Figure 1. First Floor of the BC Building (lab spaces are shaded)

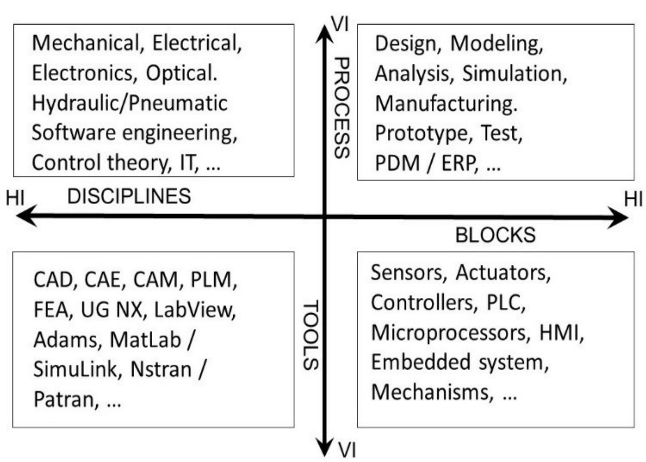

Figure 2. Horizontal Integration (HI) and Vertical Integration (VI) of Mechatronics

NKU Administrative fees

NKU charges an administrative fee of 32.5% (not calculated on tuition, equipment under $5K, capital, or amount of contracts under $25K).

Budget Summary

Table 9 shows the combined budget for this proposal.

Conclusion

The implementation of this new program is in line with the goals established by the 2013 – 2018 NKU Strategic Plan and is, therefore, supported by the administration at both university and college levels. At this time, no decision has been made by NSF on the support of the grant proposal, and the new curriculum is under evaluation by the Kentucky Council of Postsecondary Education. The new program is expected to start in the fall of 2016. The evaluation of the implementation of this project will be the subject of further academic work. The formulation of this budget can be used a model for cost estimation for the implementation of new engineering technology B.S. programs at medium-sized institutions.

Table 5. Proposed List of New and Updated Equipment for the MET Program at NKU

Brand	Item	Description	Qty.	Unit Cost	Ext. Cost	Classes where the item will be used
Laboratory Upgrades						
Hydraulic / Electro-Mechanic Systems Learning Equipment Retrofit						
Amatrol	850-CTBU	Controls Technology Double Sided A-Frame Bench Upgrade for Older 850-C1	3	2,996.00	8,988.00	EGT361, EGT386, EGT417
Amatrol	85-BH	Basic Hydraulics Learning System	3	7,222.00	21,666.00	
Amatrol	16019	24VDC Power Supply	3	772.00	2,316.00	
Amatrol	N/A	Repair parts for 85EF panels	1	1,746.00	1,746.00	
Test Equipment						
Instrom		Load Frame for Monotonic and Fatigue Loading	1	90,000.00	90,000.00	EGT300, EGT261, EGT280, EGT417
				Sub-Total	**3,646.00**	

New Equipment						
Mechatronics Learning Equipment						
Amatrol	870-PS7314	Mechatronics Learning System for Siemens S7-300 with Profibus Platform	7	5,675.00	39,725.00	EGT267, EGT320, EGT365, EGT386, EGT465, EGT408, EGT448, EGT417
Amatrol	82-900-12	Siemens Step 7 PLC Software - 12 seats	1	10,895.00	10,895.00	
Amatrol	72024	PC programming interface for Siemens S7 PLCs	7	1,344.00	9,408.00	
Amatrol	87-MS1	Pick and place feeding station	1	10,362.00	10,362.00	
Amatrol	87-MS2	Gauging Station	1	10,542.00	10,542.00	
Amatrol	87-MS3	Orientation-processing station	1	12,252.00	12,252.00	
Amatrol	87-MS4	Sorting-Buffering Station	1	8,477.00	8,477.00	
Amatrol	87-MS5-C1	Servo robot assembly station for existing Fanuc cart	1	17,063.00	17,063.00	
Amatrol	87-500F	Amatrol-Fanuc integration Package	1	3,588.00	3,588.00	
Amatrol	87-MS6	Torque assembly station	1	8,517.00	8,517.00	
Amatrol	87-MS7	Inventory Storage Station	1	10,322.00	10,322.00	
Amatrol	90-START-4	Start-up and installation	1	5,500.00	5,500.00	
				Sub-Total	**3,230.00**	

