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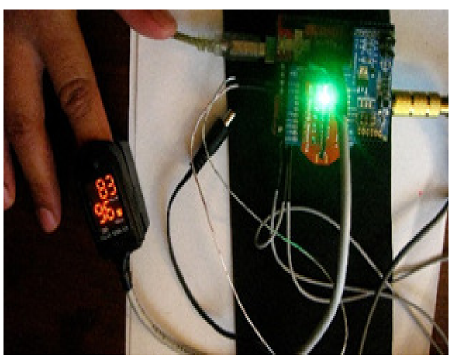
A Prototype Distributed Framework for Identification and Alerting for Medical Events in Home Care

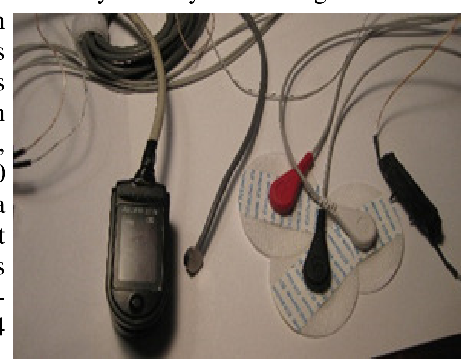
Philip Weinsier, TIIJ Editor-in-Chief

Aging in place is a movement by organizations, health professionals, and individuals to help seniors remain active and healthy throughout their retirement years and remain in their own homes. The intent is to help seniors live safely in their own homes as long as they wish, not to keep them out of senior living centers or assisted living facilities against their will or needs. In fact, the *National Aging in Place Week* is scheduled for October 13-19, 2015, during which time America's seniors and senior service providers join to celebrate the movement and expand awareness and efforts towards helping seniors.

Given the cost of healthcare in general, let alone home healthcare, it is easy to understand why so many seniors—already on fixed incomes and federal support—live under conditions that do not allow for extended-hour or 24/7 support by home healthcare nurses or high-tech medical monitoring equipment (not otherwise provided by insurance or federal programs). Thus, any novel ideas for providing such support, whether technology related or other, would no doubt help lower the death rates of the elderly and possibly reduce healthcare-related costs by the individuals and their families.



According to the United States Centers for Disease Control and Prevention (CDC) for 2013, the number of deaths in the U.S. (for all races and both sexes, aged 65+) was 1,904,772. Broken down by decade, seniors aged 65-74 died of accident-related causes at a rate of 43.5 per 100,000 persons. For those aged 75-84, the rate was 107.4 (per 100,000). And for those 85 and older, 340.0. On the whole, there were 30,208 deaths related to unintentional falls (per 100,000) in 2013, ranking this category as #8 on the CDC's list of leading causes of death in the U.S. In fact, this category has retained this ranking since 1980. Anyone who has had to deal with aging parents or relatives, or simply watched TV, understands that every year millions of seniors (65 years and older) have falls causing injuries such as hip fractures, head traumas, and lacerations. The most common fractures are of the spine, hip, forearm, leg, ankle, pelvis, upper arm, and hand. Many of these injuries can reduce a person's mobility and, thereby, his/her ability to live independently. Another problem, not specifically physical such as a broken limb, is a fear of falling. This fear, too, can limit a person's activities to the extent that his/her mobility is limited, further exacerbating his/her situation. Again, according to the CDC, of the roughly 1-in-3 seniors who fall each year, fewer than half contact their healthcare providers about the incidents. Such falls also represent the leading cause of both fatal and non-fatal injuries. As people age, the risks of accidents increases: People aged 75 or older who fall are four to five times more likely than those aged 65-74 to be admitted to a long-term care facility for a year or longer. In 2013 alone, 2.5 million non-fatal falls among seniors were treated in emergency rooms, of which 734,000 were admitted to a hospital. Direct medical costs (adjusted for inflation) were $34 billion.



The focus of this featured article, then, is on solving a number of important engineering issues related to home healthcare monitoring to make it easier and cheaper for health professionals to monitor an individual's health status using a typical Web browser. Industry trends towards wireless devices such as inertial measurement units (IMUs), heart monitors, blood O_2 sensors, and glucose monitors can serve as valuable indicators of unfolding medical issues that can be evaluated and acted upon by a patient's healthcare team. The proliferation of sensing devices and low-cost embedded systems has led to growth in perceptual robotic systems that can provide the eyes and ears to monitor the daily activities of patients and their vital measurements. Robotic assistants can serve as the remote helping hands capable of assisting in the performance of daily activities and certain interventions.

Editorial Review Board Members

USE OF MOBILE APPLICATION DEVELOPMENT TECHNOLOGIES IN CAPSTONE PROJECTS

Shuju Wu, Central Connecticut State University; Xiaobing Hou, Central Connecticut State University;
Karen Coale Tracey, Central Connecticut State University

Abstract

In this paper, the authors present their continued efforts to apply mobile application development technologies in their undergraduate and graduate capstone projects in the Department of Computer Electronics and Graphics Technology (CEGT) at Central Connecticut State University (CCSU). Specifically, the efforts are introduced in the context of three graduate and one undergraduate senior capstone projects, all of which are closely related to the State of Connecticut's first rapid transit bus system called CT*fastrak*. The projects have successfully promoted student engagement in hands-on research—a high-impact practice identified by the American Association of Colleges and Universities—and enhanced technological and project management knowledge in the areas of study and skills of collaboration with teammates, other teams, and local government and business. In addition to the development of the bus tracking and trip planning, the success of the projects has also provided a framework for faculty and students to develop similar projects, with components usually available on campus.

Introduction

In engineering and technology education, capstone project experience is a valuable component for increasing student motivation and engagement in real-life problem solving, as well as enhancing their independent study capability. In CEGT, both undergraduate Computer Engineering Technology students and the graduate Computer Information Technology students are required to take capstone project courses. One of the challenges that both students and faculty face is topic selection. A good research project will help faculty explore new research ideas and students gain real-world experience and cutting-edge technologies.

A common area shared by the two programs is computer application development; mobile application development is also an ideal capstone project topic in this area. The mobile phone industry has been growing steadily over the last several years. One study showed that there are more mobile phones in the U.S. than people [1]. A mobile application development project requires project formulation, platform and development tools selection, application design, application development and debugging, documentation, and presentation. Additionally, various design and development issues must be studied.

Mobile application development is the fruit of technological change and growth in the mobile market, and among the multiple development platforms, iPhone iOS and Google Android are now the dominant market shareholders, together with other mobile operating systems such as Blackberry RIM and Windows 8 [2]. It is also estimated to have a huge job market potential worldwide [3]. The current CEGT undergraduate and graduate programs offer some programming courses such as C++, JAVA, Visual Basic, etc.; however, none of them focuses on mobile application development. Therefore, the CEGT students are exposed to opportunities of using such technologies in real-life projects to enrich their experience and, at the same time, enhance faculty collaboration and capstone project advising. And the goal of this study was to gain experience and guidance through the capstone projects to enrich the current curriculum with related technologies.

The key to an application development project is to find a target application that solves real-life problems. The CT*fastrak* project from the state DOT aims to provide a new bus transit system interconnecting over 60 routes and providing travellers convenient access to work, shopping, universities, downtown, and other entertainment destinations. In this paper, the authors introduce four capstone projects (three graduate and one undergraduate) that use mobile application development and other related technologies to design a bus tracking and trip planning system for the CT*fastrak* project. The projects provide passengers with mobile applications on either iPhones or Android phones that enable them to view real-time bus location, delay information, bus schedules, and points of interest. The application also has trip-planning capability. In addition to the passenger-side application, the projects also provide necessary functions on the buses and the transit control centre for management purposes. At the end of this paper, guidelines and suggestions are provided to help similar programs develop their own mobile application development projects.

Related Work

Normally, in addition to printed schedules, bus information in a transit system can be accessed through one of two ways: by visiting the system's website directly, such as Where's My Bus (WMB) [4], Chicago Transit Authority (CTA) Bus Tracker [5], and NextBus [6], or by running a mobile application on a smartphone, such as My NextBus [7] and Centre Area Transportation Authority (CATA) [8], which in turn accesses information from the system and presents the results to users. Systems such as WMB can be very system-specific and target a specific city; therefore, most of the applications cannot be easily implanted and are generally not open-source. NextBus provides service to multiple transportation systems and, therefore, lack customization. Commercially available systems are sold or licensed to transportation systems and may incur continuous costs. Mobile applications are often free to end users; however, they are generally designed for specific transit authorities and are tied to server-side applications, which, in turn, are not open-source and free.

In addition to the aforementioned issues, bus-tracking systems such as WMB and NextBus do not show real-time bus locations on routes, nor do they provide points of interest service to the end users. CTA Bus Tracker shows real-time bus location information but has no mobile application. Most client-side mobile applications are similar with some providing text-based route information [7] and others providing Google Maps graphic-based route and location information [8]. The projects introduced in this paper show a complete transit bus tracking and trip planning system for the CT*fastrak* project. It not only includes a mobile application but also the necessary function on the buses as well as the transit control center server application. Unlike most systems that use Google Maps, the authors adopted OpenStreetMap [9], which is open-source and free. It also allows the user to generate updated and customized maps (e.g., community and local attractions) to reflect map change. Overall, the objective of this study was to design a customized, cost-effective, efficient, and user-friendly bus location and tracking system specifically for the CT*fastrak* project.

Case Studies

In this section, the authors present four case studies. The first study was a review of current mobile technologies aiding transit systems. In addition, both quantitative and qualitative analyses are provided to support the statement that by providing a dependable information system, the usability of the CT public transit system can be significantly enhanced. The second study was a user-friendly iPhone application design (called CCSU Go) to provide CCSU students (and others) with an enhanced transit experience that would attract and retain student riders to CT*fastrak*. The third study performed similar tasks but in the Android system. The fourth described the application design, development, and implementation of a bus tracking and planning system. Compared with these previous projects, this current one was the most complete and fully functioning system.

Bus Rapid Transit (BRT) System

In this study, the authors investigated current application technologies used in transit systems and the effects they have on commuters. Such technologies include: an automated vehicle locator (AVL) and Google Maps, which help increase user consciousness about his/her surroundings; survey links to user commentaries and suggestions for improvements; and, a CT DoT site to keep users up-to-date on the *CTfastrak* progress. The objective of this study was to provide a solid foundation on a user-friendly AVL application and valuable research for future capstone projects on *CTfastrak.*

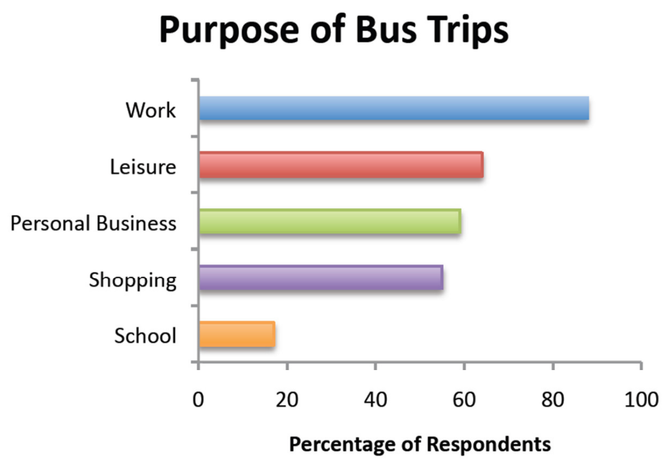


Figure 1. Greater Than 60 Percent of Responders Indicated the Most Frequent Reasons for Using It Was Work-related

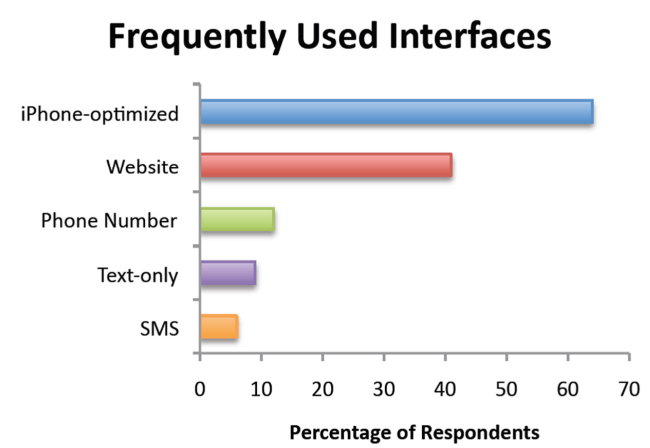


Figure 2. Greater Than 60 Percent of Responders Used Mobile Phones (iPhone) for Their Responses

Bus passengers prefer to spend as little time as necessary waiting for the bus and feel safe when entering/exiting the transit system. An AVL can contribute in both areas. An AVL device is made up of hardware, software, and a mapping system that allows the requester to determine the exact geographical location of the vehicle. One study [10] found that "travelers may increase their trip-making frequency as a result of real-time transit information use, and positive psychological outcomes are more prominent in both short and longer terms." By providing real-time information, passengers can be assured that the mobile application will minimize the time spent waiting for the specific bus that will take them to their destination, hence assuring safety. Therefore, an AVL is an indispensable component of a successful CT*fastrak* system.

The points of interest supply a user with helpful and interesting information about the route, and passengers can become more familiar with the transit system and the nearby locations. A transit application system should allow the customization of the station and point-of-interest information, which can provide more convenient service to the bus passengers in the area. For this capstone project, the authors suggest that the CT*fastrak* mobile application utilizes features similar to Google Maps, Google Latitude, or other open-source and free software such as OpenStreetMap [9] to provide location-based services.

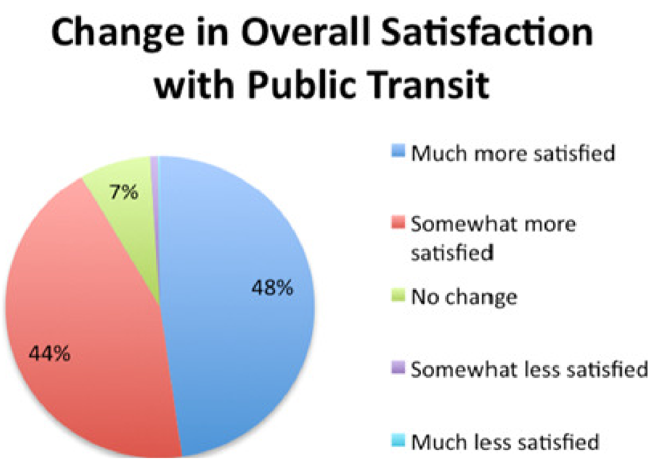


Figure 3. Change in Overall Satisfaction When Using Mobile Application Transit Tools

The study also reviewed the statistical data from research performed by universities, and public/private organizations on mobile applications that are currently in use and investigated the effects of various mobile application technologies such as OneBusAway [11] (Figures 1-3), TransLoc [12], and Google Transit [13] on commuters. The study helped to demonstrate the overall perception of using public transportation with a mobile application, including satisfaction, safety, and waiting time, versus passenger cars, when planning a trip or commuting between cities. The data were derived primarily from surveys taken by both the regular transit and first-time or infrequent users. The information provided valuable information as to what should be expected once CT*fastrak* goes into operation. Furthermore, the mobile application will help in addressing the demographics, frequency, and reason of transit usage, reliability, and usability of the mobile application software in order to make the CT*fastrak* mobile application more reliable and accommodate passengers' needs. The capstone study showed that if a reliable transit tool and transit system is available, people are more willing to utilize it. In some cases, they can even contribute to a mode of transportation switch once passengers become accustomed to it.

CCSU Go (iOS)

CCSU Go uses students as the general user pool, although the application itself can be used by anyone. The motivation for the capstone project was that recent studies [14] showed that millennial generation or adults between the ages of 18 and 31 have exhibited a behavior shift, when it comes to personal transportation. From 2001 to 2009, the vehicle-miles traveled per person for people between the ages of 16 and 34 declined by 23 percent. At the same time, the per-person miles traveled on transit increased by 40 percent, miles biked increased by 34 percent, and miles walked by this demographic increased 16 percent.

CCSU Go was developed on Apple's iOS. As shown in Figure 4, CCSU Go (CCSUtransit App in the figure) allows students to view bus schedules, find fare information, and provides location-specific listings of attractions and stations. It also enables the user to access the CT Transit Trip planner website within the application and contains phone numbers for other modes of transportation. CCSU Go also includes links to CCSU Hertz On Demand car sharing service, the NuRide Rewards program, CT ride, and CT*fastrak*. Users are connected to the webpages without leaving the application. Due to space limitations, the phone application interface will only be presented in the last case study. It should be noted that this study focused on the functionality specifications and interface design in iOS. GPS, trip planner, and points of interest require the installation of Google Maps. A later case study in this paper will have all the functions built into the mobile application.

CCSU Go (Android)

The previous case study described the CCSU GO application in Apple iOS, while this study describes another version of CCSU Go developed for Android phones. When

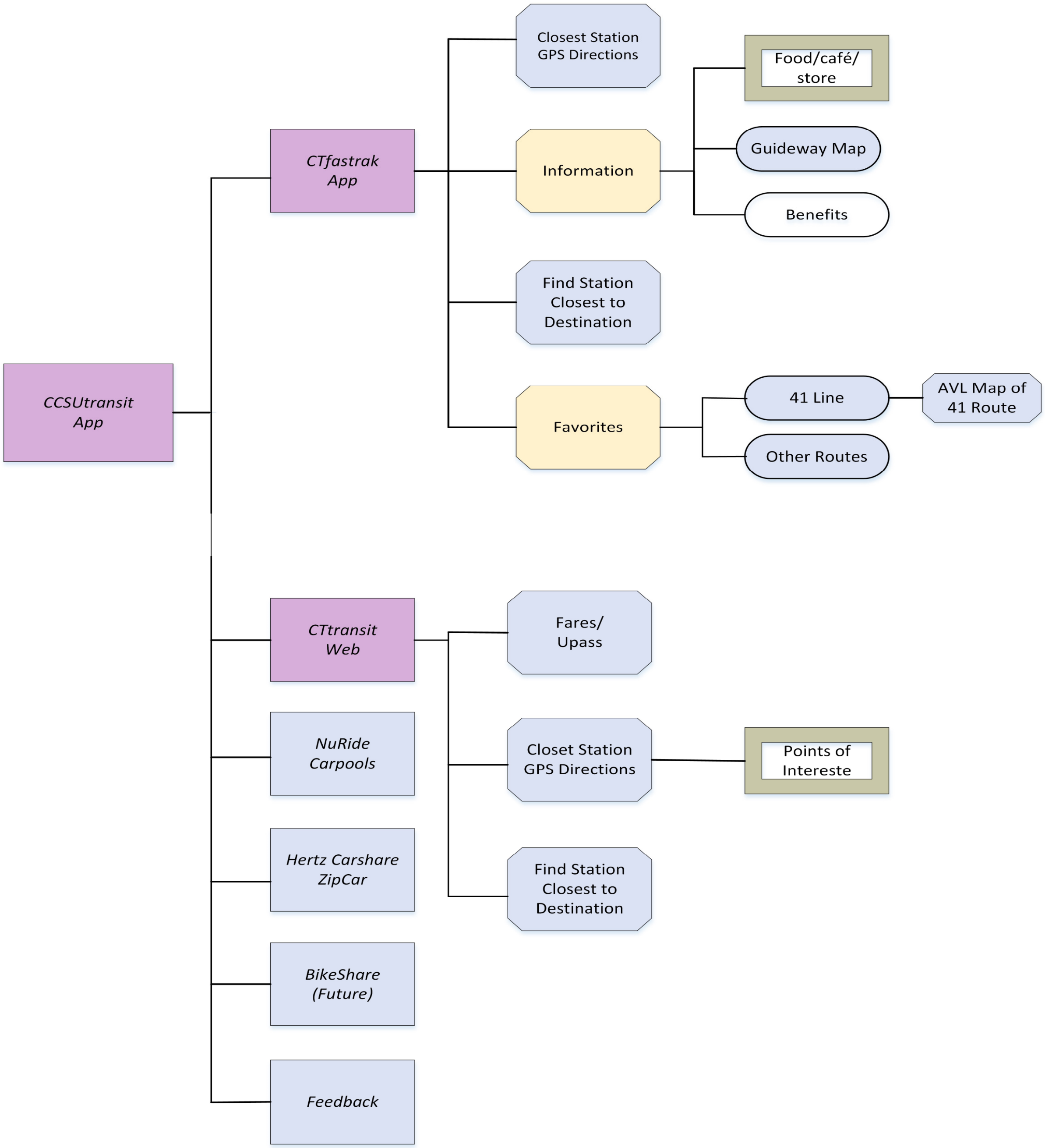


Figure 4. Application flowchart for CCSU Go

looking at the transition of CCSU Go from Apple to Android, users preferred that the usability of the application not change dramatically. As is, the platforms of iOS and Android are quite different; therefore, the plan was to make the application as similar as possible, considering both appearance and the most important functionality. Figure 5 shows the CCSU Go (Android) application interface and functionality flow chart. Due to space limitations, the phone application interface will only be presented in the last case study.

Bus Tracking and Planning System

The details of the work for this case study were published by Wu et al. [15]. Figure 6 depicts the bus tracking and planning system that consists of three modules: bus-side application, server-side database, and client-side (passenger -side) application. The current bus-side application was developed on a mobile phone with GPS receiver capability in order to acquire location information, calculate delays, and report to the transit centre (server-side). The server-side database holds the updated location and delay information for all the buses on the routes and provides responses to passenger queries. The user-side mobile application enables the clients to access the bus information from the server to find bus arrivals, departures, real-time delay, points of interest, and plan their trips.

The mobile application design for the bus-side is shown in Figure 7. The bus-side application tracks the bus location via GPS and periodically sends location updates and delays (if any) to the server. When the user-side application sends a request for location and delay, the server replies to the request. The user-side application provides the following tasks:

- Provides detailed bus route information, including route overview and information about each stop. Client users can download the client-side application and have the route and stop information updated.

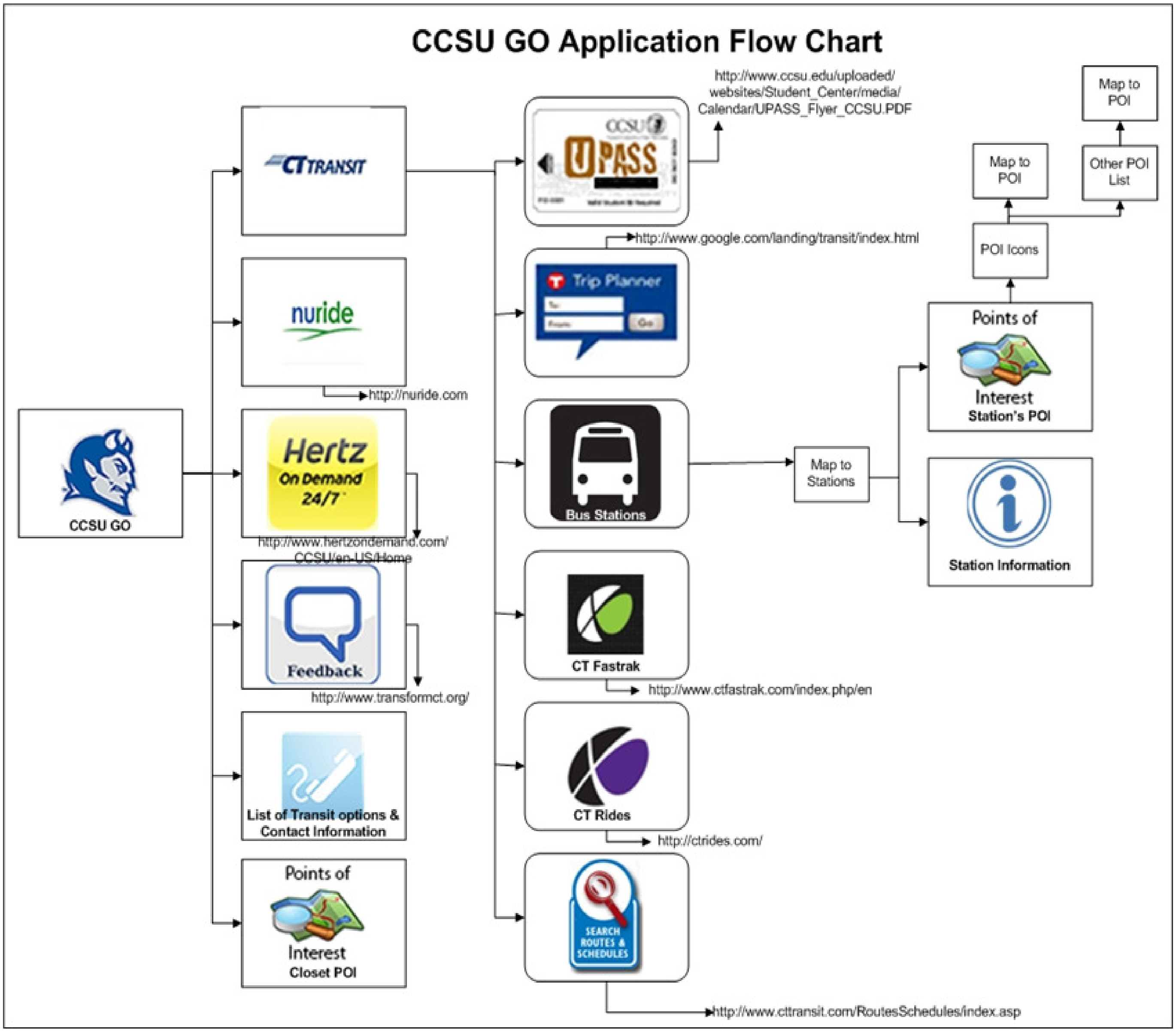


Figure 5. Application Flowchart for CCSU Go (Android)

- Provides an interactive map-based trip planning service. Client users can input the desired destination and, based on the current location of the user (through the phone's GPS module similar to the bus-side application), the system provides a calculated route and displays the route on the map.

- Provides turn-by-turn navigation to any desired bus stop. This helps a client to arrive at the nearest bus stop from the current location.

- Displays points of interest near the bus route.

- Shows clients the real-time locations of buses.

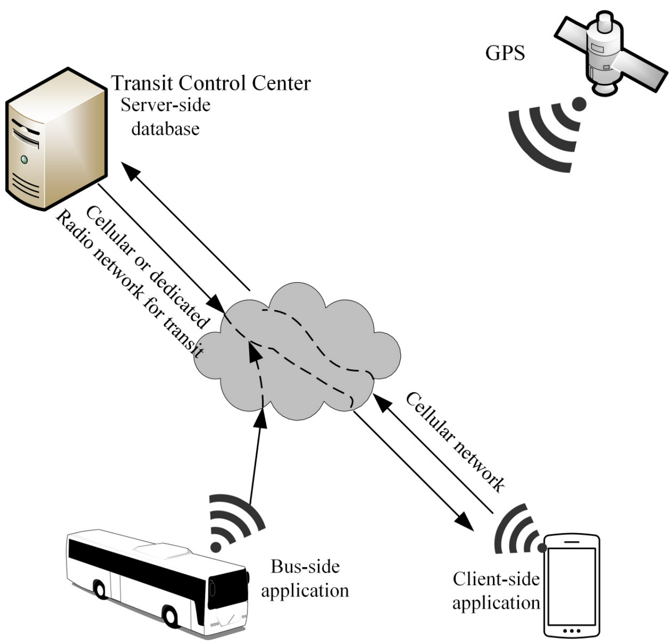


Figure 6. Bus Tracking and Trip Planning System Architecture

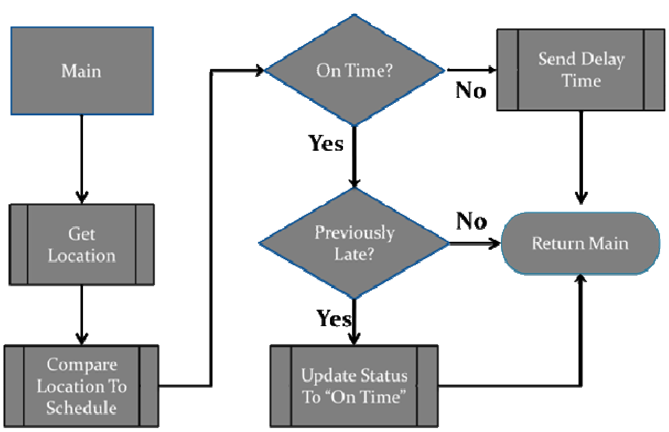


Figure 7. Bus-side Application Flowchart

Figure 8 shows the home screen of the client-side applications. By extending the menu on the home screen, clients can track the buses on route, plan a bus trip, browse the available stops, and find points of interest near the bus stops. Figure 9 shows the two buses that are currently on the queried bus route and the related information such as stop name and arrival time. Figure 10 shows the trip planning function of the system. Clients can select a destination and, based on the current location, the system will be able to find a route with departure and destination stops as well as the path to get to the departure stop from the client's current location.

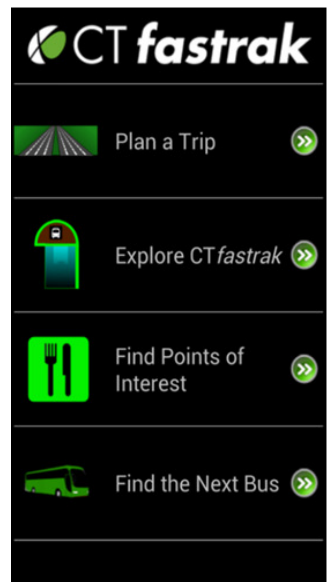


Figure 8. Home Screen

Figure 9. Bus Tracking

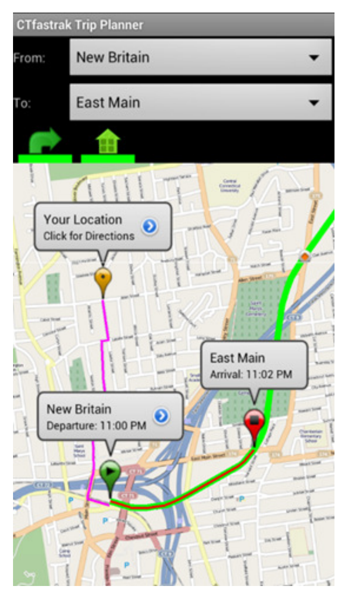


Figure 10. Trip Planner

As shown in Figure 11, the system also allows clients to check bus station information including the parking lot size, departure times, and fare costs. Clients can also find the points of interest of each station, as shown in Figure 12. The points of interest are intended to supply a user with helpful and interesting information about the route and passengers can become more familiar with the CT*fastrak* system and the nearby locations.

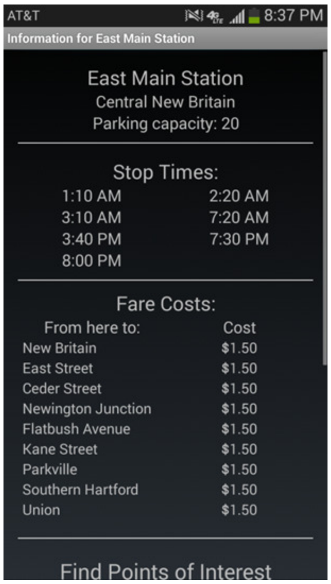


Figure 11. Station Information

Figure 12. Points of Interest

Summary

The work introduced in this paper is a continuing effort based on a previous study on mobile application development [16]. The success of the four projects demonstrates the feasibility of a framework for student hands-on research projects in this fast growing area. Similar projects can be developed for undergraduate or graduate capstone projects. Using similar devices and application development tools, different mobile applications can be developed. The applications can be realistic if faculty and students collaborate with various departments or organizations on or off campus. The following are the components required for such projects:

Devices: Different devices are needed for developing mobile applications on different platforms. Since iPhone iOS and Google Android were used in the four projects, the devices used are listed below:

- An Apple Mac computer (Mac Pro, MacBook Pro, Mac mini, etc.) was required for programming, and an iPhone or iPad was used for testing.
- A PC was required for programming, and an Android phone or tablet was used for testing.

Development tools: Same as the devices, different software tools are required by the two platforms:

- Apple Xcode was used to invoke iPhone and iOS internal functionality and HTML/CSS/JavaScript for web application development. Optionally, independent third-party development environments such as MonoTouch can be used instead of Apple Xcode.
- Eclipse is open-source software and extensible integrated development environment (IDE). It incorporates an Android development tool (ADT) plug-in to build android applications. JQuery is a user interface (UI) framework that helps build a web application for integration into an Android application. MySQL is an open-source database that helps store, manage, and manipulate data.

Curriculum: Before starting the research work, students should equip themselves with knowledge from a variety of areas including collaborative project development, information systems in business, research skills, Internet technology, foundations in computer science for arrays and dictionary used to store data, stacks used in view management, and software engineering for the design and development processes. In addition, to support remote server and database access, students must have a good understanding of networking technology, network application development, server administration, database management, and information security.

Collaboration: To target a real-life application, it is critical for the team to work with users in other departments on campus, state and local government, businesses, and various organizations. Students understand their own lives and local business or government, and such projects would benefit them in the long run by having them network with their potential employers and colleagues. On the other hand, mobile applications are a new and fast-growing market. Such applications are in great need. Therefore, students can easily find users and develop for them a free or low-cost mobile app.

Conclusions

In this paper, the authors introduce four capstone projects, including both graduate and undergraduate, that targeted a state bus rapid transit system and focused on different aspects. Together, they successfully developed a bus tracking and trip planning system. The experience achieved from these four projects was very beneficial for both the students and faculty members. As a direct result, the faculty members organized a series of workshops on Microsoft Windows mobile application development to extend the horizon. With enough feedback and support, future seminar or special topic courses could be developed on mobile application development. Also summarized in this paper is the experience achieved and the components required to develop a similar capstone project targeting various applications. The components are usually available on campus, oftentimes for free.

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TEN-YEAR EVOLUTION OF AN ACCREDITED, MULTISITE BACHELOR'S DEGREE IN BIOMEDICAL ENGINEERING TECHNOLOGY (BBET) PROGRAM

Chad E. Kennedy, DeVry University; William B. Phillips, DeVry University; Anup Majumder, DeVry University;
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Abstract

The growing demand for biomedical engineering technology personnel, compounded by the rapid expansion and integration of medical device technology, has led to a severe deficit of qualified professionals. The newly coined Health Technology Management (HTM) professional requires expanded technical, management, and communication skills beyond those required of the traditional biomedical technician. Furthermore, the broader medical, clinical, and biotechnology device industries have an unmet need for biomedical engineering problem solving, diagnostic, and failure-mode analysis skills. In answer to this need, DeVry University created a bachelor's of Biomedical Engineering Technology (BBET) degree. The BBET program was built upon an already existing Electronics Engineering Technology (EET) program as a specialization.

The goals of the BBET program were to adequately prepare students for the medical device and clinical healthcare fields by providing multi-location, campus-based, hands-on learning labs combined with blended learning and industry internship experience. Since its inception, the BBET program and has undergone Engineering Technology Accreditation Commission (ETAC) of ABET accreditations. To date, it is the only bachelor of science BET degree accredited by ABET.

The curriculum combines fundamentals of mathematics, physics, biology, chemistry, anatomy and physiology, electronics as prerequisites to advanced studies in biomedical instrumentation, biomedical imaging, medical device integration and networking, and ethics and medical informatics. In this paper, the authors present the overall structure of the curriculum, course sequencing within the biomedical engineering technology specialization, a general description of the content within each course, and a program outcomes and assessment strategy. The program has been graduating students since 2006, and there are plans to make major overhauls to its laboratory environment and pedagogical models, to split the program into a two- and four-year offering, and to develop a fully online deliverable version of the curriculum.

Introduction

The growing demand for biomedical engineering technology (BMET) personnel compounded by the rapid expansion and integration of medical device technology has led to a severe deficit of qualified professionals. According to the U.S. Bureau of Labor Statistics' *Occupational Outlook Handbook*, the biomedical engineering and engineering technologists will still outpace expected job growth rates through the year 2022 at 27% and 30%, respectively [1]. This is a startling growth rate projection and reflects an opportunity for institutions to expand their program base. Although a handful of two-year BMET programs have enjoyed strong reputations in the past, the increasing requirements demanded by the medical device and healthcare institutions have made it increasingly difficult to train students for the variety of roles in industry beyond medical device repair. This led universities such as Southern Polytechnic State University (SPSU), Purdue, and DeVry to look into the feasibility of developing a bachelor's of Biomedical Engineering Technology degree [2].

Justification for the Bachelor of Science in BET

Based on biomedical engineering and engineering technology industry research and feedback, the skill sets needed for the biomedical technology industry were recognized as rapidly expanding to include networking, medical device integration, and an understanding of advanced imaging systems [3]. In addition, many soft skills, such as written and verbal communication, conflict management, and customer service were not adequately addressed in many traditional two-year programs. The latter characteristics have long been shown to lead to career advancement into leadership positions [4].

Faculty members at SPSU and DeVry University separately analyzed the feasibility of developing a stand-alone BBET program and came up with similar conclusions [2]. The initial time and cost investment along with regulatory considerations for state approvals were significant. An expedient alternative was to incorporate BBET as a track in the already existing bachelor's in electronic engineering technology (BEET) programs, although implementations between the institutions varied. DeVry University, in particular, created the BBET degree using the foundations of the existing (BEET) program. The BEET founding team formulated and positioned an initial curriculum to meet the needs of the medical device industry (clinical and medical device manufactures), based upon industry advisory committee feedback, existing two-year program models, and industry research.

Curriculum Design

The founding team for the Biomedical Engineering Technology program design took into consideration many factors. First, programmatic accreditation requirements, as specified by the Engineering Technology Commission (ETAC) of ABET Inc., were upheld [5]. Secondly, adjustments to the program of study were required to incorporate biomedical content into an existing electronics engineering technology program. The topics and number of biomedical and science courses chosen were based upon those used in traditional two-year programs at a rigor commensurate with a baccalaureate degree, while still maintaining a strong electronics foundation. By doing this, graduating students would potentially be prepared for two career pathways: one in a traditional electronics industry position and the other as a biomedical technologist or medical equipment repair specialist. In 2004, the BBET founding team created an initial curriculum comprised of 154 credits that took nine semesters to complete. As of 2008, the credits were reduced to 139 credits, with completion possible in just over four years. Figure 1 shows a typical plan of study.

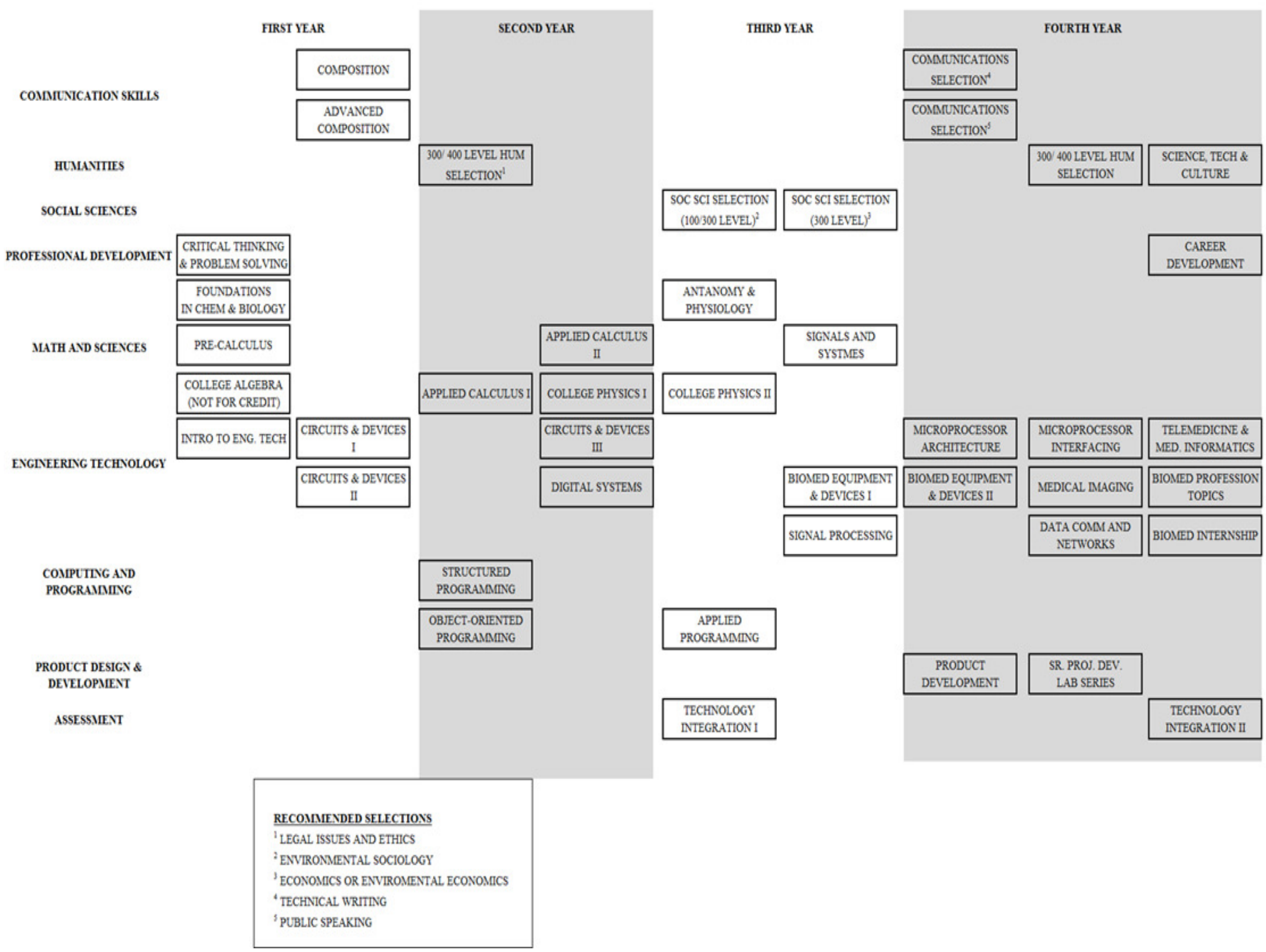


Figure 1. Typical Plan of Study at 139 Credit Hours

Standard Mathematics and Science Requirements

There are some standard math and science requirements for all engineering technology students at DeVry University that include one term of pre-calculus, followed by two terms of calculus. The second calculus term provides a brief introduction to differential equations. A 300-level course in Signals and Systems is then taken to support studies in upper-term courses in controls, signal processing, and telecommunications. Finally, critical topics to engineering technologies, such as Newtonian physics, electricity, thermodynamics, and electromagnetism, are studied across two calculus-based physics courses.

Two focused science courses are also included in order to address the specific needs of the BBET curriculum. A 100-level algebra-based, hybrid course in chemistry and biology was adopted to survey basic chemical and biological concepts that would later support the understanding of many biological processes and medical technologies, such as blood chemistry analysis and medical imaging, including nuclear medicine modalities. This option was chosen over a more traditional approach of having a standalone chemistry and biology sequence, due to limited space in the program of study. A second course covers fundamentals of human anatomy and physiology, while providing dynamic insights into body systems and physiology. Supporting concepts in chemistry and biology are reinforced, while lab exercises provide experience in measuring biological and physiological signals and processes.

Foundations in Electronics and Electrical Engineering Technology

A four-course sequence is taken by all engineering technology students, where fundamentals of DC and AC analysis, electronic devices, circuit simulation, and use of test equipment are presented and reinforced. Additionally, some basic power topics such as amplification, power devices, and transformers are presented. Students purchase a kit that provides them with all of the general materials (wire, breadboards, components, tools, etc.) necessary to conduct hands-on laboratory work throughout their curriculum. Students are also given access to facilities with workbenches replete with electronic test equipment for laboratory exercises. A fifth and final introductory course covers the basic design and analysis of digital circuits, a basis for virtually all electronic systems in use today. Seven additional courses are required by all majors to complete their fundamentals coverage. Structured and object-oriented programing, assembly language, microprocessor architecture and peripheral control, applied programming, embedded systems, and networks and data communications are introduced. These are important prerequisite areas of study for the biomedical students for later, when topics such as biomedical system design and networked biomedical devices are covered.

Upper-division Coursework in Electrical and Biomedical Technologies

Fundamental biomedical equipment and instrumentation technologies are formally presented in two 300-level courses. The first course presents principles of biomedical devices used to measure biological and physiological processes. Coursework addresses general purpose bioamplifier and filter units, electromyographs, noninvasive blood pressure systems, spirometers, pulse-oximeters, plethysmographs, tonometers, digital thermometers, phonocardiographs, and Doppler flow meters. Various transduction processes are presented, emphasizing physiological signal measurement and basic quantitative analysis techniques. The second course covers integrated biomedical systems and their associated medical applications, as well as troubleshooting techniques, safety practices, and maintenance procedures for various instruments and devices. Topics include electrocardiographs, brain activity monitoring recorders, patient monitors, pacemakers, defibrillators, electrical stimulators, electrosurgical units, dialysis equipment, and related equipment used in clinical environments. Throughout this course, students examine the basics of calibration, troubleshooting, repair, and certification necessary to determine if equipment and instruments meet specifications.

Students then advance to a series of 400-level courses including medical imaging, telemedicine and medical informatics, and professional topics. In medical imaging, various transmission- and emission-based imaging techniques—including X-rays, computed tomography (CT), ultrasound (Doppler and basic imaging), magnetic resonance imaging (MRI), and positron emission tomography—are presented. The fundamental physics of these technologies is addressed as needed, as are the basics of image acquisition, processing, image format construction and storage types, and safety standards. Picture Archive and Communications (PACs) and Digital Image Communication in Medicine (DICOM standards) are also introduced and then reinforced in the telemedicine course.

The Telemedicine and Medical Informatics course presents design principles and implementation of computer infrastructure as related to accessing medical databases, visualizing medical techniques, and transferring and manipulating medical data over communication networks using PACs, DICOM, and Health Level 7 protocols.

Finally, in a two-course sequence, students complete a 90-hour minimum internship experience at a biomedical facility and study professional topics related to the field in the classroom. Topics include projections for regulatory policy revision, advancements in equipment technology, and new medical and biotechnology frontiers. Students keep a detailed journal, logging their internship time and activities, and review their field experience with faculty.