Table 6. Proposed List of New Equipment for the MET Program at CSTCC

New Equipment						
Robotics Learning Equipment						
FANUC	LR Mate w/ Vision	Electric Servo Drive Mini-Robot	3	40,000.00	120,000.00	Various
FANUC	I-Pendant	Touch-Screen Controller	12	5,500.00	66,000.00	
FANUC	M-1iA w/ Vision	Light-Weight Assembly Robot	1	38,000.00	38,000.00	
				Sub-Total	224,000.00	

Table 7. Recruitment and Dissemination Initiatives

Initiative	Description		Estimated Cost		
			Unit Cost	Qty.	Total
STEM Summer Camp	Camp 1: Grades 7 and 8, hands-on 5 days, 4 hours per day summer camp. This camp could be run at Cincinnati State and/or NKU 98 t0 12 students)		5,000.00	1	5,000.00
Host Women in Trades, Technology and Sciences Workshop	Cincinnati State National Institute for Women in Trades, Technology and Science (IWITTS) two-day training workshop	IWITTS Workshop Trainer, travel and lodging	10,000.00	1	10,000.00
		IWITTS Workshop Breakfast (40/Day)	10.00	80	800.00
		IWITTS Workshop Lunch(40/day)	12.00	80	960.00
		IWITTS Workshop room rental, housekeeping, and A/V needs, etc.	700.00	1	700.00
Dual Enrollment Courses Offered in Grade 12	CIT 105 OSHA 10 General Industry Safety (1 CR. 1/0 Lecture/Lab). No text required. May need to train high school teacher on OSHA, but initially Cincinnati State could supply instructor. OSHA 511 Occupational Safety and Health Standards for the General Industry	CIT-105 Dual Enrollment Course OSHA 501 OSHA Course	800.00	2	1,600.00
		CIT-105 Dual Enrollment Course OSHA 511 Trainer Course	800.00	2	1,600.00
	EMET 150 Introduction to Controls and Robotics (2 Credits. 1 Lecture Hour. 2 Lab Hours)	EMET-150 Dual Enrollment Course Text Book: Basic Robots 1st Edition ISBN13: 978-1-133-95019-6	91.95	26	2,390.70
		EMET-150 (Lab Equipment)	100.00	26	2,600.00
				Total per year	**25,650.70**
				Total for 4 years	**102,602.80**

Table 8. Principal Investigators' Compensation

Inst.	Role	Weekly Rate	Qty. per year	Year 1	Year 2	Year 3	Year 4	Total
NKU	PI	1,973.58	4	1,973.58	2,003.19	2,033.23	2,063.73	32,294.95
NKU	Co-PI	2,249.77	4	2,249.77	2,283.51	2,317.76	2,352.53	36,814.29
NKU	Co-PI	2,052.23	4	2,052.23	2,083.01	2,114.26	2,145.97	33,581.86
							Total NKU	**102,691.11**
CSTCC	Co-PI	1,460.81	3	1,460.81	1,482.72	1,504.96	1,527.54	17,928.10
CSTCC	Co-PI	1,395.14	2	1,395.14	1,416.07	1,437.31	1,458.87	11,414.80
							Total CSTCC	**29,342.90**
Includes fringe benefits (7.5% for NKU) and adjustment for cost of living @ 1.5% per year								