Integrated Technology Experiences

All senior engineering technology students undertake a 32-week, senior project sequence with a focus on their chosen field of study. The sequence starts with a product development course that examines product lifecycles from initial concept through manufacturing. Students establish teams to develop a senior project, while the coursework addresses project management, total quality management, codes and standards, prototype development, reliability, and product testing. Teams prepare a written proposal for the senior project and make oral presentations to the class. The teams are often interdisciplinary in nature, with a mix of biomedical, computer, and electronics engineering technology majors working together. To ensure that the appropriate experience is provided to students with different areas of emphasis, the proposals are reviewed and approved to ensure that program -specific outcomes are met in this experience. These outcomes are addressed in Table 3.

There is also a humanities capstone course that all students complete in their senior year, called Technology, Society, and Culture. In this course, the relationship between society and technology is investigated through reading, reflection, research, and reports. In the course, conditions that have promoted technological development and assesses the social, political, environmental, cultural, and economic effects of current technology are identified. Discussions combined with oral and written reports draw together students' prior learning in a specialty area and general education courses. BBET students are encouraged to focus on contemporary issues concerning the development and utilization of biomedical technology.

Furthermore, there are several general education courses recommended that the students take in order to aid in the creation of meaningful capstone reports in this course to support achievement of the published program student outcomes (discussed in later sections of this paper) and development an inspiring biomedical technologist professional. These recommendations involve development of communication skills, business acumen, as well as legal, ethical, and environmental awareness (see notes at the bottom of Figure 1).

Lab Environment and Model

The Biomedical Engineering Technology program is heavily rooted in hands-on, experiential active learning. The lab model has been refined over the years, implementing best practices and continuous improvement feedback from faculty, students, and employers. The standard Biomedical Engineering Technology Lab Model consists of state-of-the-art equipment and workstations, where mini-lectures are integrated with lab activities (see Figure 2). Proxima, whiteboard, and screen are remotely connected with a podium to demonstrate or discuss a concept with the class and then immediately dive into an activity with the students.

A general lab station consists of a workstation computer connected to a National Instruments Elvis II+ with breadboarding, AI, AO, DIO, PWM, or encoder edge detection capabilities. In addition, standard workstations include function generators, power supplies and DMMs separately or integrated versions via the Elvis II+ units. Typically, labs have this setup for each pair of students, due to cost constraints [see Figure 3(a)]. The workstation furniture was designed to address human factors such as posture and fatigue along with workspace factors so that students could not only interact with the computer, but also have enough depth and width to the desk space to be working on a circuit design, taking notes, building a device etc., by simply moving the swivel arm flat screen away and pushing back the keyboard and mouse [see Figure 3(b)].

Several "device specific" stations were placed throughout the facility for team labs where equipment cost was a factor. As seen in Figure 3(b), the lab included an ultrasound imaging station (*Sonosite 180Plus*, Sonosite, Inc.), where students would experiment with ultrasound imaging and Doppler devices (*Model 811-B*, Parks Medical Electronics) with a variety of phantom models. Other stations focused on various skill sets such as MRI/NMR imaging and signals (*TEL CWS 12-50*, Techtronics, Inc.), infusion pumps preventative maintenance (*Alaris Systems*, CareFusion, Inc.), X-ray/fluoroscopy imaging (*JewelBox-70T*, Glenbrook Technologies, Inc.), and patient monitoring and nurse monitor integration (*Nightingale Patient Monitor System PPM2 171-7100*, Zoe Medical, Inc.) [see Figures 3(c) and 3(d)].

Other lab-specific equipment not permanently set up was stored in labeled cabinets and bins at the back of the room, along with human anatomy and physiology models used throughout the curriculum. It is important to note that internship students and program graduates have been adequately prepared for the career field utilizing this lab model. This suggests a program built around a large hospital suite environment replete with expensive pieces of biomedical

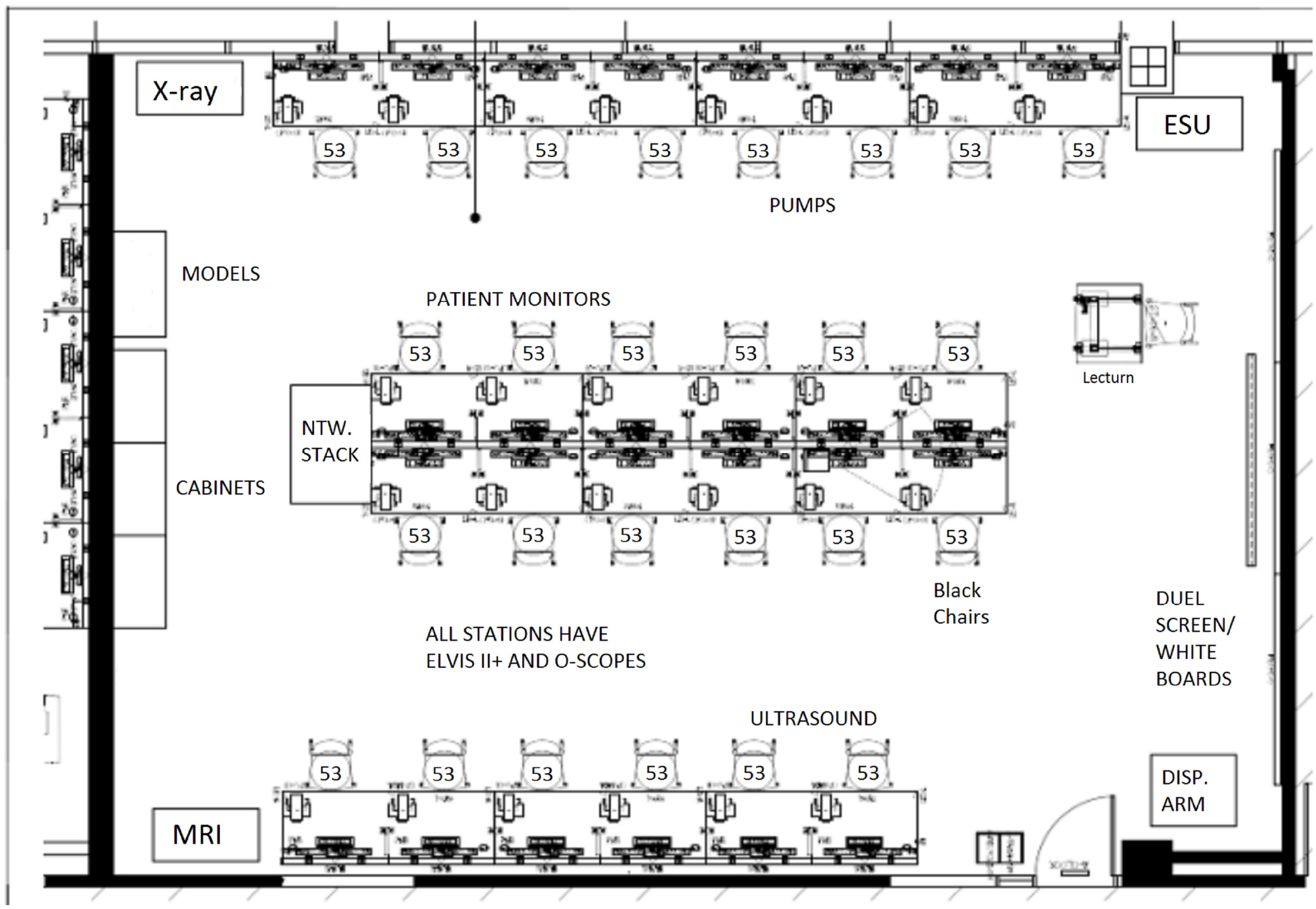


Figure 2. Classroom Workspace Model with Both Didactic and Lab Capabilities

equipment, devices, and tools may not be necessary, as long as relevant hands-on activities are made available and an internship experience is required.

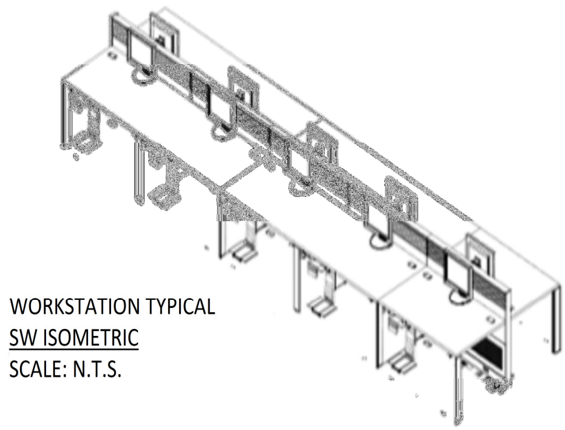
Program Educational Objectives, Student Outcomes, and Assessment Strategies

Program educational objectives (PEOs) are those attributes that graduates are expected to attain within a few years of graduation. The PEOs for the biomedical engineering technology education were written to meet the needs of and have been reviewed by the stakeholders of the program and are listed in Table 1. These statements are particularly broad and adaptable to any engineering technology field.

The skills, knowledge, and behaviors expected of the biomedical students at DeVry University at the time of graduation are provided in Table 2. These student outcomes, listed A through L, were written to satisfy the guidelines published by ETAC of ABET under General Criterion 3a-k and the Program Specific criteria for Biomedical Engineering Technology programs. Table 3 presents specific attributes expected of students completing the biomedical program. These attributes are a subset of the Program Criteria found in ABET's Program Specific accreditation criteria for BET programs [5]. The primary assessment strategy leveraged to measure attainment of SOs is summarized in Table 4.

Table 1. Program Education Objectives for the Biomedical Engineering Technology Program

Objective	Description
PEO #1	Finding employment in a biomedical technology-related position with appropriate title and compensation
PEO #2	Achieving a successful professional career
PEO #3	Adapting to change through continuous personal and professional development



(a)
Design of a Workstation Bench Set to Standard Seating Height Instead of Bench Top Height Based on Human Factors Such as Posture and Fatigue

(c)
Infusion Pump Station for Preventative and Corrective Maintenance

(b)
Ultrasound Station Next to a Standard Station with the Elvis II+ Units

(d)
Lab Cabinet Storage Behind the Patient Monitoring Station, Next to the X-ray Machine on the Back Left Corner

Figure 3. A General Lab Station

The senior project and humanities capstone were previously described. The BBET program also included two additional integrated technology experiences that serve as formative and summative assessment points. In the first course (Technology Integration I in the program of study given in Figure 1), students apply and integrate concepts learned in computer programming, mathematics, and electronics and computer engineering technology courses in the first four semesters of the program by solving problems in the particular discipline or subject area. In Technology Integration II, students review math, science, electronics, and biomedical-specific engineering technology concepts and then work to solve problems related to these concepts. Often, guest speakers and/or mini-projects are also conducted to enrich the student experience.

Initial Evaluations and Improvements

The initial collective feedback from the industry advisory committees, Technology Accreditation Commission of ABET (now ETAC of ABET), alumni and faculty was obtained through the accreditation process in 2006 and contin-

Table 2. Student Outcomes Mapped to PEOs and ABET Criteria

Rating: 0 = No applicability; 1 = Low applicability; 2 = Medium applicability; 3 = High applicability

PEO #1	PEO #2	PEO #3	Student Outcome (SO)	Description	ABET Criteria
3	2	1	A	An ability to select and apply the knowledge, techniques, skills, and modern tools of their disciplines to broadly defined engineering technology activities.	General Criteria: Criterion 3a
3	1	1	B	An ability to select and apply knowledge of mathematics, science, engineering, and technology to engineering technology problems that require the application of principles and applied procedures and methodologies.	General Criteria: Criterion 3b
3	1	2	C	An ability to conduct standard tests and measurements; to conduct, analyze, and interpret experiments; and to apply experimental results to improve processes.	General Criteria: Criterion 3c
3	2	2	D	An ability to design systems, components, or processes for broadly defined engineering technology problems appropriate to program educational objectives.	General Criteria: Criterion 3d
2	3	1	E	An ability to function effectively as a member or leader on a technical team.	General Criteria: Criterion 3e
3	1	1	F	An ability to identify, analyze, and solve broadly defined engineering technology problems.	General Criteria: Criterion 3f
2	3	2	G	An ability to communicate effectively regarding broadly defined engineering technology activities.	General Criteria: Criterion 3g
1	3	3	H	An understanding of the need for and an ability to engage in self-directed continuing professional development.	General Criteria: Criterion 3h
1	3	3	I	An understanding of and a commitment to address professional and ethical responsibilities including a respect for diversity.	General Criteria: Criterion 3i
1	2	3	J	Knowledge of the impact of engineering technology solutions in a societal and global context.	General Criteria: Criterion 3j
1	3	2	K	A commitment to quality, timeliness, and continuous improvement.	General Criteria: Criterion 3k
3	2	2	L	An appropriate level of achievement of the body of knowledge required by the Biomedical Engineer Society (BMES)	Program Specific Criteria

uously revisited annually. The main focus for initial improvement was in three areas: faculty development, internship program development, and addition of breadth to topics. Ensuring that there were enough qualified faculty to support the program was addressed with additional hiring of Ph.D.-level faculty with biomedical engineering degrees or a combination of electrical or mechanical engineering Ph.D.-level faculty with extensive biomedical engineering experience in clinical, industrial or research settings. Follow-up visits validated the faculty improvements. At flagship campuses, multiple faculty overlap to teach the cross-disciplinary nature of the Biomedical Engineering Technology program.

The internship program evolved from a tertiary form of educational experience for the students at DeVry University to a primary, integrated experience designed into the curriculum. A formalized internship program remains a requirement for graduation. The institution has partnered with local hospitals, third-party service organizations, medical device manufacturers, and industries to provide real-world, hands-on experiences for these BBET students. Oftentimes, these internship experiences lead to gainful employment for a win-win-win relationship for the student, employer, and university. The curriculum has been expanded to include more competency topics for a broader base of medical devices, testing and analysis tools, and increasing networking and health systems integration. Technical topics, such as image-guided radiation therapy, mobile telemedicine, distributed healthcare, and soft-skills topics such as conflict management, customer service, and project management are just a few of the topics that were added into the curriculum. This demonstrates the adaptability of this program to new technologies and competencies desired by the career field as they arise.

Continuous Improvement and Future Work

The ABET criteria for engineering technology programs and the current outcome-based assessment model serve as the cornerstone to the program's continuous improvement and quality assurance. The BBET program has had graduates since the spring of 2006, and the institution holds and maintains ETAC of ABET accreditation for a campus-based delivery of its BBET program at 12 locations. Originally, each location offering the program was accredited separately. In 2010, the institution successfully executed a comprehensive, multi-site evaluation of these programs nationally by ETAC of ABET. The faculty and engineering technology administration revisited the applicability and relevance of the educational objectives and student outcomes of the program in the 2012-13 academic year. Although the PEOs and SOs were generally viewed to be acceptable, there were plans to improve and update them. Furthermore, the internationally recognized framework of conceive, design, implement, and operate (CDIO) [6] was to be employed in a program redesign, following a proposed paradigm shift for engineering technology programs by Houston's Department of Engineering Technology in the College of Technology [7].

Table 3. Delineation of Student Outcome L

Subset Criteria for Outcome L	Description
L1	Demonstrate knowledge and hands-on competence in the application of circuit analysis and design, analog and digital electronics, microcontrollers, programming, bioengineering systems, and safety in the building, testing, operation, and maintenance of biomedical equipment.
L2	Demonstrate knowledge and hands-on competence in the application of physics, chemistry, and the biological sciences to building, testing, operation, and maintenance of biomedical equipment in a rigorous mathematical environment at or above the level of algebra and trigonometry.
L3	Demonstrate knowledge and hands-on competence in the ability to analyze, design, and implement bioengineering systems.
L4	Demonstrate knowledge and hands-on competence in the ability to utilize statistics/ probability, transform methods, discrete mathematics, or applied differential equations in support of bioengineering systems.
L5	Demonstrate knowledge and hands-on competence in an understanding of the clinical application of biomedical equipment.

Table 4. Primary Assessment Strategies

Assessment	Description / Summary
Formative Assessment Exam	Examination administered after 200 –level technical courses have been completed to address achievement of Student Outcome A and Program Specific Outcomes (L1 – L2).
Summative Assessment Exam	Examination of all technical coursework to address achievement of Student Outcome A and Program Specific Outcomes (L1 - L5)
Senior Project	This is an integrated curriculum experience used to assess Student Outcome B to K and L1 to L5.
Humanities Capstone	This is an integrated curriculum experience used to indirectly assess Student Outcomes E to K.

Recently, the Association for the Advancement of Medical Instrumentation (AAMI) provided an additional classification for the biomedical profession—Health Technology Management (HTM). It is particularly applicable to a four-year program in Biomedical Engineering Technology education, as the HTM definition requires expanded technical, management, and communication skills beyond those required of the traditional biomedical technician with an associate's degree. The minimum core competencies published last year by the AAMI Education Committee represent a standard set of competencies based upon a two-year program, but also include recommendations for expanded skill sets [8]. The demand for such graduates, as well as international needs, will also drive future improvements and online capabilities to train the next generation of BMET and HTM professionals. Hopefully, this program and information will encourage and empower other countries, especially developing communities, to create similar curricula and prepare BMET and HTM professionals for their respective communities.

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VALUE STREAM MAPPING: RECREATING AN INDUSTRIAL ENVIRONMENT IN AN EDUCATIONAL SETTING

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Abstract

The creation of an industrial environment in the classroom helps students to prepare for the real world of work. Manufacturing students must be prepared to apply lean manufacturing (LM) concepts in an industrial environment. Value stream mapping (VSM) is one tool that can be used to implement the LM technique. The aim of this current study was to apply VSM in the Simulated Industrial Manufacturing Company (SIMCO) class at Indiana State University. At SIMCO, mass production techniques were used to manufacture products such as diploma frames. There was, then, a need to use LM techniques to minimize waste and maximize the flow. It is known that VSM is well able to identify opportunities for enhancing value, eliminating waste, and improving flow. In this study, the authors followed four steps to implement VSM: 1) identify the product; 2) create a current-state value stream map; 3) create a future-state value stream map; and, 4) create an action plan. Takt time, process cycle time, and process cycle efficiency (PCE) were computed for prior- and post-states for comparison. Although PCE did not improve, takt time, cycle time, budget, and the number of required employees were all significantly reduced.

Introduction

The Simulated Industrial Manufacturing Company (SIMCO) is a completely laboratory-oriented 400-level capstone course. This course was designed to help students increase their practice of hands-on activities. The class is offered once a semester at the Collage of Technology of Indiana State University. The course is similar to an external industrial experience in that each student brings to the enterprise/class (or SIMCO) various skills, abilities, talents, and knowledge; and, all students must work together, while pooling their expertise, to achieve the final goal of producing a product that is of high quality, made to specifications, on schedule, and produced within a defined budget. Many products are manufactured in SIMCO such as diploma frames, clocks, coffee tables, etc. SIMCO is comprised of eight departments: manufacturing and production, design, quality, sales and marketing, purchasing, human resources, safety, and packaging. Each department should contribute to the process of developing at least one product. Machines that are available in the SIMCO lab include planers, belt sanders, table saws, miter saws, routers, and speed sanders.

The researchers focused on using the diploma frame product to teach and implement the processes of production and the proper usage of machines. The prior process of producing the diploma frame product can be summarized as 1) the sanding process created a smooth surface on both sides of the wood stock and produced the required thickness of the board; 2) an edge-joining process was used to join the wood pieces at a 90-degree angle; 3) a miter saw process permitted the workers to cut the ends of the wooden piece at exact 45-degree angles; and, 4) router processes used the router machine to shape the edges of the frame. Two passes of the router were required: the inside edge was shaped with a 3/16-inch bit and the outside edge with 5/32-inch bit. Also, a Kreg machine was used to make a screw cut on all the wooden pieces. This process was important for assembling the wooden pieces with the use of screws. Fifth, face jointing produced a smooth surface on the thicker edge of both sides of the wooden stock. Next, poly-seal painting was used to paint the wooden piece by using a brush and touch up-pens. The last step was the final assembly of the diploma frame in which the four pieces of wood were then assembled with screws.

Many dynamics have necessitated an organizational change in SIMCO. These can be summarized by five important factors:

1. The number of student workers (the average number of students, or “employees”, in a class is 25. These employees can be managed to be more effective and productive by eliminating unnecessary tasks and positions. Also, this large number of employees can lead to management difficulties (e.g., in dealing with problems and interpersonal conflicts).
2. The price of the raw material is relatively expensive, since it is purchased for each class individually, and in considerably lower quantities than would be found in a real industry. By the end of each semester, some of the unused raw materials become waste and some finished products remain unsold.

3. The high volume of inventory requires significant storage room for unused raw materials and unsold finished goods.
4. The quality of products is acceptable but not of an exceptionally high level.
5. Demand for the products of SIMCO is low. This may be due to the lower quality of the product compared to products on the market, or it may be due to the poor marketing strategy used in SIMCO.

All of these reasons inspired the authors to reorganize the production process in SIMCO. Two major decisions were made: 1) that some of the unnecessary tasks should be eliminated and replaced with tasks that will add value to customers, and 2) that the overall performance and quality of the product should be improved. This research study aimed to apply the technique of value stream mapping (VSM) in the SIMCO class, and to measure the effectiveness of this newly applied procedure (LM). In SIMCO, a mass production technique is used to manufacture products such as diploma frames, clocks, coffee tables, etc. Therefore, there is a need to use Lean Manufacturing techniques in this class to eliminate or minimize waste and to maximize flow. VSM is a constructive technique that can be used to accomplish just such goals. Four steps are followed to effectuate value stream mapping: 1) identify the product; 2) create a current-state value stream map; 3) create a future-state value stream map, and 4) creating an action plan. Takt time, process cycle time, and process cycle efficiency (PCE) analyses are used to evaluate and create the current- and future-state value stream maps.

Literature Review

Lean, as defined by Womack and Jones [1], is the process for doing more with less and less (i.e., less human effort): less equipment, less time, and less space, and all while coming closer and closer to providing customers with exactly what they want. It is also a business system and a generic process-management philosophy that comprises a systematic approach to eliminate waste through techniques such as just-in-time, continuous improvement (Kaizen), and the pull system (Kanban) [2], [3]. Lean Manufacturing and its key principles were based upon the Toyota Production System (TPS), which is more generally denoted lean manufacturing [4], [5]. Ohno defines TPS as the total removal of waste to make product in a continuous flow [6], [7]. According to Womack and Jones [1], lean thinking has five key action principles:

- Define value from the customer's perspective: value needs to be identified from the standpoint of the ultimate consumer. If the customer will not pay for an activity, it is considered as non-value-added and should be eliminated.
- Identify the value stream: the value stream is the set of all steps/action required to produce a specific product or service. All of the steps in the value stream should be identified for each product family and every action and every practice that does not create value must be eliminated.
- Make the process flow: the materials should flow through the system with a minimum of interruption and waiting.
- Pull from the customer: the customer should pull the product from the source as needed rather than have the source push products onto the customer. In other words, no upstream function or department should produce a good or service until the customer downstream asks for it.
- Head toward perfection: after implementing these steps, the managers and teams of employees should eliminate further waste and pursue perfection through continuous improvement.