Table 9. Combined Budget Summary NKU-CSTCC

Budget Summary - NKU						
Description	Expenditure Type	Period	Reference	Amount per year	Number of years	Amount
NKU Laboratory / Testing Equipment Upgrades	Equipment, capital	Initial Investment	Section 3.3	124,716.00	1	124,716.00
NKU New Mechatronics Learning Equipment	Equipment, capital	Initial Investment	Section 3.3	146,451.00	1	146,451.00
NKU Faculty Professional Development, 2 faculty members	Training, expense	Yearly	Section 3.2	6,460.00	4	25,840.00
Travel	Travel, expense	Yearly	Section 3.2	7,292.00	4	29,168.00
NKU P.I.s Compensation	Payroll, expense	Yearly	Section 3.5	See Section 4.3	4	102,691.11
Materials, Supplies and Publications for PD	Supplies, Materials, Expense	Yearly	Section 3.2	2,200.00	4	8,800.00
NKU Annual Evaluation Costs	Evaluation, expense	Yearly	Section 3.6	13,590.00	4	54,360.00
					Sub-total	492,026.11
NKU indirect cost (Administrative fee)	Administrative expense	Yearly	Section 3.7	See Section 3.7	4	71,779.00
					Total	**563,805.11**

Budget Summary CSTCC						
CSTCC Robotics Learning Equipment	Equipment, capital	Initial Investment	Section 3.3	224,000.00	1	224,000.00
CSTCC Recruitment and Students' Awareness Initiatives	Recruiting & Dissemination, expense	Yearly	Section 3.4	25,651.00	4	102,604.00
CSTCC P.I.s Compensation	Payroll, expense	Yearly	Section 3.5	See Section 3.5	4	29,342.00
					Total	**355,946.00**

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Biographies

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Addressing Challenges for Teacher Preparation: Introduction of Engineering Concepts to Early Learners in Elementary and Middle Schools

Tatiana V. Goris, Pittsburg State University; E. Shirl Donaldson, University of Texas at Tyler

Abstract

Students are usually introduced to engineering in middle school and occasionally as early as elementary school. But the way of introducing them to engineering fields at certain ages is critically important. The educational backgrounds of teachers assigned to teach introductory engineering material is essential to the success of the early learners. Quite often, K-12 schools do not have enough instructors with engineering/technology postsecondary degrees. Thus, science teachers are forced to present engineering material, without clearly understanding engineering or what to do with the concepts in the classroom setting. In this paper, the authors present some thoughts and concerns that were offered during the professional development workshop (sponsored by the State of Indiana Department of Education, MSP grant) for science teachers, who are required to teach engineering fields in the fifth and sixth grades. In this case, the findings may be generalizable enough to be similarly applicable to older students. The authors argued that a foggy early introduction and a weak foundation may hinder adult learners coming to study engineering at the postsecondary level.

Introduction

The first introduction to engineering, oriented towards young learners, is critically important. First attempts at presenting engineering can significantly impact the future interest of young students to learn more about it, or possibly even students devoting themselves to the pursuit of a career in engineering or technology fields. The authors strongly believe that introduction to engineering in college or even at high school levels is too late. In many states, public middle or even elementary schools make serious efforts to teach engineering to address this concern. An absence of qualified teachers with an engineering background creates severe problems for many forward-thinking schools. Frequently, science teachers are in charge of presenting engineering to students. The majority of highly qualified science teachers still have ambiguity about differences between science and engineering, as well as what methods should be presented in the classroom to create student interest in engineering. This statement was confirmed during the professional development workshop for science teachers sponsored by the Indiana Department of Education in January of 2016.

During this workshop, the conversation outlined many interesting topics that might be applicable and attention grabbing for the majority of science teachers, who—due to various curricular settings, and sometimes without appropriate background—need to teach engineering concepts to young audiences in elementary or middle schools. The topics that the authors attempted to explain in an understandable manner included:

- What is engineering?
- An overview of the three-century history of American engineering education.
- A discussion of the current state of advanced manufacturing in U.S., since this field is inseparable from engineering.
- A presentation of the importance of detecting student misconceptions about scientific and engineering concepts.

A majority of misconceptions are created in very young, elementary-school-age students, and then are carried through to college and sometimes over entire professional careers [1].

What is Engineering?

This is the first question that a science teacher must answer. The next question is, "How and why engineering differs from science"? Without a clear understanding of the similarities and differences between these two fields, further progression would be difficult. The authors recommended the perspective that engineering brings about a solution of a particular problem in particular settings. Thus, at some point, an engineer is not just a professional specialist in a specific field, but often an engineer, who may carry many roles, including scientist, manager, supervisor, and the first responsible person if something goes wrong.

A conversation about different engineering fields, such as civil, mechanical, electrical, food production, biomedical, and computer, is a useful approach for presenting a broad career orientation to young learners. In the U.S., to become an engineer, a student has to satisfy two main requirements: initially, to graduate from an institution of higher education that holds accreditation by the American Board of Engineering and Technology (ABET); and, if desired, to obtain a professional engineering license. The second requirement is not mandatory, but might be a highly desired factor that may have an impact on carrier growth.

Engineering Education in the U.S.

In any country, engineering education is developed in specific historical circumstances, which are different from other regions. It is a challenge to briefly describe almost 300 years of history of American engineering education, but the authors believe that this information should be presented to teachers and students, while adapted to the age of the audience. In North America, engineering was established and highly influenced by military and army needs [2]. The first reference that mentioned engineering goes back to the American Revolution, when George Washington, in 1775, appointed the first military engineering officers. The interesting point is that there was no way to educate those engineers. Only in 1802, a separate permanent division of the engineering corps was established, giving engineers responsibility for setting up the first Military Academy at West Point. In the 19th century, national growth drove the need for engineers. In those times, working as apprentices on railroad or canal projects presented a typical gateway for starting an engineering career. Only a few classes (e.g., graphing and surveying) were taken in addition to their experience in order to satisfy professional engineer credentials.

In the second half of the 19th century, the number of the U.S. universities began to grow. Some established schools were based on the French Educational model supporting industrialization and commerce. But the interesting point was that engineering still remained apart from the university. The Morrill Act of 1862 changed this situation. Engineering became officially recognized and included in curricula and degree programs. Some of the oldest American engineering schools that have become first-tier research institutions include Purdue University, Michigan State University, Penn State University, and Virginia Tech. In tandem, to address a separate political agenda, many Historically Black Colleges and Universities (HBCU) were created after the second Morrill Act of 1890. HBCUs educated the descendants of former slaves in the arts, sciences, agriculture, technology, and engineering [3].

From this period, the balance of shop and classroom experience (that is, theory and practice) evolved. Shops dominated in early engineering curricula. In the beginning of the twentieth century, the classroom settings began to prevail, but progress was very slow. Back in 1893, the newly established American Society for Engineering Education directed the shift from practice to theory. As the discipline shifted, the shop transitioned to modern day laboratories.

After the First World War, Europeans brought their ideas and perspective on engineering education to the U.S. For example, complex mathematical analysis was brought by European leaders in mechanics and fluid dynamics. A few important people, who made enormous changes in American engineering education, included Stephon Timoshenko, Theodore von Kármán, and Harald Westergaard. Stephon Timoshenko started his engineering and scientific carrier in the Russian Empire. Becoming a professor at the Saint Petersburg Institute of the Railways (1911–1917), he immigrated to the U.S. after the Russian Civil War and Revolution. Working at the University of Michigan (1927), and later at Stanford (1936), he wrote mathematically based textbooks on the strength of materials, structural mechanics, and dynamics [4]. In 1930, Theodore von Kármán (Hungary) brought to California Tech German-based theoretical fluid dynamics [5]. Later, he became a founder of the Jet Propulsion Laboratory (JPL).

The Second World War (WW II) was a big stimulus to engineering education, which dramatically re-evaluated racial and gender roles in higher education and engineering education as well. After the war, thousands of veterans returned to school. Expansion of atomic and radar weapons raised the importance of technology. But all the credit was given only to scientists. The Cold War with the USSR and the launching of Sputnik (the first handmade Russian satellite, 1957) encouraged the American federal government to expand military funding and to support the renovation of theoretically based engineering. From those times, the status of engineers was compared to the status of scientists. In most institutions, engineering science was fully integrated into the classroom. A unique characteristic of this time was that the majority of engineering fields after WW II were Cold War driven. The Cold War created the space race and, as a result, more interest in engineering. At that period, universities paid little attention to the needs of industry, and adjusted curricula to please government demands.