The lean technique is not just a concept but also a foundational philosophy; it states that every organization and work environment must seek to eliminate waste (non-value-added activities) and to save on labor, material, and machines costs [8]. Lean techniques use standardized work practices to minimize efforts and improve product quality so as not just to meet customer expectations but rather to exceed them [9], [10]. There are many advantages and goals for lean production. These can be summarized via the following needs:

- Improve quality: understanding customer needs helps companies remain competitive in the marketplace. Therefore, a company must design its services to meet customer expectations, needs, and requirements [1], [11].
- Eliminate waste: waste can be defined as any activity that does not add any value to the process (i.e., product or service) [12]. Waste can be due to any of the following: overproduction, superfluous motion, transportation issues, waiting time, setup time, processing time, unnecessary inventory, defective products, and underutilized workers [12-14].
- Reduce production time: using the available time in the most efficient way will reduce the time and effort that is needed to deliver the service or product. This also will help eliminate waste and reduce costs [1].
- Reduce total costs: companies can minimize total cost by producing in quantities that are sufficient to meet customer demand. Producing more than customer demand will increase inventory costs [15], [16].

The VSM technique was essential for the implementation of lean production in SIMCO. VSM was used to analyze the current situation and to develop a new production process to minimize waste, maximize flow, and improve customer satisfaction by improving the product quality. A value stream takes into account all of the value-added and non-value-added steps needed to convert a product or service from a raw material into what the customer ultimately requires. Managing the value stream employs processes for measuring, understanding, and improving the flow and interaction of all of the associated tasks; the goal is to keep the costs, service, and quality of a company's products and services as competitive as possible [17], [18]. Value stream mapping could continuously identify opportunities to enhance value, eliminate waste, and improve flow. There are four steps an organization can use to implement value streams in their production processes. These steps are: identifying the product, creating a current-state value stream map, creating a future-state value stream map, and creating an action plan [19], [20].

In order to improve the production in SIMCO, a lean manufacturing technique has been employed. A comparison was made between the spring 2012 SIMCO class (after lean was implemented) and the pervious mass production process used in the spring 2011 class. The comparison helped the researchers to evaluate the effectiveness of the lean manufacturing technique in classroom settings. The VSM analysis has been invaluable for the improvement of the production process at SIMCO. The Smart Draw Software application was used to develop the maps.

Tracking the time needed to perform each process was important in this research project. Data was collected by the students of the SIMCO class using a digital stopwatch. The time in seconds for each process was measured three times and the average of the three trials was calculated. This method was used to calculate different factors and to build the current value stream mapping that is described in the next section. It was also of great value to determine the cycle time for each process [21]. Different mathematical equations were used to accomplish this. One equation, process cycle efficiency (PCE) [22], is given in Equation (1):

$$PCE = \frac{customer\_value\_added\_time}{process\_cycle\_time} \tag{1}$$

Process cycle time is the sum of design time, manufacturing planning time, manufacturing control time, and manufacturing lead time. Thus, cycle time is the sum of value-added and non-value-added times [23]. Takt time [24] is calculated using Equation (2):

$$takt\_time = \frac{net\_time\_available\_to\_work}{time\_demand} \tag{2}$$

It was assumed that the production year in SIMCO was the academic year that consisted of two semesters, 16 weeks for each semester. The class was scheduled to be held semi-weekly for two hours each day. Also, it was assumed that the walking time was fixed, because the production processes took place in the same SIMCO lab without any changes in the locations of the machines.

Findings

The findings from this study are summarized by three primary factors: organizational structure, budget, and production process and cycle time.

The organizational structure for SIMCO spring 2011 was a functional structure based on job's purpose within the SIMCO Company. Functional organizations were comprised of departments that aimed to accomplish a single function/goal. Figure 1 shows the organization chart for SIMCO spring 2011 before applying the VSM. Matrix structures were developed in SIMCO to generate the best results by which to manage the company. The matrix structure was created by forming a team consisted of the most qualified students/employees (based on their experience) for the project. Figure 2 illustrates the organizational structure for SIMCO spring 2012 after applying the VSM.

Eight departments in the old structure were reduced to five functional areas by using the matrix organizational structure. The packaging department was integrated into the production area. The purchasing department was integrated into sales, but this new entity was denoted as the logistics area. The human resources department was eliminated, as it was not needed under the matrix structure that eliminated centralized management.

Table 1 illustrates the budget for producing 35 diploma frames before applying VSM. Table 2 shows the budget for producing just 10 diploma frames, i.e., because, historically for this course, the demand for the diploma frame product is 10 units per semester. Therefore, there is no need to order material for more than 10 units unless more units are requested by customers. Thus, the total budget was reduced from the pre-change value of \$609.88 to \$273.82.

Before applying the VSM, the number of diploma frames to be produced was determined by the number of students in the SIMCO class (in this case, 35). Company departments were also formed based on the number of the enrolled students. The goals were to manufacture diploma frames in large quantities (35 frames) and in standard form. Fifteen main processes were used to produce the diploma frame product. These steps are explained in Table 3.

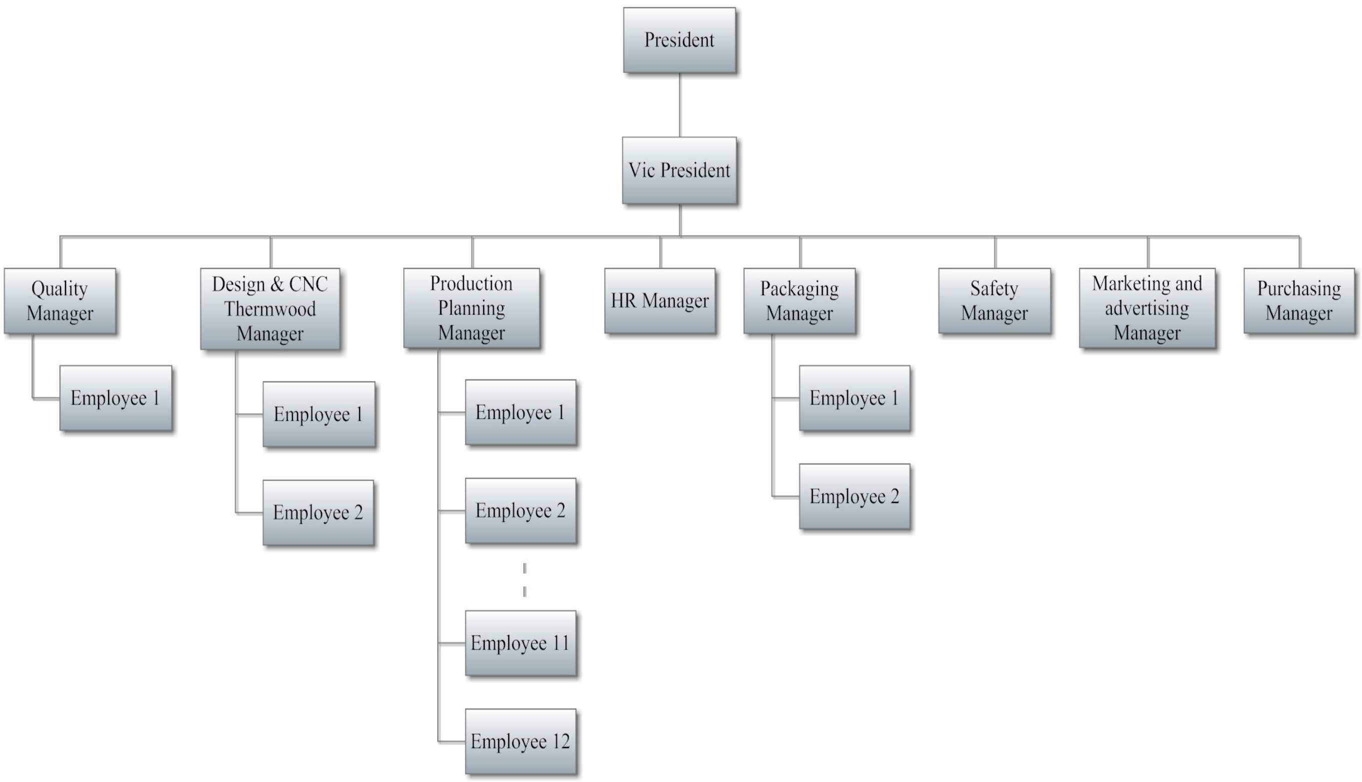

Figure 1. Organizational Structure for SIMCO in the Spring of 2011 Before Applying the VSM

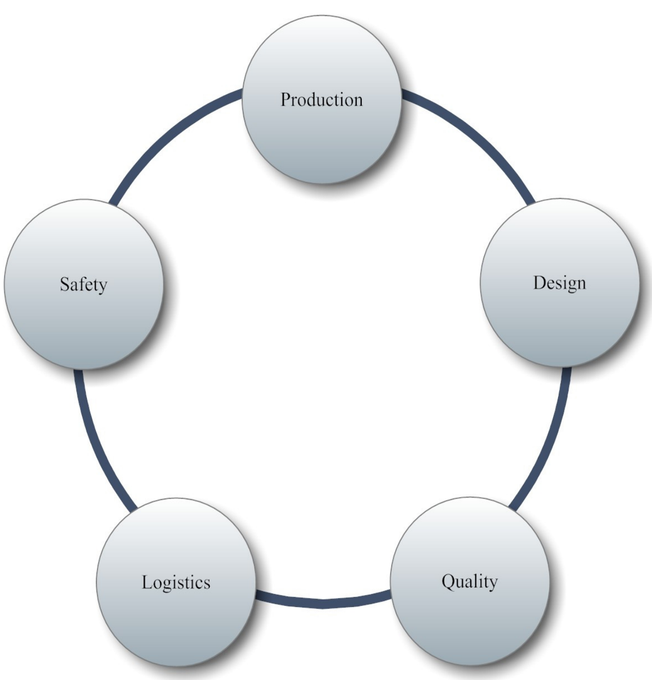

Figure 2. Organizational Structure for SIMCO in the Spring of 2012 After Applying the VSM

Table 1. Budget for SIMCO in the Spring of 2011 Before Applying the VSM

QTY	Description	Unit price	Total
75	White Oak (Board Feet)	$2.50	$187.50
35	S. S. Glass 15.25" x 12.75"	$3.90	$136.50
35	Blue Matting	$3.90	$136.50
35	Gold Matting	$3.90	$36.50
35	1/8 in. Foamcore Board	$1.00	$35.00
1	Custom Frame – Turn Buttons	$5.00	$5.00
1	1” Fine Thread Pan Head Screws	$25.99	$25.99
4	4” All-purpose Glue Sticks (24 pack)	$4.97	$19.88
1	MinWax Polycrylic Semi-gloss (1 Qt.)	$16.57	$16.57
1	6-Pack Foam Brush 2”	$2.98	$2.98
1	Finish Factor 12-Pack Terry Towels	$7.46	$7.46
		TOTAL	$609.88

Table 2. Budget for SIMCO in the Spring of 2012 After Applying the VSM

Quantity	Description	Price Per Unit	Total Cost
5	Frame	$12.31	$61.55
10	Backing 1	$3.41	$57.94
10	Backing 2	$3.41	$57.94
10	Frame Glass	$4.34	$43.40
1	1 pack of 10 30"x20"	$39.97	$39.97
1	Gunstock Color	$6.27	$6.27
1	16oz Bottle	$6.75	$6.75
		TOTAL	$ 273.82

Table 3. The Production Processes for SIMCO in the Spring of 2011

NO	Process Name
1.	Material Inspection
2.	Planning
3.	Edge Joining one side to create 90 degree angle
4.	Ripping
5.	Dado Cutting
6	Routing Inside Edge
7	Routing Outside Edge
8.	Sanding Edges
9.	Sanding Bottom and top surfaces
10.	Miter Cutting
11.	Cutting holes for screws
12.	Engraving upper and lower pieces with Thermwood
13.	Painting Letters
14	Waxing
15	Assembling

Table 4 shows the time in seconds for each of the value-added processes for producing 35 frames by the mass-production technique (Spring 2011 before applying the VSM). Also, the time for each process is summarized in Figure 3. These data helped to create the current value stream mapping illustrated in Figure 4.

Table 4. Total Time for Each Process for SIMCO in the Spring of 2011

Step	Total Time (Second)
Planer	9.73
Sander	51.89
edge Jointing	576
Ripping	0.91
Dado Cut	94.23
Miter Cut	978.67
Routing	589.2
Drill Holes	250.67
Waxing	1246.44
Engraving	600
Finishing	1252.33
TOTAL	5650.07

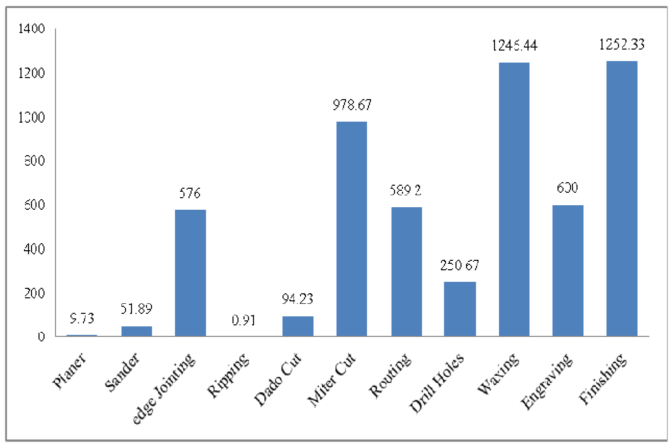

Figure 3. Total Time for Each Process in Seconds for SIMCO in the Spring of 2011

Three parameters were computed: takt time, process cycle time, and process cycle efficiency (PCE). As previously mentioned regarding assumptions, the production year in SIMCO was the academic year that consisted of two semesters, with 16 weeks per semester. The class was scheduled semi-weekly with two hours per class. Therefore, the time available for each class was 110 minutes (= 6600 sec), excluding time for breaks and clean up. Based on the actual sale of the diploma frames, the annual demand was 20 units. Demand per class day was computed by dividing the annual demand by 64 days per year (2 days/week → 8 days/month → 32 days/semester → 64 days/year); daily demand = 0.3125 piece/day. From the value stream map, it can be

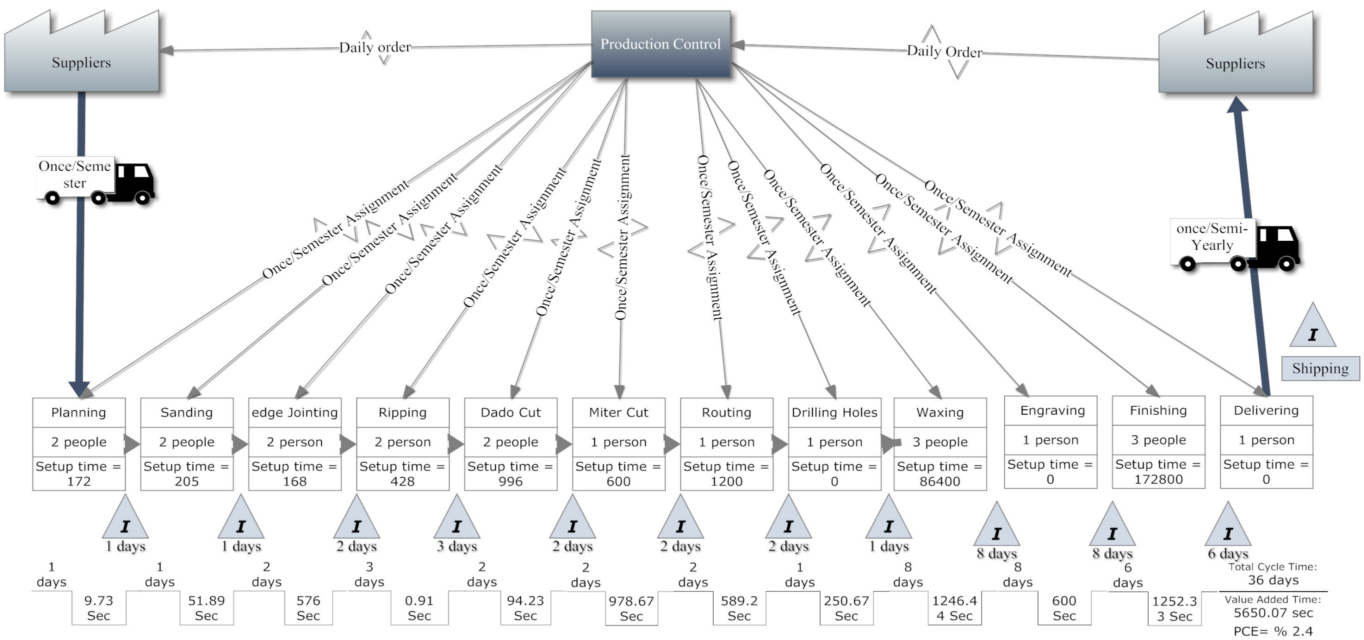

Figure 4. Value Stream Mapping for SIMCO in the Spring of 2011

found that the value added time required was 5650.07 sec and total process cycle time (PLT) was 36 days (37×6600 = 237,600 sec). From Equation (1), PCE = 5650.07/ 237,600 = 2.4%. From Equation (2), takt time = 6600/0.3125 = 21,120 sec/piece. Table 5 summarizes the result of the calculations.

Table 5. The Production Measurements for Mass Production Before Applying the VSM

Measurement	Result
Daily demand	0.3125 pieces/day
Takt time	21,120 sec/piece
PCE	2.4%
Process cycle time	237,600 sec
Value-added time	5650.07 sec
Non-value-added time	231,949.93 sec

The scheduling of the production process for spring 2012 was amended using Lean Manufacturing concepts. The change was accomplished with four important steps. First, the product was advertised to determine the actual demand. Second, the number of employees that would just satisfy that demand was determined. Third, the list of materials that would just meet the required demand was computed. Fourth, customers were given the option to customize their frames. It was found that the demand per semester for this product was 10 frames (annual demand = 20). Prior to the change, 25 students (employees) were needed to produce 35 diploma frames. After this change of manufacturing protocol, six employees were now needed to produce 10 frames. Thus, the other students, typically 19, could engage in other organizational or manufacturing functions rather than work on producing frames. The new production method reduced the number of processes from fifteen to ten by eliminating those deemed unnecessary, and by doing the following:

- Purchasing finished wood: This eliminated the time needed to inspect the incoming material and reduced the number of production steps, such as planning and sanding the unfinished wood.
- Using product design driven by customer requirements: This was implemented by changing the product design, making it simpler so as to be accomplished with fewer and simpler steps and fewer machines. Customers now had the option to customize their frames by selecting them from a variety of pre-specified designs.
- Changing some production processes: Waste was greatly reduced by modifying some production processes, such as the method of connecting the edges. The joint process was changed from using screws to biscuit connections; this reduced the time needed to make a corner joint from 250.67 sec to 12.9 sec. Table 6 shows a comparison of the time in seconds needed for the main processes for SIMCO in the spring of 2011 (before VSM) and spring of 2012 (after VSM).

Table 6. Time Needed for Each Process Before and After Applying the VSM

Processes Before VSM (Time in Seconds)		Processes After VSM (Time in Seconds)	
Finishing	1252.33	Finishing	1627
Waxing	1246.44	Waxing	57
Miter Cut	978.67	Miter Cut	59.7
Engraving	600	Engraving	765.3
Routing	589.2	Routing	65.1
Dado Cut	94.23	Dado Cut	46.1
Drill Holes	250.67	Biscuit cut	12.9

Table 7. The Production Processes Employed in SIMCO in the Spring of 2012

No	Process
1	Rough Cut
2	Dado Cut
3	Routing
4	45° Cut
5	Biscuit Cut
6	Sanding
7	Thermwood Routing
8	Pre-Stain
9	Stain
10	Assembly

Table 8 illustrates the time in seconds for each of the value added processes for producing 10 frames. The times required for each process are summarized in Figure 5. A flowchart and the time required for each process helped to create the value stream mapping shown in Figure 6.

Three parameters were computed: takt time, process cycle time, and PCE. As mentioned previously regarding assumptions, a production year in SIMCO is the academic year that consists of two semesters and 16 weeks per semester. Table 9 summarizes the results of the calculations. The class was scheduled semi-weekly with two hours per class; however, under the new procedure, the class time available each day was 90 minutes, excluding the time needed for breaks and clean up. Daily demand = 20/64 = 0.3125 piece/day. From Equation (2), takt time = (90×60 sec)/0.3125 = 17,280 sec/piece. From the value stream map, value added time was 2648.3 sec and total process cycle time was 29 days × 90 min × 60 sec (= 156,600 sec). From Equation (1), PCE = 2648.3/156,600 = 1.7 %.

Table 8. Time for Each Process per Second

Process	Time in seconds
Ripping	15.2
Dado Cut	46.1
Routing	65.1
Miter Cut	59.7
Biscuit cut	12.9
Waxing	57
Engraving	765.3
Finishing	1627
Total	2648.3

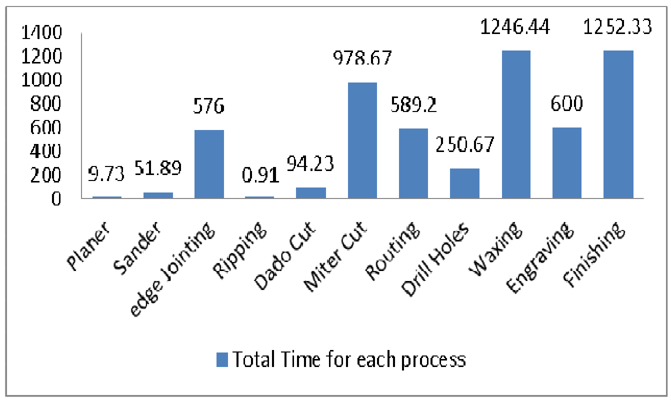

Figure 5. Time Required for Each Process after Applying the VSM

Conclusions

It can be concluded, then, that the new procedure was effective in reducing the takt time from 21,120 sec/piece to 17,280 sec/piece. Also, the process cycle time was reduced from 237,600 sec to 156,600 sec. In addition, non-value added time was reduced from 231,949.93 sec to 153,951.7 sec. Moreover, the new process reduced the budget for producing this product from $609.88 to $273.82. The new process also provided an opportunity for those students not involved in the frame process to engage in different organizational and production activities. Table 10 summarizes the difference between production process for SIMCO in the spring of 2011 and the spring of 2012.

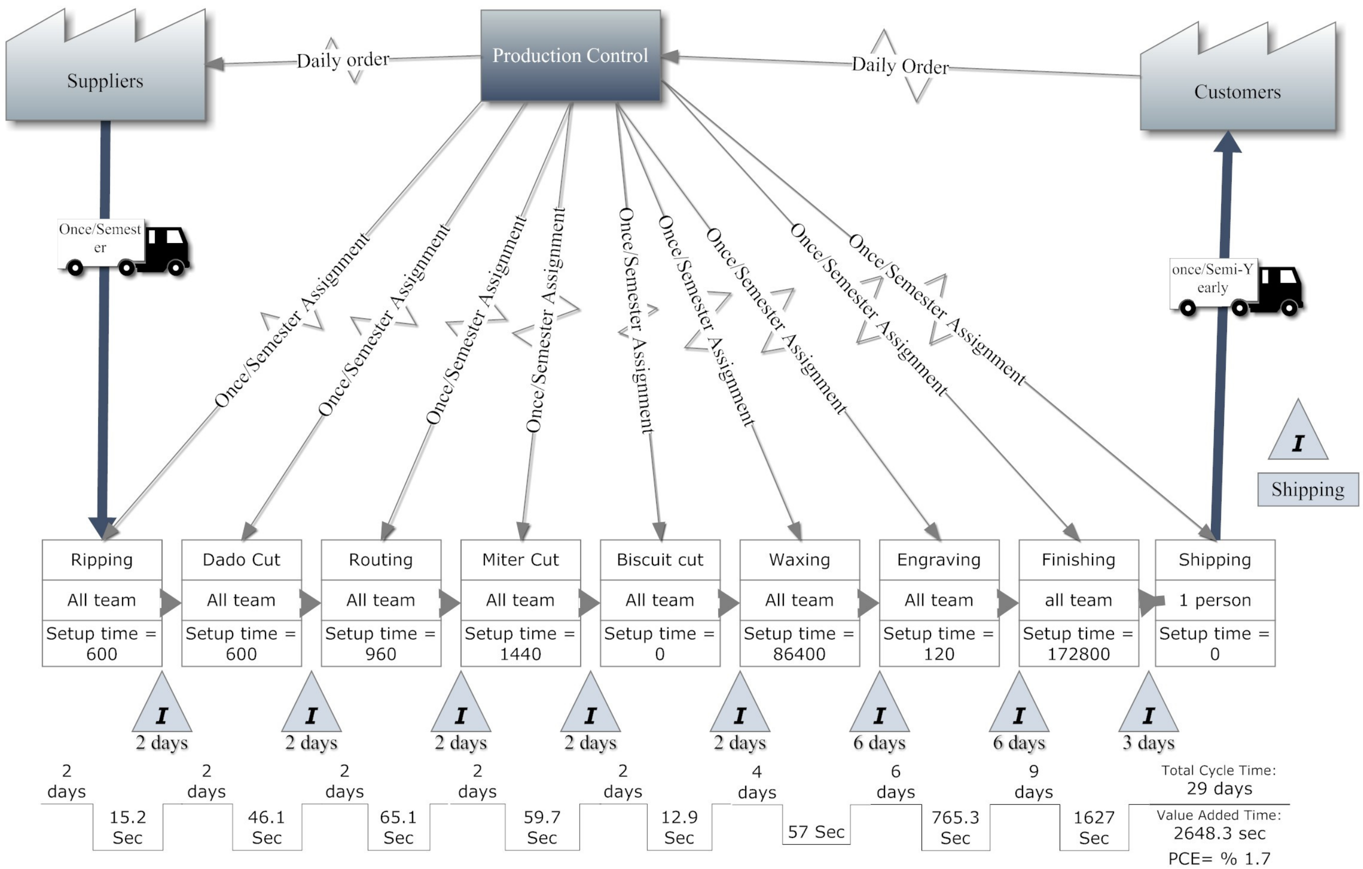

Figure 6. Value-stream Mapping for SIMCO in the Spring of 2012 After Applying the VSM

Table 9. Measurements for Lean Production in SIMCO in the Spring of 2012

Measurement	SP 2011- before VSM	SP 2012- after VSM
Daily demand	0.3125 pieces/day	0.3125 pieces/day
Takt time	21,120 sec/piece	17,280 sec/piece
PCE	2.40%	1.7%
Process cycle time	237,600 sec	156,600 sec
Value added time	5650.07 sec	2648.3 sec
Non-value-added time	231,949.93 sec	153,951.7 sec
budget	$609.88	$273.82
Employees	25 employees	6 employees

It is clear from Table 10 that value stream mapping helped the researchers improve the SIMCO class significantly. Looking at the post-change data, PCE did not improve; however, other parameters such as cycle time, non-valued added time, takt time, budget, and number of required employees to make the diploma frames, all were reduced significantly.

Table 10. Production Measurements Before and After Applying the VSM

Measurement	Result
Daily demand	0.3125 piece/ day
Takt time	17280 sec/piece
PCE	1.7%
Process cycle time	156600 Sec
Value added time	2648.3 Sec
Non-value added time	153951.7 sec

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ENGINEERING MANAGEMENT: UNIVERSITY-INDUSTRY PARTNERSHIPS CREATE BUSINESS-SAVVY SCIENTISTS

Saeed Foroudastan, Middle Tennessee State University; Dianna J. Prince, Middle Tennessee State University

Abstract

National organizations such as the National Academies of Science have warned that there is a strong disconnect between the abilities of the American workforce and the capabilities Americans need to stay competitive in today's world economy. Recommendations to correct this often focus on programs involving science, technology, engineering, and mathematics (STEM) [1]. The Professional Science Master's (PSM) is a nationally recognized interdisciplinary degree program that educates students in the STEM disciplines, while simultaneously introducing them to the basics of business. At Middle Tennessee State University (MTSU), the PSM degree takes the form of the Master of Science in Professional Science (MSPS) degree. The MSPS program was the first of its kind in Tennessee and has been the most successful and expansive program. At its inception, the program housed two concentrations: Biotechnology and Biostatistics. After receiving recognition for its success both locally and nationally, the program expanded to include four additional programs: Actuarial Sciences, Healthcare Informatics, Geosciences, and most recently Engineering Management.

The goal of the Engineering Management (EM) concentration is to create individuals with a mind for business and a heart for engineering. When designing the curricula for the EM concentration, the creators of the syllabi worked closely with local industry partners to ensure that future EM graduates would be prepared for the competitive job market. With the integration of the College of Engineering Technology and the College of Business, students are taught the importance of leadership, management, and engineering skills needed for success in manufacturing, industry, and business. Students are required to take courses that focus on project management, safety planning, research methods, and technology trends. Additionally, at the core of this MSPS degree is a 250-hour internship that enables students to gain real-world experience in an industry setting.

Introduction

According to the Council of Graduate Schools, interdisciplinary studies are crucial to maintain America's competitiveness in an evolving nation. In the 21st century, various issues confronting the nation will be addressed by a workforce comprised of individuals with interdisciplinary skills. Many U.S. graduate schools offer programs in collaboration with industry that will produce the future workforce that America needs in order to stay competitive. Businesses and government will need to collaborate with universities to develop and expand professional master's programs that produce graduates with interdisciplinary skills [1].

In response to changing workplace needs, the Professional Science Masters (PSM) degree is being implemented at various universities and becoming a staple in the graduate school environment. This nationally recognized two-year interdisciplinary degree allows students to pursue advanced training in Science, Technology, Engineering, and Mathematics (STEM), while simultaneously training them in management and workplace skills such as communications, teamwork, financing, and marketing. This interdisciplinary program fills the demands for a workforce that possesses not only technical and scientific training, but also soft skills [2]. The Master of Science of Professional Science (MSPS) degree at Middle Tennessee State University (MTSU) is part of a national movement of PSM programs. When established in 2005, the program housed concentrations in Biotechnology and Biostatistics. Due to its tremendous success, the program expanded the subsequent skills sets available to incoming students to include Actuarial Science, Engineering Management, Geosciences, and Healthcare Informatics.

A major attribute of the MSPS program is a 250-hour internship at a company related to the students' field of study. The internship enables students to put their skills, obtained within the classroom, to the test and gain real-world experience within industry. At the conclusion of the internship, students must prepare a portfolio and give a professional presentation regarding their experiences as an intern. Approximately 75 percent of the students gain employment from the company that hosted their internship. The MSPS program at MTSU has been recognized both at the local and national levels. With retention and graduation rates of 95 percent, it is the fastest growing program at MTSU. In 2010, the program was recognized by the Tennessee Board of Regents (TBR) for its promotion of math and science and received the Academic Excellence Award [3]. In addition, the Council of Graduate Schools uses MTSU's MSPS program as a national model for traditional PSM degrees [4].

Program Created Through Partnerships

Among the many successes of MTSU's MSPS program is the model collaboration of three colleges and over thirty faculty members. The MSPS program was created by a collaboration of the College of Basic and Applied Sciences, the College of Behavioral and Health Sciences, and the Jennings A. Jones College of Business. The interdisciplinary program has been pivotal in the renowned success of MTSU. The success of the program has brought recognition not only to the university, but also to the staff involved in its creation and the state of Tennessee.

When the program's curriculum was created, an advisory board was set up. This advisory board contained members of the academic society and local industry within a 200-mile radius of the university. The board meets to discuss how to form the curriculum in order to meet the needs of both the students and industry. Furthermore, the advisory board still holds meetings once or twice a year to mold and manipulate the current curriculum in order to produce the most viable graduates for the demanding workforce. The scientific and business industries cross paths every day; by educating new graduates on both sides, new partnerships can be formed and better trades can be made. This degree establishes a knowledge base that propels the scientific and business industries into the future. As engineering technology programs advance, the model for industry-based and practical research opportunities for undergraduate students is expanding. The rationale for active collaboration between undergraduate programs and industry is clear. The research opportunities afforded by such relationships help the students to gain real-world experiences, while preparing them for their careers. The partnership is both beneficial to the students and industry leaders [5].

Engineering Management

The most recent addition to the MSPS program is the EM concentration. This degree is also a new program in terms of the PSM. The MSPS Engineering Management concentration was developed in order to meet the demand for professional leaders in manufacturing. In this degree, students learn the interpersonal, management, and engineering skills that are required for success in manufacturing, industry, and business. When EM was introduced as a concentration in the MSPS degree, the hope was to continue the renowned success of similar programs at universities such as Duke University, George Washington University, Cornell, and many others. The creators of the curriculum took into account the need of industry and then partnered with local industry to design a curriculum that was strong in both science and business. The resulting curriculum requires students to take courses that focus on project management, safety planning, research methods, and technology trends; as a part of the business core, students are taught valuable business skills through courses such as Probabilistic and Statistical Reasoning, Accounting and Legal Perspectives for Managers, Leadership and Motivation, and Managerial Communication.

In addition to gaining advanced training in science and business, students gain certifications as a result of taking certain concentration courses. A Green Belt certification is awarded to students after completion of a business/industry Green Belt project. Through the Green Belt project, students gain hands-on experience in a company or business. With business becoming increasingly complex, the demand for executives, managers, and other professionals having the skills to eliminate waste, reduce defects, shrink inventory, and make other critical business process improvements has increased dramatically. Individuals obtaining a Six Sigma certification are a very attractive asset to companies seeking employees.

An additional certification gained through the EM coursework is in lean manufacturing. Having this certification benefits both the student and his or her future employers. Lean certification is becoming a prerequisite for employees and organizations. With a Lean Manufacturing Certificate, future employees are able to help companies develop lean standards, learn techniques for improving processes and develop abilities that are highly portable and internationally recognized. By having this certification, the student's career prospects and earning potential are enhanced. The MSPS Engineering Management degree prepares students for future careers in the management of technology and engineering in such diverse occupations as technology managers for manufacturing operations, healthcare, food production, governmental research initiatives, etc. The interdisciplinary coursework that this two-year degree provides prepares students for high-pressure, high-paying jobs, while simultaneously teaching them the skills they need to manage others and manage a job site.

To conclude the intensive course work laid out for the Engineering Management students, they must complete a 250-hour internship. The internship is designed to replace the thesis work required of other master's programs. During the internship, the students have the chance to gain highly valued industry experience. They also get the chance to engage in comprehensive research projects that prepare them for the complex issues that arise in the workplace. Students have completed their internships at companies such as Tennessee Valley Authority (TVA), Nissan, and Asurion. These students were either promoted or received employment at another company immediately upon graduation.

Conclusion

As the worlds of science and business merge, the workforce will need a new type of scientist in order to maintain America's competitive edge in an ever-changing world economy. The key to attaining this new breed of scientist is through the creation of interdisciplinary programs such as Middle Tennessee State University's Master of Science in Professional Science program. The MSPS program at MTSU provides students with advanced scientific training in Biostatistics, Biotechnology, Geosciences, Healthcare Informatics, Actuarial Sciences, and Engineering Management, while simultaneously introducing them to the fundamentals of business. The program's goal is to produce graduates that have the ability to serve in dual capacities within the same job, which is greatly beneficial for career placement.

Graduates of the MSPS Engineering Management program are highly capable and able to fill the wide gap between science and business. These individuals will be able to create, innovate, and problem solve, while at the same time coordinating and communicating fluidly with upper-level business personnel. More importantly, the MSPS program at MTSU addresses the current national need for a workforce with more masters-level graduates that are highly skilled and well-educated in the Science, Technology, Engineering, and Mathematics (STEM) disciplines. The MSPS program at MTSU serves as the national model of PSM programs because it is not only the fastest growing program at MTSU, but also the fastest growing PSM program in the nation.

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Biographies

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UNDERGRADUATE RESEARCH SCHOLAR: THE FIRST STEP TOWARDS A HYBRID LECTURE-BASED AND INQUIRY/RESEARCH-BASED ENGINEERING PROGRAM

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Abstract

With the accelerating changes in technology, self-directed learning is becoming an important skill for the next generation of engineers. Accreditation agencies such as ABET have recognized the importance of continuous learning/improvement and allocated a student learning outcome to assess lifelong learning skills. Undergraduate research has been proven to help develop and improve lifelong learning among engineering students. In this paper, the authors present a novel approach to integrate research into a lecture-based curriculum through summer workshops, research-designated courses, and undergraduate research grants. This approach was thought to be the first step towards implementing a hybrid lecture-based and inquiry/research-based undergraduate engineering program. This could be achieved by instituting a series of undergraduate research workshops during the summer to better prepare students for conducting research.

Moreover, an undergraduate course was developed to provide students with the opportunity to engage in supervised research activities. Upon completion of this program, students were granted "Undergraduate Research Scholar" status on their transcripts or diplomas, as recognition for participation in undergraduate research. Finally, a set of surveys to identify the students' learning style and their willingness to engage in undergraduate research is presented and discussed in this paper.

Introduction

In the late 1970s, the Council of Undergraduate Research was founded by a small group of faculty to help promote research among undergraduate students [1]. Due to the growing interest and subsequent support of funding agencies such as the National Science Foundation (NSF), undergraduate research programs have witnessed an exponential growth across the U.S. However, one of the main obstacles limiting undergraduate research is the conventional lecture-based teaching style used by the majority of engineering programs. Other limiting factors include the absence of incentives and student lack of prior understanding of research methodologies [2].

Based on the Felder and Silverman index of learning styles [3], the human natural learning style is mainly inductive. Inductive learning occurs by drawing inference of generalized conclusions from particular instances through inquiry, observation, and data measurement. For instance, inquiry/research-based learning, problem-based learning, and project-based learning are all considered to be inductive learning methodologies. Unfortunately, the traditional teaching style is focused on lecture-based learning, which is mainly deductive learning. Deductive learning is implemented by introducing new concepts and explaining how they can be used to solve real problems. Therefore, deductive learning is a teacher-centric approach, while inductive learning is student-centric and requires an inquiry-based learning environment. In the last decade, student learning styles have witnessed a drastic shift towards inductive learning, especially with the advancement of interactive gadgets and applications. However, inductive learning methods alone are not sufficient to achieve a highly effective teaching model. Therefore, the co-existence of both inductive and deductive learning methods is essential.

In this study, a set of surveys was conducted in order to identify the students' learning style, the students' favorable teaching style, and the students' willingness to be involved in undergraduate research. Based on these surveys, a hybrid lecture-based and research-based undergraduate engineering program was proposed as an undergraduate research scholar model (URS). It was argued that this URS model would bridge the gap by integrating undergraduate research into a lecture-based curriculum through summer workshops, research-designated courses, and undergraduate research grants. Furthermore, a model for an undergraduate research office was also proposed to help facilitate research and oversee its integration into the curriculum. Upon the completion of a certain number of undergraduate research credit hours and the dissemination of findings, the students were granted Undergraduate Research Scholar status on their transcripts or diplomas, as a recognition of their research efforts.

Student Learning Styles

Student learning styles are models that utilize different measures to help identify the best teaching methods to accommodate different learning styles. Over the past few decades, many models for learning styles were developed, such as the Myers-Briggs Type Indicator, Kolb Model, Felder-Silverman Model, and others. Felder [3] in a later revision of his work entitled “Learning and Teaching Styles in Engineering Education”, omitted the deductive/inductive dimension from his model. As a justification, Felder indicated that the majority of students, especially at the undergraduate level, favored the deductive learning style despite the fact that the inductive approach was more effective. These results were used by faculty as a reason to resist employing inductive methods, since deductive learning presented a well-defined recipe for students to succeed, unlike the inductive learning style, which required more effort [3].

In this current study, the Felder-Soloman index of learning styles (ILS) survey was used to illustrate the student learning style profile. In the Felder-Silverman model, there are four scales for learning aptitude, which are defined as: 1) Active/Reflective learners; 2) Sensing/Intuitive learners; 3) Visual/Verbal learners; and, 4) Sequential/Global Learners [4]. Since the deductive/inductive dimension was omitted from this model, a few questions were added to check the students’ ability to use inquiry/research-based learning techniques. The outcomes of this study were found to be consistent with Felder’s findings. The profile of the students’ learning styles obtained from the ILS survey is presented in Figure 1.

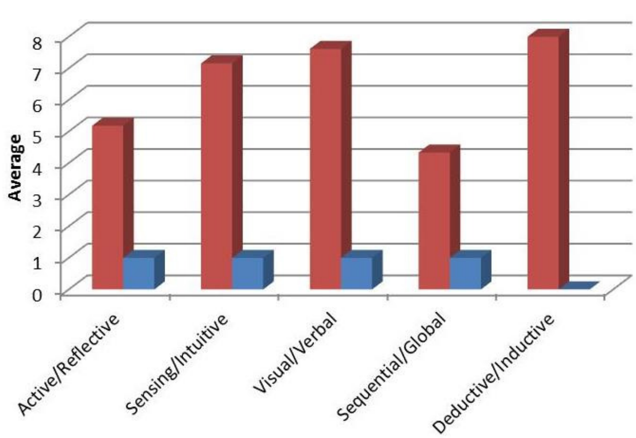

Figure 1. Student Learning Style Profile

As expected, the undergraduate students’ learning style profile (see Figure 1) predominantly favored the active, sensing, visual, sequential, and deductive scales. Despite the fact that the students favored the deductive learning style, the inductive learning style was proven to be instrumental in the success of undergraduate students [3], [5]. Therefore, an enhanced teaching process that integrates undergraduate research is needed to better prepare students for tackling the complex, multi-faced technical challenges of the 21st century [6].

To help trigger an institutional cultural change, a top-down approach was proposed to promote undergraduate research among students and faculty. This change can be greatly facilitated by the establishment of an office of undergraduate research having an objective to integrate undergraduate research into the curriculum as the first-step in achieving a hybrid lecture-based/inquiry-based engineering program. The curriculum design shown in Table 1 is divided into four categories in order to emphasize the interrelated research and teaching-learning process [7], [8].

Table 1. Classification of Undergraduate Research Curriculum

	Emphasis on Research Content	Emphasis on Research Processes
Student-focused (students as participants)	Research-tutored (engaging students in research discussion)	Research-based (engaging students in research to become researchers)
Teacher-focused (students as audience)	Research-led (teach students about research)	Research-oriented (develop the students’ research skills and techniques)

In the following URS model, a balanced approach for incorporating undergraduate research within the curriculum is presented as follows:

1. The research-led process is integrated through course instructions and relating topics to current research activities.
2. The research-tutored process is integrated through course projects involving paper reviews and presentations pertaining to contemporary research topics.
3. The research-oriented process is integrated through the offering of a series of workshops to help students acquire new research skills and methodologies.
4. The research-based process is integrated through the introduction of an undergraduate research course within the curriculum.

Undergraduate Research Model

In an effort to adopt the best practices for undergraduate research, several institutions were visited including the University of Central Florida, the University of Florida, the University of North Carolina at Greensboro, and the University of South Carolina. The work conducted in this study was based on the best practices for establishing, running,

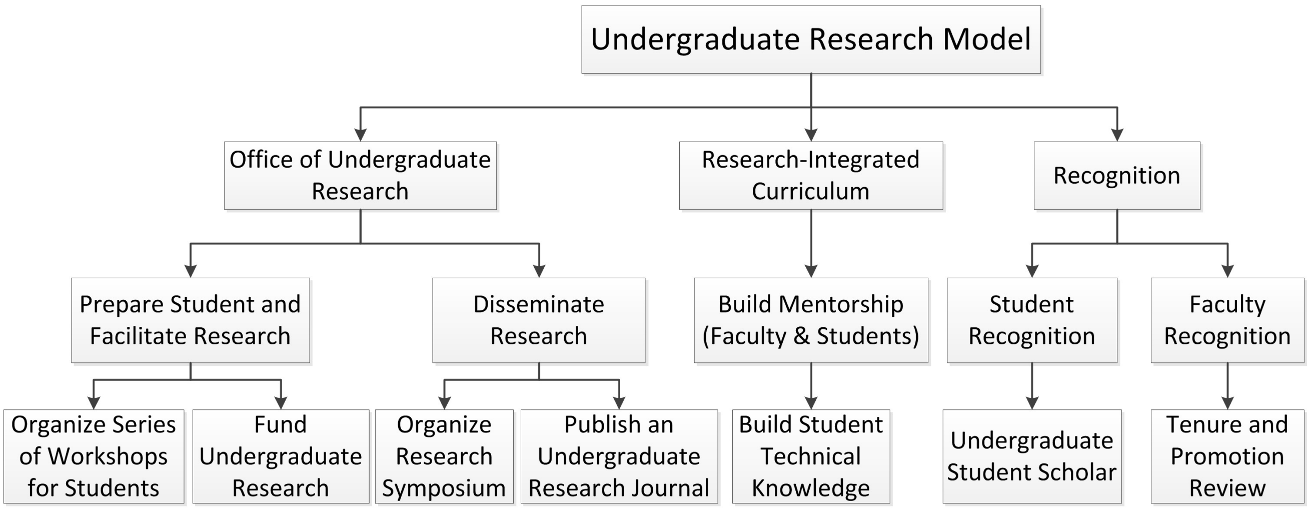

Figure 2. Proposed Undergraduate Research Model

and promoting undergraduate research programs at those institutions. As a result, the proposed URS model was devised as illustrated in Figure 2.

As speculated, the framework for any effective undergraduate research engineering program must encompass the following components:

1. Creating an office of undergraduate research staffed by a dedicated full-time Director and an Administrative Assistant with support of an Advisory Committee. The Director should report to the Associate Dean of Research. The primary benefits of establishing an Office of Undergraduate Research are to:
   a. Increase awareness of undergraduate research and highlight its effectiveness in the learning process;
   b. Help attract external funding to support and enhance undergraduate research in the college and throughout the university;
   c. Coordinate efforts between academic and administrative units to maximize the success of the undergraduate research program; and,
   d. Help the university to become a leader in developing and conducting cutting-edge research.
2. Integrating undergraduate research into the curriculum through research-designated courses such as the proposed UREH 4999 course with 0-3 credit hours. The primary objectives are to:
   a. Increase the likelihood that high-achieving students will look at this opportunity as a culmination experience and decide to stay and pursue graduate studies rather than transferring to other institutions;
   b. Accurately track the number of students actively engaged in undergraduate research and provide statistics to the Vice President for Research and Economic Development;
   c. Establish a minimum set of expectations for faculty advisors and students (as suggested by UREH 4999 course syllabus) in order to ensure a consistent research experience; and,
   d. Reward participating undergraduate students by recognizing their status as Undergraduate Research Scholar on their transcripts or diplomas.
3. Promoting undergraduate research through funding and scholarships with a minimum of 100 awards per college at a maximum of $2,500 per award. The student stipend should not exceed $750 and the faculty stipend should not exceed $250. The remainder of the award ($1,250) should be allocated to other research-related expenses. The student stipend should be divided into two equal payments at the beginning and the completion of the project. All funded research projects must be presented at the annual undergraduate research symposium. Funding for the undergraduate research programs should be allocated to the colleges as part of the budget from the Office of Undergraduate Research. While applying for funding is optional, students with financial aid would still be eligible to use the funds to purchase equipment and supplies. This could be indicated in the funding application budget. In such a case, funding would be mainly allocated for purchasing equipment and supplies.
4. Developing a series of undergraduate research workshops during the summer to prepare students for research. As an incentive, each student would earn one

research credit hour at no cost for attending these workshops. Workshop attendance is required for students receiving undergraduate research funds.