In the 1960s and 1970s, engineering education was dominated by science. There was an enormous nationwide leap in the engineering curricula: from practice to science. Federal funding to universities was reduced, due to the recession. As a result, by the 1980s, hands-on skills and experience dropped dramatically. Lack of skills produced the shift back from science to practice. Significant changes happened in the 1990s, when universities attended more to industry concerns, causing a greater shift away from science to a hands-on and applied work. Nowadays, the majority of universities have to find the right way to balance theoretical and practical knowledge into a certain number of assigned credit hours to satisfy ABET criteria and requirements in their engineering curricula.

The Current State of Advanced Manufacturing in the U.S.

In engineering fields, a majority of educators agree that students are prepared for jobs that do not exist yet. Thus, there are many predictions what skills and experience students might need for joining future job markets. Thus, it is critically important to inform elementary/middle school teachers, who introduce engineering to the youth audience, about the current situation in the manufacturing industry. According to the U.S. Department of Labor, manufacturing in the U.S. is highly differentiated geographically. A majority of high-tech industries are formed in economic clusters, located in metropolitan areas [6].

Now, one of the biggest nationwide challenges comes from the decreasing number of domestic jobs and the moving of manufacturing jobs overseas. According to the Bureau of Labor Statistics, the number of manufacturing occupations declined by 40.7% from 1980 until the present [6]. Fast technological changes make education a continuous process. With enlarged global competition, attention should be placed on skills and preparation of the workforce, mostly the ability to adapt changing technologies and shifting product demand.

Student Misconceptions

This topic aroused a genuine interest in the participating teacher audience. At the present time, there is a large body of well-established research studies about misconceptions of natural events and science concepts. Misconceptions are defined as incorrect mental models, deeply rooted in everyday experience [7]. They significantly affect learning, are robust, and are resistant to change. Often, high student grades do not guarantee the absence of misconceptions. And the most important point, even teachers have them. Earlier detection of misconceptions prevents serious learning obstacles. The problem is that the majority of teachers are unaware of existing diagnostic methods for detecting and analyzing student misconceptions [8].

Conclusions

After working with wide group of K-12 science educators that are, in essence, being forced to become early engineering educators, the authors continue to seek methods of supporting effective instruction. One suggestion is that science and math teachers work together to address misconceptions along with basics skills development that will be required for problem solving later. A case could be made for more comprehensive professional development for these teachers and a specialization opportunity at critical points in their careers. This case is justified by the pipeline issues that are visible at every juncture, as millennials and the following generation hemorrhage from the STEM trajectory. New research is needed to determine which model would best address this shortfall.

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INFORMATION SECURITY RISK AWARENESS PROGRAMS IN K-12: IS THIS THE RIGHT APPROACH?

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Abstract

In his State of the Union address, President Obama stated that "America must…face the rapidly growing threat from cyber-attacks" [1]. He signed an executive order allowing the U.S. government to share intelligence on potential cyber threats with public and private firms because U.S. schools are not preparing kids for cybersecurity literacy in the digital age [2]. While the Internet has provided powerful tools for education, it also has created risks and raised some improper and unsafe behavior inside and outside of the classroom [3]. In a recent study conducted by Zogby International and released by the National Cyber Security Alliance (NCSA), the data indicated that more than 90% of the more than 1000 teachers, 400 school administrators, and 200 technology coordinators surveyed, noted that they supported the teaching of cyber ethics, safety, and security in schools. However, more than 50% of the teachers indicated that their school districts had no requisite inclusion of these subjects in their respective K-12 curricula [4].

In this paper, the authors propose an awareness program (Cyber-IQ Summer Camp) that should be launched in K-12 to address the need for user awareness about cybersecurity issues. The topic of cybersecurity risks must be introduced early in the curriculum to promote students' understanding of their roles in cybersecurity protection. Since 21st century kids believe that they cannot live without technology, they must understand the implications of security issues [5]. The awareness program through summer camps will build a strong foundation with the motto: "No Child Left Behind in Basic Cyber Security Knowledge"; moreover, students today need to learn strategies to help them understand the concepts of cybersecurity and how to address/apply them—through knowledge, experience, and skills-based activities. Nearly 80% of computer users are becoming victims of fraud and are affected by some type of security threat, due to a lack of awareness about security risks associated with usage of the Internet [6]. A survey conducted by the Ponemon Institute showed that the average cost of cybercrime for U.S. retail stores more than doubled from 2013 to an annual average cost of $7.6 million per company in 2014 [7].

According to an estimate by Morgan [8], a contributing writer with Forbes.com, one million open and unfilled cybersecurity positions were available at the end of 2016, and the predicted cybersecurity service market is anticipated to grow to a $170 billion service industry by 2020. Therefore, technological supply and demand techniques need to be used in order to fill these high-tech positions, presently and in the future. One such highly potential training opportunity is the CyberPatriot program, established in 2009 as an Air Force Association's National Youth Cyber Education Program, designed to motivate students to enter careers in cybersecurity and/or other science, technology, engineering, and mathematics (STEM) disciplines that are critical to our nation's future. In order to expand this initiative in various states, there is a significant need to inform our 21st century digital kids about upcoming cybersecurity demands. To this end, a model program to promote awareness and to encourage K-12 cybersecurity participation has been developed. This program, dubbed the Cyber-IQ Summer Camp, will soon be announced in the K-12 Alabama School System in the River Region, located in Montgomery, Alabama, and participating counties.

Introduction

The aim of this paper is to initiate the first steps towards developing an awareness of and mindset for understanding why cybersecurity is necessary in today's world. The primary focus of cybersecurity awareness is to create and influence the adoption of secure behaviors. This paper is the first in a series of three. Two other papers are expected to follow in which answers about what works, what does not, and why will be identified. Figure 1 shows the developmental model to which this series of papers will subscribe. As indicated in Phase 1, the basic infrastructure has been established. Subsequent to Phase 1, the implementation and data-collection phase will begin, in order to process and report the results in Phase 3.

According to Setalvad [9], in 2015 there were approximately 209,000 cybersecurity jobs vacant, with a trending-up rate of 74% over the past five years in the number of cybersecurity job listings. In other words, there are more cybersecurity jobs open than there are qualified candidates to fill them, and in recent years the media have reported an increase in information security incidents; therefore, President Obama has made information security a national priority [10].

Figure 1. Three-Paper Series Process

Awareness and encouragement about cybersecurity is a skills-based element both in the current K-12 environment and in society in general. Giannakas et al. [11] introduced cybersecurity awareness to K-6 students through an innovative mobile app named CyberAware, in order to educate K-6 students about cybersecurity threats. Another aspect of awareness, named the CyberPatriot program, created by the Air Force Association (AFA), is designed to motivate and inspire K-12 students by delivering basic cybersecurity education and promote STEM [12]; but there is no program directly related to summer initiative programs to promote cybersecurity education for K-12 students.

According to the U.S. Secretary of Defense Ash Carter [13]: "The dominant power of the 21st century will depend on human capital. The failure to produce that capital will undermine American security." Different cybersecurity jobs require more understanding of security or technology; therefore, different avenues need to be developed in order to prepare these digital kids. As previously noted, Butler [3] stated that our district leaders need to take responsibility for teaching students how to wisely navigate the Internet to develop an understanding of cyberworld threats. Therefore, there is a need for strong student participation in cybersecurity activity programs to provide awareness about cybersecurity risks and issues for K-12 students, who will become several generations of cyber-warriors for the U.S.

President Obama [14] stated: "We know hackers steal people's identities and infiltrate private email. We know foreign countries and companies swipe our corporate secrets. Now our enemies are also seeking the ability to sabotage our power grid, our financial institutions, and our air traffic control systems. We cannot look back years from now and wonder why we did nothing in the face of real threats to our security and our economy." For competitive advantage, most business and educational organizations have installed the latest security applications; but, due to a lack of trained staff and users, there is still vulnerability in these respective systems. Hence, to update the organizational infrastructure means nothing if users do not have detailed appropriate awareness and practical skills about cyber safety.