5. Using undergraduate research towards tenure and promotion as an incentive for faculty in addition to receiving an honorarium ($250) for any research project successfully completed. Faculty participating in undergraduate research would also help identify prospect graduate students. The Office of Undergraduate Research would regularly recruit faculty to join as affiliate faculty and maintain a database of all participants.
6. Organizing an annual undergraduate research symposium to present and highlight the achievements made by the students engaged in these research activities.
7. Creating a venue such as an Undergraduate Research Journal in which students could publish their results.
8. Forming a regional Council for Undergraduate Research (CUR) in collaboration with other higher education institutions in the region.
9. Organizing and hosting statewide/national conferences to promote undergraduate research.

Office of Undergraduate Research Duties

The Office of Undergraduate Research plays an integral part in the success of any undergraduate research program since it would help:

1. increase the number of students participating in undergraduate research;
2. reduce the number of students transferring to other graduate institutions;
3. improve student retention, progression, and graduation rates (RPG);
4. provide a platform for students to apply lessons learned in the classroom;
5. develop mentorships between students and faculty advisors;
6. provide experience to help students succeed in their professional careers; and,
7. increase the likelihood that students will enroll in graduate programs.

The duties of the prospective director include:

1. promoting undergraduate research among faculty and students;
2. recruiting students to participate in undergraduate research;
3. serving as coordinator for the undergraduate research course;
4. developing a marketing plan for undergraduate research;
5. organizing research-related workshops, seminars, and symposiums;
6. facilitating the process of pursuing research opportunities;
7. managing internal/external research funding and undergraduate research grants;
8. keeping track of all students and faculty engaged in undergraduate research including previous and current research activities;
9. developing an assessment plan to evaluate the student research outcomes and report the results to the Vice President for Research and Economic Development;
10. representing the Office of Undergraduate Research at university and community levels; and,
11. organizing all related activities including the undergraduate research symposium/conferences.

Research-integrated Curricula

At the curricular level, the main objective of the proposed UREH 4999 Undergraduate Research course was to provide students with an opportunity to get involved in supervised research activities. The course was designed to have a group of students performing a research project and assisting in the dissemination of the research findings. Depending on the research topics, project types may include but not be limited to inquiry, design, investigation, scholarship, discovery, or application. A set of expectations was developed and agreed upon by each research group. Students were held responsible for certain tasks within the research projects to create a multidisciplinary experience within the groups. Each student usually assisted a faculty member with a research project by preparing the study and contributing in a meaningful way so as to meet the objectives of the study. The student also worked with a graduate assistant under the supervision of the research faculty member.

It should be noted that integrating this URS model is simple if the engineering program is new or under development. However, if the program is well established, it may be difficult to modify existing curricula. In such a case, it would be advisable to complement or substitute elective courses with the research-designated courses or even apply research credits towards future graduate degrees.

Enrollment and Course Credits

To recognize research activities, credit hours were awarded depending on the nature of the research and student involvement in the research activities. Credit hours earned varied between zero and three hours per semester. Any student interested in pursuing undergraduate research had to receive prior approval from a faculty advisor. The student and the faculty advisor had to agree on the topic and the set of expectations for the intended research project. The student then submitted an application signed by both the student and the faculty mentor. All students engaged in research had to enroll in UREH 4999, with the section number specific to the faculty advisor's department. If a student was pursuing research under the supervision of a faculty mentor from a different department or college, the student had to obtain approval from his/her home advising center. To increase student success rate, participation in undergraduate research activities was made optional. Based on the survey data collected from different institutions, it was observed that student participation in undergraduate research programs accounted for only 2-5 percent of the student population.

Course Prerequisites

While no prerequisites were listed for this course, the research faculty advisor had the right to set the appropriate prerequisites, depending on student preparation and the complexity of the research project. However, it was understood that students taking this course would have already completed the basic math and science courses required in a typical engineering program.

Course Website

To provide information and maximum visibility, the Office of Undergraduate Research hosted the course website for all students enrolled in undergraduate research. This website housed information related to safety, research methodologies, ethics in research, best practices in recording and keeping data, etc.

Course Objectives

After completion of the course, the student will be able to:

- Conduct a literature review and perform a research inquiry.
- Effectively use equipment in the laboratory to perform experiments.
- Properly keep an accurate record of research performed.
- Formulate a research problem and develop a research methodology.
- Write a professional technical report.
- Exhibit professional and ethically accepted standards while conducting research activities.
- Accurately present and communicate research results to technical/non-technical audiences.

Assessment of Research Activities

For assessment purposes, a grading rubric was developed, as shown in Table 2:

Table 2. Undergraduate Research Assessment Rubric

Grading	Performance Criteria*
50%	Meeting preset research expectations (determined by the faculty)
20%	Significance of the student's contribution
10%	Final report/publication
10%	Final presentation
10%	Work ethics, diligence, and collegiality

*This grading rubric is subject to change.

The following are the minimum expectations:

1. Perform a thorough literature review.
2. Define the research statement.
3. Develop a research plan.
4. Perform experimental work (simulation/applied).
5. Write and present a technical report.
6. Publish research results in at least one venue.

No letter grade was assigned in this course. The final grade was either satisfactory (**S**) or unsatisfactory (**U**). A grade of **S** was given if the grading rubric reflected 70% of the total points or better, otherwise a grade of unsatisfactory (**U**) was given. Upon graduation, if the student has earned at least six credits of undergraduate research, he/she would be granted Undergraduate Research Scholar status as recognition for participating in undergraduate research.

Conclusions

In this paper, the authors presented an undergraduate research model that provided students with integrated research experience needed to succeed as engineers in the 21st century. The proposed model consisted of three main tenets: establishing an Office of Undergraduate Research, developing a research-integrated curriculum, and instituting a recognition system as an incentive to encourage participation. A systematic approach to integrate research through summer workshops, research-designated courses, and undergraduate research grants was developed based on a review of best practices at peer institutions through student surveys. Results showed that inductive and deductive learning styles are best served in a hybrid lecture-research-based model in which students can voluntarily participate. Finally, the offering of a research course entitled UREH 4999 Undergraduate Research was an integral component of this proposed undergraduate research model.

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LEVERAGING NEXT-GENERATION VIRTUALIZATION TECHNOLOGIES FOR ADVANCED MALWARE ANALYSIS IN THE CLASSROOM

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Abstract

Malicious software (malware) represents an ever-increasing threat to our technological lives. In the last decade, the proliferation of malware on traditional computing devices has expanded to include mobile platforms and embedded technologies. The development and use of malware is no longer limited to computer scientists and hackers; it is now becoming an integral operational capability of militaries and governments worldwide. Recalling that in 2003 a primitive MS-SQL worm resulted in the shutdown of a nuclear plant, the threats faced today and in the near future are alarming. In 2013, it was estimated that the business cost of malware exceeded $114 billion.

Technology, computing, and engineering students of multiple disciplines can be better prepared to deal with malware risks by a comprehensive study of malware. Traditional pedagogical methods typically involve isolating computers and/or networks to enable students to learn without posing a risk to connected networks. While this method does provide a relatively safe environment, modern malware is frequently dependent on a complete network connection, and isolation is no longer representative of current best practices in malware analysis.

In this project, the authors developed a new course in malware analysis that uses innovative methods of infrastructure-as-a-service (IaaS) and network-as-a-service (NaaS) technologies to enhance student learning in an instructor-controllable and inherently safe environment. In this paper, the authors show how these approaches can be leveraged to allow a variety of dynamic and static analysis techniques to be optimized this approach for a typical classroom schedule. Also demonstrated in detail is how this solution can be implemented on a limited budget using low-cost surplus hardware. In conclusion, this implementation is contrasted with traditional approaches and its benefits and limitations are discussed.

Introduction

There is some debate over the precise timing, author, and indeed definition of the first computer virus; however, most will agree that the first one discovered in the wild, and utilizing removable media, was "Elk Cloner," written by Rich Skrenta in February of 1982 at the age of 15. The virus was able to self-replicate using the boot sector of floppy drives and consisted of a payload that, on occasion, displayed messages during the system boot process. In stark contrast, a recent report by McAfee shows almost 12 million new virus samples were discovered in Q4 2012 with over three million utilizing illegitimate public key certificates to pass as an authentic application [1]. Malware payloads today target the confidentiality, integrity, and/or availability of both services and information for a variety of end-goals that include the acquisition of intellectual property and extortion of ransom payments for user data.

As society becomes more dependent on technology in every aspect of life, criminals have a target that is becoming increasingly easier to attack. A modern cyber-criminal can use computer programs, with relative anonymity and ease, to conduct cyber-crime on an immense scale with an extremely low risk-versus-reward outcome; yet, as our technological lives continue to evolve, there is no sign that these risks will do anything except continue to grow. It is in the face of these alarming trends that the authors present the following approach for advanced malware analysis and propose a wider uptake of the topic by computing disciplines [2]. Although this paper focuses on malware education within the information technology discipline [2], the authors believe that other disciplines can benefit from, and should consider incorporating, some of these ideas within a dynamic learning environment.

Prerequisite Knowledge

The foundation and strategy for this current approach are rooted within the ABET Information Technology (IT) Model Curriculum [3]. While this is certainly not the only domain within which malware analysis may be located, it does provide some unique advantages when compared with traditional computer science programs. As an applied discipline, IT suggests a holistic approach to computing technology and does so from an applied perspective; these naturally lead to a systems engineering-aligned model [4]. Systems engineering is a natural approach for IT students and provides an excellent baseline for malware analysis.

The pillars of an IT education include programming, networking, human-computer interaction, databases, and Web systems [3]. Each component pillar is connected by a common foundation and a pervasive security theme. Before a strong understanding of malware analysis can occur, students must possess knowledge of certain foundational topics and be skilled in their application. These include an understanding of user and kernel operating system modes, the C compiler process, familiarity with instruction sets, registers, opcodes and their notation, and a solid understanding of networks with experience in OSI layer 2 and 3 configuration. Knowledge of a scripting language such as Python or Ruby is also advantageous.

Learning Outcomes

The focus of this course is to understand the malware process through the stages of creation, infection, operation, discovery, analysis, mitigation, and remediation. Table 1 lists the course learning outcomes.

Table 1. Learning Outcomes

1	Analyze a computing system in an unknown state and determine the state of malware infection.
2	Employ dynamic and static analysis techniques to determine the characteristics of suspected malware.
3	Identify, analyze, and classify various types of malware.
4	Derive effective strategies for mitigating the impact of malware and be able to evaluate their relative strengths and shortcomings.
5	Analyze vulnerabilities that may give rise to malware infection and be able to apply countermeasures to prevent infection.
6	Understand a variety of techniques used by malware to self-conceal or hide from analysis.

Instructor Objectives and Rationale

One of the challenges of many computing-based disciplines is maintaining relevancy with current technology. It is the nature of the domain that rapid obsolescence is a way of life. And while the persistence of methodologies allows for a form of academic continuity, this is, at times, challenged by the rapid rate at which technology evolves. Hence, in the development of any course with envisaged longevity, particular care should be taken to minimize the course-maintenance overhead. When discussing the topic of malware analysis, the issue becomes even more problematic. Unlike topics such as networking or operating systems in which significant evolution is often seen in intervals ranging from a few years to a decade, the rate of malware evolution may be measured in months to a year. Indeed, simply understanding the scope of the malware problem may be problematic, as shown by the discovery of the Flame virus in 2012; in this specific case, researchers discovered evidence suggesting that the malware had been operating completely undetected for over five years [5].

One technology in particular that has proven useful in malware analysis is virtualization [6]. The ability to effectively "sandbox" an operating system within another allows analysts to examine malware with relative safety from accidental infection. In more advanced cases, multiple operating systems may be virtualized simultaneously on a host, while also providing isolated networking capabilities. The advantages offered by these approaches are significant: analysts have the ability to revert to previous known states at any time; emulate network and communications protocols; easily attach kernel-level debuggers; and, perform forensic file-system analysis and compare system states, to name but a few [7]. While these techniques have proven effective for experienced analysts, they still present a significant overhead in a classroom of several students. Experience has shown that even with the best of instructions, well-intended students may be careless in their execution. For example, in a closely related penetration testing course, mistakes such as inadvertently connecting to a wireless network and performing scans have been known to happen. While steps are taken to minimize the occurrence and severity of such errors, malware can present an even greater danger to connected networks.

Summary objectives may be derived as follows:

1. Students must have complete access to all levels of the operating system.
2. Students must be able to create virtual networks.
3. Instructors must be able to minimize the probability of malware leakage onto adjacent networks.
4. The system should not cause security events outside of the lab environment (e.g., IDS alerts).
5. The system must provide a low-maintenance sandbox environment that can be rapidly updated and swiftly cater to new malware variants.

The following are methods that have been previously attempted and include any associated limitations:

Physical/Logical Isolation: Physically isolating the lab by removing the uplink connection or by logically isolating the lab VLAN has succeeded in protecting infrastructure from directly attached systems but often results in frustration, given the inability to access online resources. Many students prefer to undertake labs on their own equipment, which often results in user-owned devices being simultaneously connected to the lab and campus wireless networks. This circumvents the isolation and re-introduces the risk of accidental malware propagation.

Lab Filtering: An attempt was made to place a firewall between the lab and outside network. However, it was found that this took significant effort to maintain and would often result in disruption to other courses sharing the same lab space. The issue of students using their own equipment and creating bridges to wireless networks remained a risk.

Dedicated Hypervisors: Perhaps the most secure solution that prevents the network bridging issue is to run virtual machines on equipment owned and managed by the department. Unfortunately, this introduces a new risk by moving the threat directly onto one of the systems requiring protection. Even if dedicated hardware is used, this solution still presents risks of the inadvertent spreading of malware through the network. It should be noted, however, that for classroom instruction, this approach has a significant advantage in its ability to provide a constant, uniform environment that is well-suited to a classroom environment. All students should see the exact same information in a debug window, as the hardware, OS, and patch levels are consistent.

The Solution: Software Defined Networks

A recent "cloud" hot-topic is network virtualization. The concept of network virtualization, more commonly known as software defined networks (SDNs), is similar to that of platform virtualization in that it allows the abstraction of configuration from hardware. More specifically, SDNs allow the rapid creation of networks and their association with virtualized operating systems [8] by adding a network control layer as a software-based management component. SDNs in general represent a relatively new approach to networking and, in contrast to server virtualization, are still viewed as immature. However, the use of SDNs is growing rapidly and virtualization vendors such as VMWare, Citrix, Oracle, and Microsoft are implementing SDN capabilities into their commercial products. SDNs bring significant benefits to an educational environment and seem particularly well-suited to handling learning activities that can pose security risks to their surrounding environment.

Using SDNs allows an instructor to maintain complete control of a student's network connections on a virtual PC. In this scenario, virtualized computers are hosted on a department-owned hypervisor with students being provided virtual console access to the system. SDN allows the creation of logically isolated network segments with highly controllable access to the outside world without impeding lab connectivity. It also facilitates the capture of network traffic at a single one-to-many point, as opposed to workstation deployments that require local capture for each student.

Requirements

Vendor-supported SDN is a relatively new feature of systems such as Cisco Unified Computing Solution (UCS) and vCenter Cloud Director. These systems tend to be too expensive for many programs. The authors implemented their solution on a variety of hardware types and found it to be feasible on any platform that is capable of running a modern hypervisor such as Hyper-V or VMWare ESXi. In the current deployment, the system used six HP-BL460-G1 servers equipped with dual Xeon 4-Core CPUs with 32-GB RAM each. These were connected to a Synology DS1610+ NAS system, providing shared storage using the iSCSI protocol. These servers will comfortably support up to 30 students at an acceptable performance level with each student using 1 VM.

Architecture

The system's architecture consists of three elements or control planes, each of which must be managed in coordination with the others: the hypervisor, SDN layer, and egress/ingress. The term "infection zone" will be used to describe the malware analysis hosts and infrastructure.

The initial intent for the hypervisor was to employ VMWare vCenter 5.5 to manage ESXi installations on the physical hardware. VMWare is probably the best known virtualization platform and benefits from extensive support. Unfortunately, during testing, these were issues with academic licensing restrictions that prevented the creation of a usable operational environment, despite being successful in prototype designs. This led the authors to investigate different offerings that may provide a similar capability and culminated in a selection of Microsoft Virtual Machine Manager (VMM) 2012R2 with HyperV 2012R2 for several reasons. During analysis, it was discovered that the out-of-the-box VMM feature set was much more comprehensive without requiring advanced licensing options. This became advantageous, given that the school's MSDNAA agreement covers the use of all Microsoft System Center products and does not limit use within educational infrastructure. Effectively, this set at zero the software costs for hypervisors and their management. It should be noted, however, that the initial configuration of the VMM was a much more complicated affair than vCenter.

The objective of the SDN layer is to rapidly deploy dynamic LAN segments and connect them securely to the IT network, while providing isolation for malware. This requires a centralized model for configuring a variety of network equipment including:

- Blade switches (Cisco 3020 HP)
- Router (FastIron Edge X448-Prem)
- HyperVisor networking (vDS Switch or HNV SDN)

The proposed solution uses VLANs to provide layer 2 separation in combination with the Ingress/Egress plane in order to provide controllable routing and deep packet analysis capabilities. A range of unused VLANs and subnets was defined within the IP space that could be rapidly set up and torn down by PowerShell and Python scripts; a DHCP server was then configured to allocate addresses within each range, as these networks were created. SDN provisioning was achieved by a Web front-end that provides instructors with complete control using simple mouse action provisions, move, and/or tear down an entire live network range in real-time.

Perhaps the most critical part of the system is the connection point to the rest of the department's network. It should be noted that this program already exists on a separate IP range from the rest of campus, thus inherently affording other departments a level of protection. The system was prototyped using a simple IPTables firewall running on Debian 7.1. However, a simpler implementation was found in pfSense, an open-source firewall appliance that offers several advanced features. Of particular interest in the pfSense appliance is the ability to perform Web proxying and SSL inspection to decrypt encrypted traffic. The latter requires the addition of a trusted root certification authority on each client. This was implemented as part of the virtual machine template; a Bluecoat Security Analytics Platform (formerly Solera Deepsee) virtual appliance was connected to a mirrored traffic port in order to record all network traffic attempts from the infection zone. The use of the analytics platform in this way provides real-time deep packet logging and analysis capabilities to students.

To minimize alerts from campus intrusion detection devices, the campus IP address of the infection zone egress/ingress was known and provided to campus IT services.

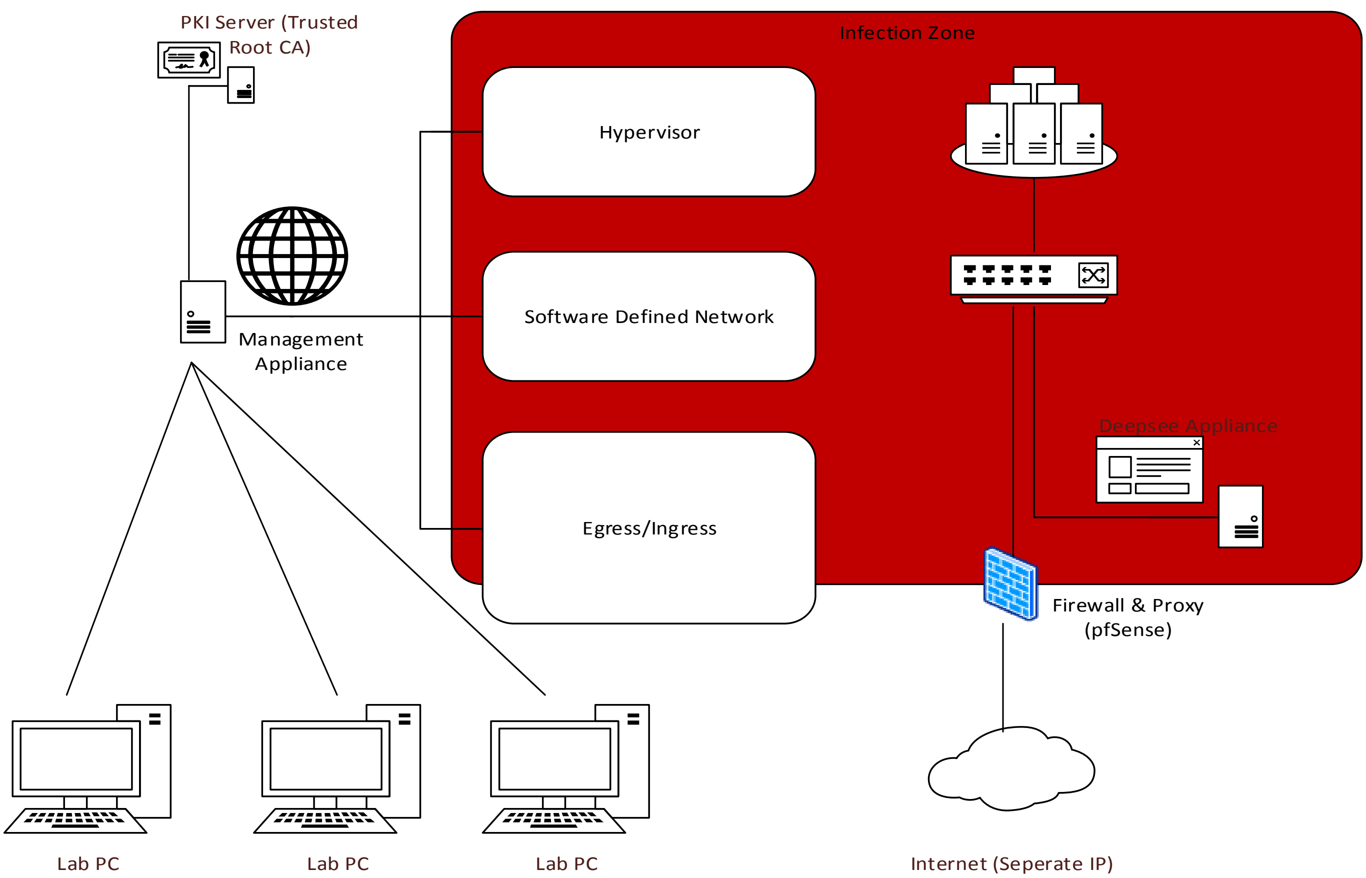

Figure 1. System Architecture

This allowed for casual monitoring of activity without creating panic every time a sample sent traffic across the network. The principal advantage of the SDN approach is the ease with which a classroom virtualized network may be connected to, or isolated from, the physical network. The instructor may, using simple scripts, connect an SDN VLAN to the physical network, allowing students to download tools, scripts, and perform updates. Firewall configuration scripts that limit access to HTTP/HTTPS traffic only to known sites, offer full HTTP/HTTPS to any site, or offer unhindered external access to all services was employed. Once a student is ready, the malware sample is made available and the SDN disconnected from the physical world and instead connected to a catch-all DNS service and network traffic monitoring devices. Thus, during the analysis, the student-managed virtual environment has no network traffic route to a physical network. Students are able to manage their environment by a console connection to the hypervisor.