This proposed initiative was designed to provide awareness and encouragement for K-12 students to join Cyber-IQ Summer Camps and obtain a certification of completion; furthermore, this initiative encourages students to join local and state-level programs for Cyber-IQ competitions within and between public and private schools. This process will persuade them to join the cybersecurity field to support President Obama's initiative "… information security [as] a national priority" [14].

Awareness Model

Kortjan and Von Solms [15] stated that in order to reduce computer security risks, training and awareness programs played a vital role in educating individuals. For example, Cyber Portfolio is another attempt to support a cutting-edge methodology for those seeking an innovative approach to integrate technology into curricular lessons [16]; moreover, successful cyber training programs require a substantive technology change in existing curricula throughout a significant number of school districts, with these decisions being supported or avoided by the various Boards of Education.

The Information Security Forum in 2014 [17] and Wilson and Hash [18] with the National Institute of Standards and Standards in Technology, similarly reported that people know the general-nature answers to awareness questions, but they do not act accordingly. Toth and Klein [19], in the NIST Special Publication 800-16, defined awareness as follows: "Awareness is not training. The purpose of awareness presentations is simply to focus attention on security. Awareness presentations are intended to allow individuals to recognize IT security concerns and respond accordingly." Therefore, it is necessary to develop these recognition skills through interactive programs so that the digital kids are not only cognizant of security issues and techniques, but that they are more attuned to the presence of digital intrusions. Figure 2 shows a model of how the process of educating digital kids to the presence of digital intrusions can be accomplished in a step-by-step process. Table 1 defines descriptive identifiers for Figure 2.

The interrelated and interdependent model shown in Figure 2 interacts with and guides students in different workstreams and provides a high-level snapshot of what needs to be done in regards to the cybersecurity process. Instruction through lectures or advice from a person of cyber-authority might set the tone of cybersecurity, but individual knowledge and understanding of cybersecurity are the main influencers on behaviors [20]. Consequently, the main purpose of the awareness model is to establish a competition among K-12 kids about Cyber-IQ. The Cyber IQ-Summer Camp will teach them how to develop secure behaviors by passing a set of interactive awareness training activities though different standardized modules with the collaboration of the CyberPatriot Program. (Note: Maxwell Air Force Base Cyber College is located in Montgomery, AL.) Although the Internet has provided powerful educational tools for student learning, it has also created many illegal, inappropriate, and unsafe behaviors among users, especially K-12 students. For teaching the next generation of students about cybersecurity fundamentals, it is required to add knowledge of cybersecurity in all grade levels. Virginia, for example, requires school districts to teach all kids Internet safety and cybersecurity issues for districts receiving certain Federal E-Rate funds; however, this process is not available in all states. The proposed cybersecurity awareness program offers an opportunity to the Alabama School District systems to join Cyber-IQ Summer Camps and participate in Cyber-IQ competitions.