Care must be taken in this approach to ensure that the hypervisor is regularly patched in order to avoid any traversal of malware from the guest environment to the host physical system. The authors believe that this is an acceptable risk and are aware of no malware currently available that is capable of attacking a Microsoft HyperV host from within a virtual machine. A benefit of this arrangement is that students may safely access and manage the infected virtual machine from any lab system within the department network, their own personal laptops, or a home PC connected via a VPN. This greatly increases the valuable out-of-class time that students can spend analyzing malware. This approach was found to be naturally supportive of malware research projects.

Systems Management

The management appliance is under development and acts as a provisioning and management portal that allows a simple drag-and-drop-style arrangement of network segments, virtual machines, and firewall configurations. All management is performed out-of-band using separate network interfaces on each server and/or network device. An instructor will be able to manage a library containing VM templates of standardized configurations and deploy en masse as required for class exercises or laboratory assignments. Deployed VMs must be assigned to a VLAN and IP subnet, which are taken from a pool of available containers. The container is dragged to the main window and a template placed within it. The instructor may then specify how many VMs to create and either assign a pre-defined firewall template, manually configure firewall settings, or disconnect the SDN from the physical network. After deployment, students may connect to the management consoles of provisioned virtual machines. This provides an additional layer of protection to lab PCs by providing distinct data paths for infection zone traffic and infection zone management. Students are also provided access to the Security Analytics Platform instance and firewall logs to examine traffic flow and perform network forensics.

Configuration and Evaluation

At the time of writing, the system has been through multiple levels of testing and design ratification and is now in the final integration stages. Backend management scripts and architectural testing have been completed, and the management appliance is near completion. The authors intend to conduct large-scale testing in the fall of 2014 with the system ready to support a new malware analysis course in the winter of 2015.

One of the advantages of the VM-library and SDN approach is its ability to remain up-to-date and analyze new samples on an ongoing basis without jeopardizing network security. Currently, the library includes pre-configured virtual machine templates for all major Windows versions between Windows 95 and Windows 8.1, including both 32-bit and 64-bit editions and server counterparts, where appropriate. Additionally, there are images for a variety of Linux and OSX-based systems over a 10-year timespan. Unfortunately, due to licensing restrictions, the OSX VMs may only be deployed on Mac hardware, and the authors are working to find a solution to this problem. The authors have included several relevant security distributions of Linux such as Kali, Remnux, and SIFT. The library also includes over 2,000 malware samples, although access is currently restricted to instructors for the complete dataset. Finally, a variety of standard firewall configuration scripts are included, which include blocking all traffic, allowing HTTP/HTTPS only (with full SSL inspection), allowing common Windows/Linux protocols (such as SMB/NetBIOS), and unrestricted access. All of these may be selected via the Web drag-and-drop interface.

Fusion of Research and Education

The architecture described here benefits a fused learning and research environment. While instructor-guided walk-throughs can be extremely useful in acquiring malware analysis skills, students also benefit from self-guided analysis and often thrive when they pursue their own choices. It is recommended that students go to several online malware repositories and that their instructors set research projects in order to analyze samples not discussed in the course using the SDN-based system. There are plans to evaluate this during the first iteration of the course and report on its effectiveness along with any issues discovered.

Future Work

The use of SDN in a malware analysis environment allows a great amount of flexibility at the networking layer. The authors envisage expanding the architecture to allow for network layering between the analysis VM and the egress/ingress firewall. This would allow the insertion of inline network devices such as intrusion detection systems, honeypots, and traffic emulators. It would also facilitate research into the effectiveness of such devices in a malware detection and mitigation scenario.

Conclusion

In this paper, the authors presented a novel approach for utilizing software defined networks in a malware analysis classroom environment. It is believed that using SDNs in this manner will decrease the overhead in maintaining courses and open avenues to project-based research in an undergraduate environment. The security and usability advantages of the system have been discussed and compared in relative terms to existing approaches of malware analysis that rely on both standalone and networked hosts. In conclusion, the authors maintain a positive outlook for the prospects of SDN in malware analysis education and believe that the capabilities it brings will be revolutionary in better preparing students to understand and defend against this ever-increasing threat.

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Biographies

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REDESIGNING THE ORGANIZATIONAL STRUCTURE OF A PROJECT-DRIVEN COMPANY: A CASE STUDY

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Abstract

The strategic management literature is replete with research related to organizational design and its relationship to firm profitability. In this paper, the authors describe the organizational restructuring of a project-driven company and its departments in order to maximize efficiency and firm performance. Although this company experienced rapid growth in the first five years of its existence, there were few significant changes to its organizational structure. Any changes that did take place to the actual and working organization structure evolved in an ad-hoc fashion, which directly contributed to the problems related to managing and controlling the processes within the organization. As a result, tasks and responsibilities of various departments were unbalanced in terms of number of personnel and volume of work and, in many cases, departments had conflicting missions and overlapping responsibilities, resulting in inefficiencies and increased bureaucratic costs. Through the reorganization, 36 main departments, 25 line departments, and 11 staff departments were transformed into a new organization with 17 main departments, eight line departments, and nine staff departments. This revised organizational structure was much more effective and efficient, satisfying the stakeholders of the company.

Introduction

There is a plethora of research within the strategic management literature that addresses organizational design and its relationship to organizational complexity and structure [1-4]. One consistent finding of this research stream is that increased complexity increases the bureaucratic costs, often due to additional communication and coordination [5]. And, because these costs negatively impact profitability, it has been suggested that unnecessary organizational complexity be minimized [6], [7]. What follows is a case study that undertook the challenge of reorganizing a company's structure to reduce bureaucratic costs and improve performance.

To protect its identity, the company in this study will not be identified here and will only be referred to as "the company." The mission of the company was designing, manufacturing, assembling, installing, and commissioning automotive production lines. The main offerings included various production lines and logistic equipment required for auto manufacturing companies, including press lines, body assembly lines, paint shop equipment, casting lines, powertrain assembly lines, and final assembly lines. The company fulfilled and supervised all activities required for each project, from the initial design work to the final commissioning phase. The primary customer of the company was an auto manufacturing company, referred to here as "the customer." In recent years, the customer has been expanded, and the company has played an important role in this expansion, leading to significant growth of the company.

Rapid growth over the last five years has resulted in a large increase in employees. After five years, there were over 600 employees. Also during this time period, the number of projects contracted with different customers increased to 80, and the volume of sales increased to approximately \$350 million. The company's initially approved organizational structure had remained unchanged during the 5-year time period. Meanwhile, the actual and working organizational structure evolved in an ad-hoc fashion, which had directly contributed to its problems, including increased bureaucratic costs, due to managing and controlling this complex organization. Approximately 36 top managers worked directly with the CEO. The departmental workload and responsibilities were unbalanced in terms of number of personnel and volume of work and, in many cases, departments had conflicting missions and overlapping responsibilities. For example, similar projects were assigned to different departments with conflicting objectives.

After five years, when the CEO was replaced, the Organizational Development Department became dedicated to analyzing the company's needs and developing a new organizational structural design more suitable for a company of this size and type of business. This case study examined this company's struggle with organizational structure, after a period of rapid growth resulting in increased complexity. This study contributes to the strategy and organizational design literature by outlining this company's strategic process of redesigning an efficient and effective organizational structure, in an attempt to achieve a competitive advantage.

Literature Review

The extant strategy literature includes abundant research that delves into organizational design and firm performance [8], [9]. One stream of this research focused on the effects of complex designs on organizational bureaucratic costs. Jones and Hill [5] addressed the issue of strategy and structure fit and determined that related diversification often requires a more complex structure, due to increased coordination between commonalities within the firm. They concluded that the structural complexity of related diversification increases bureaucratic costs and therefore may negatively impact firm performance. A 1992 empirical study of vertical integration in the forest products industry by D'Aveni and Ilinitch [10] found support for Jones and Hill's study [5] by suggesting that complexity created additional bureaucratic costs, due to managerial inefficiencies stemming from increased control and coordination problems between interdependent units. In 1994, D'Aveni and Ravenscraft [11] built upon the 1992 study [10] by hypothesizing that, while vertical integration can improve firm performance, it is for reasons other than efficiency, because vertical integration increases costs, due to the high level of coordination and communication between activities. Additional research concluded that vertical integration leads to a more complex organization, which in turn increases bureaucratic costs, due to communication distortion [12-14].

In 2000, Ashmos et al. [15] completed an empirical study examining eight companies' responses to increasingly complex environments. They concluded that those companies that responded to more complex environments with more complex, organic structures outperformed the companies that implemented simpler, mechanistic responses, supporting the notion that there should be a "fit" between organizational complexity and organizational structure.

While Ashmos et al. [15] examined the need for increased structural complexity, when the organization's complexity increases, Skaggs and Huffman [7] conducted an empirical study of service firms and concluded that, while organizational complexity is sometimes needed in a firm, they should be careful not to be any more complex than is required because the associated bureaucratic costs may negatively affect firm performance. In 2003, Elliott [16] examined the costs of structural complexity within the HR function and supported Skaggs and Huffman's assertion that excessive complexity adds costs and, therefore, should be minimized.

A related study by Martinez-Tur et al. [17] examined the relationship between organizational complexity and customer satisfaction. As hypothesized, this study found that structural complexity had a negative correlation with customer satisfaction, suggesting that increased complexity decreases firm performance in service industries [17]. In sum, while there is ample evidence to suggest that, while organizations may need to boost their structural complexity as a firm grows and diversifies, firms should strive to minimize complexity to a required level as additional bureaucratic costs, due to increased level of control and coordination between business units, are likely to have a negative impact on firm performance. This study took place because the company recognized that their organizational design increased their bureaucratic costs.

Organizations perform work in order to achieve a set of objectives. Generally, work can be categorized as either projects or operations [18]. Operations are routine and repetitive, whereas projects are new and temporary [18]. Projects are performed to generate new outcomes during a specific time frame [18]. Large projects are usually divided into smaller subprojects. Subprojects are contracted to other companies or other units and departments within the organization. Examples include subprojects based on the project process, such as a single phase of the project lifecycle, subprojects based on employee skill requirements, such as plumbers or electricians needed on a construction project, and subprojects involving specialized technology, such as the automated testing of computer programs for a software development project. Large subprojects of a very large project can also be divided to smaller subprojects. A project portfolio is a collection of projects that are grouped together to facilitate effective and efficient project management in order to meet strategic business objectives [18]. Project-oriented (project-driven) organizations simultaneously perform a number of different projects. Actually, they hold a portfolio of projects [19].

In order to cope with intensified competition, changes in customer preferences, increased demands for shorter lead times, demand for lower prices, and improved technical quality in products, companies often need to change and/or rearrange old and ineffective structures to new and more effective structures [20], [21]. Since project-driven organizations fulfill a portfolio of projects and projects have temporary and unique properties, their environments are more dynamic than operational organizations. So change in organization structure is more essential and critical for project-driven organizations.

Nobeoka and Cusumano [22] described the objectives and outcomes of changes in Toyota's product development department. They suggested that this reorganization was the most fundamental change in their product development process that Toyota has implemented since it established the organization around 1965. The new organizational structure focused on multi-project management. With respect to their structural innovation, Toyota has led the way in establishing a project-based management system, aimed at coordinating and integrating activities between different functional areas in order to develop well-integrated new products. Previously, they had many problems with the old organizational structure. Nobeoka and Cusumano also suggested that most of these organizational problems were caused by Toyota's rapid growth, which created difficulties with both project integration and inter-project coordination. They go on to assert that there were too many functional engineering divisions with narrow specialization of engineers and there were too many vehicle projects for each functional manager to manage both the engineering details of each project and the inter-project coordination.

Through the reorganization, Toyota was able to divide all of its new product development projects into three centers. The center structure focused on grouping projects based on platform designs. Center 1 was created for rear-wheel-drive vehicles, while Center 2 was for front-wheel-drive platforms and vehicles, and Center 3 was grouped around utility vehicle/van platforms. The new structure improved both project integration and inter-project coordination. Important features of this reorganization included reduction in the number of functional engineering divisions, reduction of the number projects handled by each functional manager, modification in the responsibilities of the center head for multiple vehicle projects, creation of planning divisions for each center, and implementation of a hierarchical organization for chief engineers. They concluded that while it may seem that a traditional function-oriented, rather than project-oriented, organization is appropriate for managing inter-project interdependencies, this type of structure is weak at cross-functional integration. Functional structures also lack a mechanism to ensure that individual products retain distinctive features and a high degree of what has been called product integrity. Therefore, organizations should aim at achieving both cross-functional coordination and inter-project coordination simultaneously through the way they organize and control multiple projects. This goal cannot be achieved by either traditional project-oriented or function-oriented organizations. The inter-project interdependencies must be coordinated within the context of a specific project as an integrated system. To share components, while retaining the distinctiveness of individual products, firms also need organizational structures and processes that enable system-level coordination across multiple projects.

Danilovic and Borjesson [23] used a dependence structure matrix (DSM) methodology, based on an empirical case showing how a systemic relations and dependence analysis can identify clusters of engineering tasks that form an integrated project structure. The DSM analysis is also used to identify relationships between new project structure and the prevailing basic organizational structure in order to identify where coordination and integration is needed between the temporary project-based structure and the basic organizational structure. The results of this research showed how DSM methodology can be used to create a project portfolio by analyzing a business portfolio and engineering tasks to form a multi-project structure. They searched for relationships between the exchange of technical information needed to design a proper multi-project structure and the departments in the basic organization at Saab Aerospace AB, a Swedish aircraft manufacturing company (labeled Material Groups, as these departments follow the technical logic of the aircraft such as hydraulic and air systems). They attempted to show how DSM analyses can be used to design a structure for a project-driven organization on the basis of a relational analysis. The results indicated that a series of business decisions and engineering tasks conducted on a functional basis could be reorganized into projects following business logic and deliverables to the customer.

Recognizing the Working Organization

Since the working organizational structure of the company and its departments had changed over the years but had not been clearly recognized and documented, the first task was to perform an assessment of current organizational structure. This process included an analysis of mission, processes, and structures of all departments, duties, and responsibilities of departments and sub-departments, and the reason for conflicting goals and objectives. This was accomplished by initiating dialog with all managers and engineers to gain an in-depth understanding of work process, documentation, and reporting relationships within the company. Concurrently, some of the completed and current projects were reviewed, and one or two projects within each category of similar projects were selected. For example, the team visited several press lines, a body assembly line, a paint shop, a casting line, an axle assembly line, an engine assembly line, and a final assembly line. These lines largely utilized robotic systems and logistic systems. Approximately 15 project worksites were examined and analyzed.

Developing the New Organizational Structure

In general, each main project (contracted with a customer) was allocated to one department that was responsible for reporting to the customer. The project was then divided into subprojects and was subcontracted to other departments within the company. The subcontracting often continued to expand and branch out to more departments. As part of a restructuring process, the team analyzed the relationships between projects (past and present) and the line departments by using a project-department relationship matrix, shown in

Table 1. The matrix is a From-To matrix in which the number of subprojects given by each department to another department can be seen. In Table 1, the list of line departments that were directly reporting to the CEO in the old organizational structure is shown. It should be noted that row 19 in Table 1 represents five separate departments that were responsible for five distinct paint line projects. Basically, 25 line departments, directly reporting to the CEO, existed in the old organizational structure. In Table 1, the number of main projects of each department is shown in the last column.

The process continued by consolidating and categorizing the old departments into seven new departments. The list of new departments is shown in Table 2. The criteria for this categorization were as follows:

a) Product types
b) Interactions between departments (based on the matrix shown in Table 1)
c) Department specialties
d) Balancing departmental personnel and work load

Table 1. Project-department Relationship Matrix

	From / To	Design and Engineering	Material and Tools Engineering	Body	Press and Die	Robotic Welding and Material Handling	Robotic Cells	Robotic Installation and Maintenance	Logistics and Final Assembly	Conveyor	GPS Project	Vision and Instrumentation	Monitoring and CCR Systems	Control Systems	Building Technology	Body Lines Electrical Systems	Painting Lines Electrical Systems	Material Handling Equipment Elec. Sys.	Special-Purpose Machines Elec. Sys.	Paint Projects (5 Paint Projects)	Car X Axle Project	Car X Engine Project	**No. of Subprojects**	**No. of Main Projects**
1	Design and		7	1	1				7			2								1	4	3	**26**	**29**
2	Material and Tools Engineering				1	2																	**3**	**20**
3	Body				1		2							1									**4**	**25**
4	Press and Die																						**0**	**18**
5	Robotic Welding and Material		1	8	4		4		4														**21**	**22**
6	Robotic Cells		1	1		2			5											3	2	3	**17**	**5**
7	Robotic Installation and Maintenance			1		2	7																**10**	**2**
8	Logistics and Final Assembly																			1		3	**4**	**11**
9	Conveyor		1	3		1			7											2	1	1	**16**	**11**
10	GPS Project																						**0**	**1**
11	Vision and Instrumentation			1		2	3		1						1	1				1	1		**11**	**2**
12	Monitoring and CCR Systems			3				1	3									1		3		1	**12**	**0**
13	Control Systems	7	1	2	2				6	1												1	**20**	**3**
14	Building Technology	1							3											1		1	**6**	**2**
15	Body Lines Electrical Systems			5	7	6			1														**19**	**0**
16	Painting Lines Electrical Systems						2		2											3			**7**	**0**
17	Material Handling Equipment Electrical Systems						2		4	7												1	**14**	**1**
18	Special-Purpose Machines Electrical Systems	1					5			1											3	2	**12**	**0**
19	Paint Projects (5 Paint Projects)						1																**1**	**14**
20	Car X Axle Project																						**0**	**2**
21	Car X Engine Project																						**0**	**2**
	Total	**9**	**11**	**25**	**16**	**15**	**26**	**1**	**43**	**9**	**0**	**2**	**0**	**1**	**1**	**1**	**0**	**1**	**0**	**15**	**11**	**16**	**203**	**170**

Table 2. Categorized Project-department Relationship Matrix

		Press & Die	**Body**	**Power Train**				**Painting**	**Logistics & Final Assembly**		**Robotic Systems**			**Electrical Systems**									**No. of Subprojects**	**No. of Main Projects**
	From / **To**	Press and Die	Body	Design and Engineering	Material and Tools Eng.	Car X Axle Project	Car X Engine Project	Paint Projects (5 Paint Projects)	Logistics and Final Assembly	Conveyor	Robotic Welding and Material Handling	Robotic Cells	Robotic Installation and Maintenance	GPS Project	Vision and Instrumentation	Monitoring and CCR Systems	Control Systems	Building Technology	Body Lines Electrical Systems	Painting Lines Electrical Systems	Material Handling Equipment Elec. Sys.	Special-Purpose Machines Elec. Sys.		
Press & Die	Press and Die																						**0**	**18**
Body	Body	1										2					1						**4**	**25**
Power Train	Design and Eng.	1	1		7	4	3	1	7						2								**26**	**29**
	Material and Tools Eng.	1									2												**3**	**20**
	Car X Axle Project																						**0**	**2**
	Car X Engine Project																						**0**	**2**
Painting	Paint Projects (5 Paint Projects)											1											**1**	**14**
Logistics & Final Assembly	Logistics and Final Assembly						3	1															**4**	**11**
	Conveyor		3		1	1	1	2	7		1												**16**	**11**
Robotic Systems	Robotic Welding and Material Handling	4	8		1				4			4											**21**	**22**
	Robotic Cells		1		1	2	3	3	5		2												**17**	**5**
	Robotic Installation and Maintenance		1								2	7											**10**	**2**
Electrical Systems	GPS Project																						**0**	**1**
	Vision and Instrumentation		1			1		1	1		2	3						1	1				**11**	**2**
	Monitoring and CCR Systems		3				1	3	3				1								1		**12**	**0**
	Control Systems	2	2	7	1		1		6	1													**20**	**3**
	Building Technology			1			1	1	3														**6**	**2**
	Body Lines Electrical Systems	7	5						1		6												**19**	**0**
	Painting Lines Electrical Systems							3	2			2											**7**	**0**
	Material Handling Equipment Elec. Sys.						1		4	7		2											**14**	**1**
	Special-Purpose Machines Elec. Sys.			1		3	2			1		5											**12**	**0**
	Total	**16**	**25**	**9**	**11**	**11**	**16**	**15**	**43**	**9**	**15**	**26**	**1**	**0**	**2**	**0**	**1**	**1**	**1**	**0**	**1**	**0**	**203**	**170**

As shown in Table 2, the Press and Die Department had not received any subprojects from any department but had contracted out many subprojects to other departments. So the Press and Die Department was identified as a department in the new organizational structure. Similarly, the Body Department, which supported body assembly line projects, had received a few small subprojects but had contracted out many subprojects to other departments. So it was also identified as a department within the new structure. The Design and Engineering Department was supporting two types of projects: engine assembly line projects and special-purpose and ancillary machine subprojects (these special-purpose and ancillary machines are required in different types of production lines). However, at that time, the majority of its workforce was assigned to engine assembly line projects with just a few of their personnel working on special-purpose and ancillary machines subprojects. Also, most of the projects in the Material and Tools Engineering Department were centered on developing engine-block casting lines. These two departments were merged together along with Car-X Axle project and Car-X Engine projects to form a new department called the Power Train Department.

Five separate painting projects were merged to form the Painting Department. At the time, the old Logistics and Final Assembly Department was responsible for final assembly line projects as well as logistics projects such as ASRS (Automated Storage and Retrieval System). By analyzing the process of final assembly line projects, it was discovered that a considerable portion of final assembly line projects were composed of different types of conveyors and material handling equipment. As shown in Table 2, the Conveyor Department had received many subprojects from the old Logistics and Final Assembly Department. However, the old Logistics and Final Assembly Department had not contracted out some conveyor subprojects to the Conveyor Department; the work was performed in-house. To increase efficiency, these two departments were merged into a single department called Logistics and Final Assembly Department.

The Robotic Welding and Material Handling Department, the Robotic Cells Department, and the Robotic Installation and Maintenance Department had had many interactions with each other and all their work was focused on robots on different types of production lines. As a result, they were consolidated to form a new department called Robotic Systems Department. Although the GPS Project, the Vision and Instrumentation Department, the Monitoring and CCR Systems Department, the Control Systems Department, the Building Technology Department, the Body Lines Electrical Systems Department, the Painting Lines Electrical Systems Department, the Material Handling Electrical Systems Department, and the Special-Purpose Machines Electrical Systems Department had a few interactions with each other. As most of the work done by these departments was centered on electrical and electronic systems, they were grouped into one Electrical Systems Department.

Since the company specializes in designing and manufacturing robot applications and robot installation, customers usually prefer to receive robot maintenance services directly from the company. This work had been traditionally performed by the Robotic Installation and Maintenance Department. Meanwhile, other departments provided services to customers in many other areas of production line maintenance. However, a non-centralized system of providing maintenance services had resulted in several inconsistencies. It appeared that customers preferred to outsource all maintenance services of various types of machines and equipment within a production line (such as electrical equipment, robots, and conveyors) under one contract. So, to satisfy this demand, an independent Maintenance Department was created with centralized responsibility for all maintenance activities. So, as the eighth new line department, the Maintenance Department was added to the seven new departments shown in Table 2.