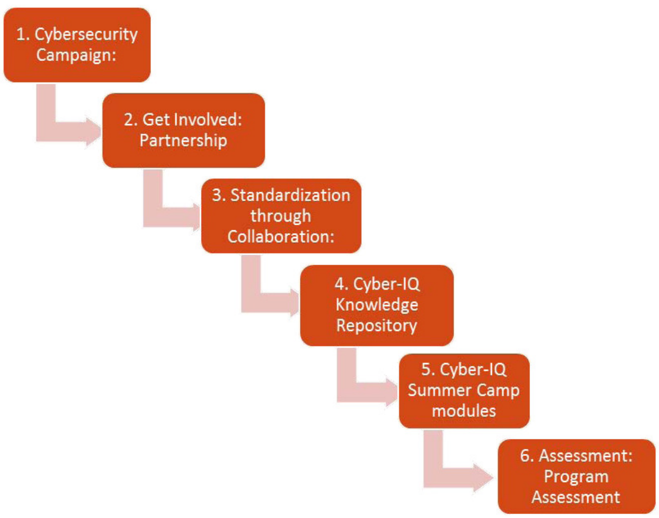

Figure 2. Cybersecurity Awareness Interaction Process

Security Awareness Programs

According to Abawajy [21], there is no doubt that cybersecurity topics provide a great value to industry, as well as in the computer information systems (CIS) world with a concrete delivery method such as information security awareness using text-based, game-based, and video-delivery methods. Cyber experiences enhance a strong collaboration and interaction between individuals within the cybersecurity community. The Security Awareness Program Special Interest Group [22] identified the best practices for implementing security awareness programs in different organizations; in contrast, Bada (Global Cyber Security Capacity Centre, University of Oxford) and Sasse (Department of Computer Science, Science of Cyber Security Research Institute, University College London) [23] have identified various nations that have implemented cybersecurity awareness campaigns (e.g., Canada, UK, Australia, and Africa). [Note: All the campaigns are related to professional organizations.] In this paper, the authors describe the process of developing a Cyber-IQ Summer Camp, where students in the Montgomery School District might better understand the issues and prevention techniques required for cybersecurity awareness and applicable actions to be taken.

Table 1. Descriptive Identifiers for the Cybersecurity Awareness Interaction Process

Process Function	Process Descriptor
Cyber Campaign	To show your support and dedication to promote cybersecurity education.
Get Involved Partnership	Visit schools and present the Cyber-IQ Summer Camp Initiative.
Standardization Through Collaboration	Develop similar training modules related to CyberPatriot, an Air Force Association's National Youth Cyber Education Proram.
Cyber-IQ Knowledge Repository	Provide value stream to gain knowledge management about cybersecurity awareness to students.
Cyber-IQ Summer Camp Modules	Four Week modules based on standardization in Step 3 (Standardization Through Collaboration).
Assessment	Assessment of the program with a strong emphasis on feedback for improvement of the Cyber-IQ Summer Camp Modules.

Cybersecurity Awareness Benefits

- Desire: Establish a desire to participate and support a change in mindset about cybersecurity.
- Earn Certificates of Completion: Students earn a Certificate of Completion by attending this awareness program and are eligible to participate in local and state-level Cyber-IQ competitions.
- Mindset: Establish a secure mindset to accept the importance and necessity of implementing required skills and behaviors in industry.
- Jobs Creation: Awareness programs help students enter into industry with prerequisite knowledge (e.g., collaboration efforts with the Department of Homeland Security workforce development).

- Program Assessment: One of the key factors in having a successful effort is being able to prove that your effort is successful. Therefore, different assessment methods will be used, such as surveys on Internet usage attitudes, pre- and post-assessment awareness training data, and identification of the factors that potentially lead to failure/success/modification of the Cyber-IQ Summer Camp program.
- Develop a collaboration with CyberPatriot, an Air Force Association effort to develop standardized modules of training.
- Develop a bridge to encourage students to get certified through standardized security tests and pursue their respective education and certifications in security-related disciplines.

Conclusion

The National Cyber Security Alliance (NCSA) has organized different resources related to Internet literacy, such as cybersecurity that focuses on how to avoid spam and viruses. These free resources can be used in the classroom. Similarly, WiredSafety.org has various free videos and presentations that can be used to develop a secure mindset. To reiterate, the average cost of cybercrime for U.S. retail stores more than doubled from 2013 to an annual average of $7.6 million per company in 2014. Different universities and colleges have engaged K-12 kids in their summer technology programs in order to prepare them for use of technology, but there are no Cyber-IQ Summer Camps (or programs) in the Alabama region, where K-12 students can be educated and informed about the challenges of cybersecurity in today's world. Also, it is crucial for the success of cyber programs that these students be provided with the opportunity to participate in Cyber-IQ competitions.

Acknowledgements

The authors would like to thank the anonymous reviewers for their careful reading of the paper and insightful suggestions for changes, including Amy Smith. This paper is based upon collaboration between Trenholm State Community College Faculty, Faulkner University Faculty, and the Project Manager, Walmart, Inc.

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