In all, eight new line departments were created, including the Press and Die Department, the Body Department, the Power Train Department, the Painting Department, the Logistics and Final Assembly Department, the Robotic Systems Department, the Electrical Systems Department, and the Maintenance Department. While working through the organizational structure analysis process, it was discovered that some departments were duplicating efforts with regard to similar projects. So overlaps were identified and isolated and some activities and specialties were shifted from one department to another. So, in addition to merging missions, the missions of some departments were altered.

In Table 3, interactions of old departments were summed up based on the configuration of the new departments. Obviously, the subprojects between similar new departments would be eliminated in the new organization; the related cells are shaded in Table 3. The subprojects in the shaded cells would be eliminated in the new organization, as they do not need to be contracted out to other departments. As seen on each row in Table 3, the new number of received subprojects for every new department is calculated by subtracting the number of subprojects in the shaded cell from the previous number of subprojects. Also, on each column, the new number of contracted subprojects for every new department is calculated by subtracting the number of subprojects in the shaded cell from the previous number of subprojects. So, the total number of subprojects is reduced from 203 to 164 in the new organization.

Table 3. Summarized Project-department Relationship Matrix

From	Press	Body	Power Train	Painting	Logistics	Robotic	Electrical	**New Number**	**Number**
Press and Die								**0**	**18**
Body	1					2	1	**4**	**25**
Power Train	2	1		1	7	2	2	**29 – 14 = 15**	**53**
Painting						1		**1**	**14**
Logistics and Final		3	6	3		1		**20 – 7 = 13**	**22**
Robotic Systems	4	10	7	3	9			**48 – 15 = 33**	**29**
Electrical Systems	9	11	20	8	29	21		**101 – 3 = 98**	**9**
Total	**16**	**25**	**47 – 14 = 33**	**15**	**52 – 7 = 45**	**42 – 15 = 27**	**6 – 3 = 3**	**164**	**170**

As shown in Table 3, the Press and Die Department does not receive any subprojects from other departments. The Body Department also rarely receives subprojects from other departments (the previous subprojects were usually very small and old). Also, the Painting Department usually does not receive any subprojects from other departments. The Power Train Department receives some subprojects from other departments; these subprojects are usually special-purpose and ancillary machine subprojects. The Logistics and Final Assembly Department receives some subprojects from other departments; the subject of these projects is usually conveyors. The Robotic Systems Department receives many subprojects from other departments. And, the Electrical Systems Department receives many subprojects from other departments.

The Press and Die Department, the Body Department, the Power Train Department, the Painting Department, and the Logistics and Final Assembly Department fulfill main projects rather than subprojects. This conclusion was reached after considering the numbers of subprojects and main projects of each department as well as the budget of their projects; based on calculations, the budgets for their main projects tended to be much higher than the budget of their subprojects. In actuality, the structure was reorganized based on product families. The proper purpose of an organization's structure is to identify and channel the value stream for a family of products so that value flows smoothly to the customer [24]. Womack and Jones [24] suggested that in order to transform an enterprise to a lean enterprise, one of the steps is reorganizing the organizational structure based on product family. A product family is usually a group of products that need the same set of processes or procedures.

Conversely, the Robotic Systems Department and the Electrical Systems Department fulfill subprojects rather than main projects. This conclusion was reached after considering the numbers of subprojects and main projects of each department as well as the budgets of their projects; based on calculations, the budget of their subprojects was much higher than the budget of their main projects.

Also, some changes were made in the structures of staff departments to improve communication and coordination throughout the organization. The Computer, Technical Archive, and Organizational Development Departments were merged to create the Organizational Development and Systems Department. The Industrial Relations Department, which was previously under the direction of the CEO, was transferred to the Commercial Department. In addition, since the company's strategy included a focus on exports, it needed to have a more powerful Public Relations Department. Therefore, the Public Relations Department, which was previously under the Administration Affairs Department, was moved to the direct purview of the CEO. In summary, the company's organizational structure was transformed from 36 main departments (25 line departments and 11 staff departments) into a more efficient and effective structure that now includes only 17 main departments (eight line departments and nine staff departments).

Developing Departmental Structures

After the top level organizational structure was designed, attention was focused on the development of appropriate departmental structures. Based on the information obtained through previous steps, and in collaboration with top management, departmental missions, structures, and section duties were defined. Since project completion and delivery is emphasized in all line departments, similar functions are applied in different projects, and the portfolio of projects changes frequently (some projects finish and some projects start during the same time period), it was suggested that a matrix structure would be the best structure for the line departments. A generic matrix structure for a line department includes several functional units (sections) such as design, manufacturing, and installation and commissioning. Each unit has a manager, who oversees a group of employees.

In addition to unit managers, several project managers directly report to the department manager. Project managers are responsible for coordinating all project tasks in order to provide project deliverables on time, within budget, and with determined quality to the customer. Each project manager handles one or more projects. Based on an agreement between the project manager and unit managers, one or more employees from each unit are temporarily assigned to each project. As the project ends, those employees will be released and can be assigned to other projects. It should be noted that in a matrix structure each employee in a functional unit can be assigned to more than one project. Therefore, one advantage of the matrix structure is that employee utilization is increased. In order to implement a matrix structure, department managers categorized their projects based on types of projects and assigned each type to one project manager. Using this type of structure, specific knowledge is stored in functional units and project managers guarantee project delivery.

The matrix structure is useful when an organizational structure needs to be multi-focused in that both projects and functions are emphasized at the same time [25]. Using a matrix structure, resources (people and equipment) can be flexibly allocated across different projects and the organization can adapt to changing external environmental factors [25]. Volberda [26] believed that organizational flexibility plays an important role in the success of organizations in hypercompetitive environments. He indicated that the market-oriented grouping of people and the use of project teams with interchangeable personnel and equipment suggests structural flexibility. He further asserted that the matrix organization form is one of the organic organization structural forms. In organic structures, planning and control systems are predominantly performance-oriented instead of means-oriented [26]. Organic structures provide substantial leeway for structural flexibility [26].

Approving the New Organizational Structure

Since a new organizational structure requires the approval of the top management team and the Board of Directors, the proposed new organizational structure of this company along with the proposed departmental structures were presented to the Board. A summary of the analysis and the steps taken leading to the recommendations were explained and discussed. The Board of Directors approved the structural redesign. The implementation of a redesigned organizational structure requires the supervision and coordination of many activities. The implementation of a major structural reorganization is a daunting undertaking. For the company in this study, the process took about six months. Important activities in the implementation process included the selection of top and middle management, authority distribution planning, defining the location of employees in the new structure, transferring employees among departments or units (sections), changing human resource and financial information system data (data associated with the organization's structure), and even the physical relocation of many of the company's departments. After six months, the organizational structure redesign was successfully implemented without the reduction of workforce personnel.

Conclusion

In this paper, the authors discuss the process of organizational restructuring performed for a project-driven company. Based on the review of strategy literature, a restructuring and simplification of this company's organizational design is indicated in order to minimize the bureaucratic costs that arise from duplication, increased coordination, and communication distortion [5], [12-14]. Due to rapid growth, the company needed to redesign its organizational structure along with departmental structures. After studying and analyzing the structure, the new structure was developed in order to resolve conflicts and overlaps within the organization and to satisfy the company's stakeholders. The organizational structure was transformed from a structure of 36 departments to 17 departments.

After implementation of the new structure, the controllability of organization increased by decreasing the number of top-level managers and departments. Conflicts and overlaps of missions and responsibilities were removed. The number of subprojects decreased and, as a result, extra and unneeded bureaucracy was eliminated. Assignment of personnel to projects was facilitated by using flexible matrix structures and personnel capacity was utilized more efficiently. Storage of specific knowledge was facilitated by integrating departments and organizing matrix structures for line departments. Project managers gained official job titles, making each of them more responsible and accountable. Some authorities and responsibilities were distributed to middle managers as a result of having a multi-level structure. Departments are more balanced in terms of number of personnel and work volume as many small departments, previously under the supervision of CEO, were merged with other departments. And, many organizational affairs, such as performance appraisal, budgeting, reporting, and personnel training and planning, were facilitated by building a multi-level organization structure with fewer departments.

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Modifying the Curriculum of an Engineering Technology Program to Meet the Needs of a Local Manufacturing Consortium

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Abstract

Northern Kentucky hosts many advanced manufacturing companies, producing high-value-added products. Companies such as Mazak, ZF Steering Systems, Johnson Controls, Toyota, and others play a significant role in the region's economy. The availability of adequately trained individuals is paramount in fulfilling their human resource needs, as has been repeatedly expressed to the local institutions' faculty and administrators. In this paper, the authors describe the adoption of the CDIO (conceive-design-implement-operate) initiative, as proposed by Crawley et al. [1] at the Massachusetts Institute of Technology in response to the requirements and advice from industry and other stakeholders with respect to the desired knowledge, skills, and abilities of future graduates.

The Engineering Technologist

Engineering technologists are the graduates from four-year engineering technology programs. These professionals are most likely to enter positions in sectors such as construction, manufacturing, product design, testing, or technical services and sales. Those pursuing further study often consider engineering, facilities management, or business administration [2]. In the Northern Kentucky area, these professionals perform in many areas such as:

- Manufacturing—auto industry, auto parts, appliances, machinery, etc.
- Services—transportation, construction, quality control, etc.
- Public services—water treatment, energy generation, etc.

Undoubtedly, the primary task of higher education institutions is to prepare students to manage those jobs in fast-changing markets. Today, innovation is paramount in surviving in the business environment. In that regard, higher education institutions are required to prepare their graduates to be innovative in ways that contributes to the improvement of the technological efficiencies that U.S. industry must have in order to maintain a competitive, cutting edge [3]. Moreover, in high-velocity industries with short product cycles and rapidly shifting competitive landscapes, the ability to engage in rapid and relentless continuous change is a crucial capability for survival [4].

Societies, businesses, and technologies are changing rapidly, and this development has led to the creation of what is today commonly labeled "the knowledge society" [5]. Institutions offering technical education face the challenge of building curricula better suited to the needs of industry. Curriculum adequacy, at national and/or local levels, is essential to assure the placement of graduates [6]. It is worth mentioning that even with the general success of engineering technology programs in meeting their learning outcomes, some gaps in the students' industrial readiness and competencies still exist and need to be addressed. In response to requirements and advice from industry and other stakeholders, with respect to the desired knowledge, skills, and abilities of future graduates, the authors proposed the CDIO initiative. Therefore, the starting point was a restatement of the underlying need for engineering technology education, as proposed by Crawley et al. [1] for education of aeronautical engineers.

The CDIO Initiative

The goal of the CDIO initiative is the education of students, who will be able to 1) master a deeper working knowledge of technical fundamentals; 2) lead in the creation and operation of new products, processes, and systems; and, 3) understand the importance and strategic impact of research and technological development on society. To reach those goals, a framework of best practices in education reform was established, represented by a set of 12 standards (see Table 1), and developed in response to requests from industrial partners, program leaders, and alumni for attributes of graduates of CDIO programs [1].

This current approach for coping with the CDIO standards is as follows:

Program Philosophy and Curriculum Development: The results of a survey conducted among industry representatives in the Northern Kentucky area [7] point in the general direction that the curriculum design should take; for example, towards a more attentive approach in prizing knowledge integration, increasing student responsibility in the learning process, and adding industry-integrated, extracurricular activities. Creating close relations with industrial partners in educating future engineers/technologists would help prepare more skillful graduates [8]. Accreditation bodies also expect graduates to meet outcomes in terms of their technical knowledge, skills, and attitudes, such as the student learning outcomes as defined by ABET [9].

Table 1. CDIO Best Practices Framework

CDIO Standards	Addresses
1 - The Context	Program philosophy
2 - Learning Outcomes	Curriculum development
3 - Integrated Curriculum	
4 - Introduction to Engineering	
5 - Design-Implement Experiences	Design-implement experiences and workplaces
6 - Engineering Workspaces	
7 - Integrated Learning Experiences	New methods of teaching and learning
8 - Active Learning	
9 - Enhancement of Faculty Skills Competence	Faculty development
10 - Enhancement of Faculty Teaching Competence	
11 - Learning Assessment	Assessment and evaluation
12 - Program Evaluation	

Design-Implement Experiences and Workplaces: The already established program capstone course, EGT417 Senior Project in Engineering Technology, was used as part of the CDIO best practices framework. This course is a requirement for all students in the engineering technology program. Students are expected to select a senior project that shows their ability to apply their knowledge and skills to design, manufacture, test, and evaluate their project, based on their proposed performance standards. As part of the senior project, students are also required to conduct research and use their problem-solving skills to complete tasks in a timely manner. The projects are usually presented in groups, but individual work is also acceptable. The duration is one semester, with extensions granted in exceptional circumstances.

New Methods of Teaching and Learning: New methods have been experimented with in order to enhance student learning experience. Last fall, in cooperation with Mazak Corporation, an innovative training program aimed at providing students with hands-on industrial experience, as part of graduation requirements through EGT417, was implemented [10]. What makes this university-industry cooperation novel is that it is a part of the academic program being taught by NKU faculty and Mazak management supervision, at their facility. This program incorporates many elements of the case method in experiential learning [11], which has been largely used in a variety of disciplines. Students are also offered the opportunity to participate in service learning initiatives [12]. Students were assigned to work on their senior projects (also through EGT417) by designing and implementing devices and methods to improve the manufacturing capabilities for institutions like the BAWAC Community Rehabilitation Center, a non-profit organization, whose mission is to help adults with disabilities or other barriers to employment in order to maximize their vocational potential and quality of life [13].

Faculty Development: As part of recommendations made by the ABET Engineering Technology Accreditation Committee, a professional development plan is being prepared to keep faculty members current in their academic fields.

Assessment and Evaluation: Course outcomes are evaluated on a regular basis, following a rotation schedule. This assessment is made by the application of a set of questions, to be answered by students at the end of every semester. Also, surveys are conducted in order to capture additional data from other stakeholders, such as industry partners and the graduates' potential employers.

Conclusions

As the manufacturing industry rebounds from the last economic crisis, companies say they are struggling to replenish the workforce that was cut during the recession [14]. The difficulty faced by industry is to hire graduates with appropriate higher education and expertise in the manufacturing field. The lack of such graduates may pose serious consequences for the U.S. economy in general and for the local economy in particular. By responding to the needs of industry stakeholders, who hire the school's graduates, students going through the bachelor's degree programs in engineering technology will be better prepared to meet employers' needs. In this study, the surveys conducted by the Northern Kentucky Industrial Park Advisory Committee for Continuing Education were used to assess the needs of local employers. NKIP current membership consists of over 85 companies located in the Northern Kentucky area, in the sectors of manufacturing, aviation, biotechnology, and information technology [15]. An estimate of 6250 skilled positions will need to be filled by employers in the Northern

Kentucky area in the next 10 years, distributed as shown in Table 2 [7]. Engineering technologists have the competencies to perform many of those activities [16]. Building relationships with local industry is essential to the process of providing graduates with the core competencies and skills required to fulfill those positions.

Table 2. Ten Years' Worth of Projected Growth

Demand Level	Title	Growth Estimate
High Demand	Manufacturing Technicians	2671
	Machine Maintenance Specialist	695
	Electronic Technician and Repairer	532
	Welders	453
	Engineer - Process/ Manufacturing	326
	Engineer - Design	330
Some Demand	Machinists	281
	Machine Tool Operator	260
	Industrial Electricians	180
Near Stable	Applications Engineer	120
	Metal Fabricators	96
	Engineering Technician	94
	CAD Drafters	53
	CNC Press Brake Set-up and Operators	71
	Finishers	49
	Hydraulic/Pneumatic	38

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Biographies

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TECHNOLOGY-DRIVEN INNOVATION: STRENGTHENING INDUSTRY-ACADEMIA PARTNERSHIPS FOR ADVANCED MANUFACTURING GAINS

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Abstract

Industry-academia collaboration has become a subject of great interest to industry, academics, and policy makers. It is now acknowledged by noted industry advisors that industry-academia collaboration is valuable for innovation. In today's global economy, disruptive innovation and disruptive technology may well be the catalysts that determine whether a manufacturing or service organization even exists. Industry-academia partnerships could well be the vehicle that propels an industrial organization to the front of its field, or the lack of such a partnership may well doom the organization to oblivion. The primary goal of this study was to explore the dichotomy between the strong motivations of both industry and academia to conduct research that promotes new product development, more efficient processes, scholarly productivity and, of equal importance, to make the collaborative effort effective.

Strengthening industry-academia partnerships means industry personnel in the classroom and academic students in the industrial workplace. To develop cutting-edge products and services at the pace that advanced manufacturing innovation gains demand, academia and industry must change the way each thinks about education and industrial relationships. Educators and learners must be engaged in hands-on activities so that learners can contribute immediately to innovate at faster levels. Concepts such as active learning must be encouraged. Nurturing Science, Technology, Engineering, and Mathematics (STEM) schools where students, who have a propensity for the STEM disciplines, are encouraged to pursue career paths in these disciplines early in the education process is important.

New manufacturing programs such as Advanced Manufacturing and Manufacturing Execution Systems (MES) can be taught along with more mature manufacturing concepts such as six sigma, lean manufacturing, supply chain management, and enterprise resource planning (ERP). A joint industry-academic comprehensive approach to this very complex problem of educating the workforce will most likely yield the best results.

Introduction

Since industry-academia collaboration has become a subject of great interest to industry, academics, and policy makers, such a relationship is now acknowledged by noted industry advisors to be valuable for innovation. In today's global economy, disruptive innovation and disruptive technology may well be the catalysts that determine whether a manufacturing or service organization even exists. Two-year and four-year public institutions of higher education face dwindling state and federal financial support, creating a perfect storm for average higher education institutions to eventually reach zero state funding. Mortenson [1] studied the opportunities in higher education and reported that: "Based on the trends since 1980, average state fiscal support for higher education will reach zero by 2059, although zero state funding could happen much sooner in some states and later in others. [Eventually] public higher education [will] gradually [become] privatized."

Background/Problems

With an undetermined future for state funding, higher education administrators are working in the unknown territory of a skill set (collaboration with business) that could come to be commonly used in industry. Mortenson [1] further stated that both state and public institutions have begun addressing longer-term collaboration. Therefore, the issues remain: who will fund public institutions if these institutions are no longer supported by the state, or under what category of control and monitor will these institutions be? All of these are necessary to measure the performances of the activities in such institutions. The inevitability of state government to fund public schools raises an alarm as to who controls public schools and whose interest should the public schools serve? The graphical illustration of college pricing from the College Board's annual report [2] agrees with the findings of Mortenson [1] findings. The graphical illustration of college pricing (see Figure 1) also illustrates declining state funding for higher education since its peak of almost +10 percent of appropriations per full-time equivalent (FTE) (student) in the mid-1980s to a drastic low of approximately -10 percent in 2009, and back up to approximately -5 percent in 2011. Figure 1 shows the graphical representation of the College Board findings.

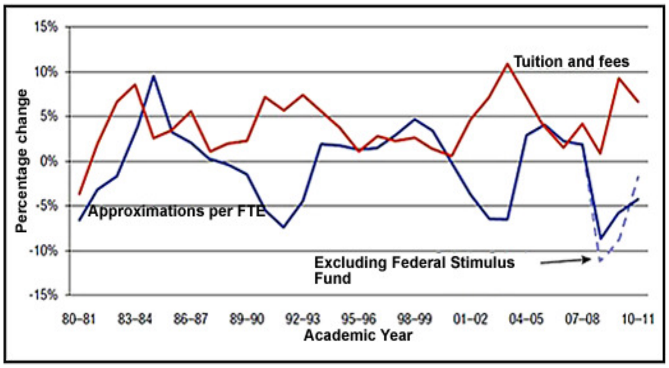

Figure 1. The 2011 College Board Annual Trends in College Pricing Report

The graph of Figure 1 shows approximately a 40.2 percent decrement in college funding from 1980 to 2011. Inferring the trend in the graph, by fiscal year 2059, higher education funding from state investment will reach zero. This trend indicates that the states are already 40 percent of the way to zero. If this continues over the next 48 years, state founding for higher education will be totally finished. Public higher education is gradually being privatized. So, where will the funding for institutions come from?

Theoretically, today's two-year higher education institutions face the same challenges as traditional four-year institutions, due to declining governmental support. The federal government's stimulus money temporarily delayed the inevitable end, or great decrease, in government funding for higher education, as shown in Figure 1. In June, 2012, the Center for American Progress released an article by Steigleder and Soares [3] in which the authors proposed a plan to overhaul and reform the workforce training and counseling system. The authors further emphasized that "Programs would be implemented with private-sector partners and linked to projected job openings in high-growth regional industries. Participants would earn associate degrees, technical certificates, and industry-recognized credentials." This may suggest that there is a paradigm shift from higher education for general purposes, or liberal arts education, at least in part to education for specific jobs and career occupations.

Four-year institutions of higher education and industry employers may favor a two-pronged approach to a college education [4]. The study (see Figure 2) was prepared for the Association of American Colleges and Universities, which included community colleges. As evidenced by the results of this study, Figure 2 reflects a better understanding of the four academic years in higher institutions. Therefore, a majority of employers and a majority of recent college graduates reject a higher education approach that focuses narrowly on providing knowledge and skills in a specific field. The

Figure 2. Findings of the Four Areas of Need to be Taught by Colleges and Universities, Adapted from the Study by Hart [4]

Integrative Learning	Personal and Social Responsibility	Knowledge of human cultures and the physical and natural world	Intellectual and Practical Skills
• The ability to apply knowledge and skills to real world settings through internship or other hands-on experiences (70%) more emphasis	• The teamwork skills and the ability to collaborate with others in diverse group settings (76%) • Global issues and developments and their implications for the future (72%) • A sense of integrity and ethics (56%) • Cultural values and traditions in America and other countries (53%)	• The Concepts and new developments in science and technology (82%) • Global issues and developments and their implications for the future (72%) • The role of the United States in the world (60%) • Cultural values and traditions in America and other countries	• The Teamwork skills and the ability to collaborate with others in diverse group settings (76%) • The ability to effectively communicate orally and in writing (73%) • Critical thinking and analytical reasoning skills (73%) • The ability to locate, organizes, and evaluates information from multiple sources (70%) • The ability to be innovative and think creatively (70%) • The ability to solve complex problems (64%) • The ability to work with numbers and understand statistics (60%)

study by Hart [4] indicated that the majority of employers and recent college graduates believe that an undergraduate college education should provide a balance of a well-rounded education, knowledge, and skills in a specific field. In presenting the employers' point of view on the responsibility of a college education, the study concluded that the majority of employers think that colleges and universities should place more emphasis on the areas listed in Figure 2.

Hart [4] further expressed concern of both employers and recent college graduates over the opportunity to put learning outcomes into practice. Employers and recent college graduates believe that higher education should give students more experience with real-world applications of the student knowledge and skills through hands-on learning. Upon hearing a description of liberal education, a large majority of employers and recent graduates endorse it as important for colleges and universities to provide this type of education. The study further revealed that about 56 percent of business executives thought that America's colleges and universities should focus on providing all students a balanced, well-rounded education. Eleven percent favored a focus primarily on providing a well-rounded education. About 22 percent of employers endorsed a narrow focus on providing skills and knowledge in a specific field. Furthermore, the so-called gen Y, X, and the popularly known "jet" generations' work performance and ethics in the industrial sectors have proved the significant effects of the decline in governmental funding on higher education. Therefore, these demand a quick intervention so as to save the future of America's children.

Suggested Solutions

Based on the evidence presented here, the authors opine that academic institutions, industries, and policy makers/governments should collaborate and strengthen relationships by soliciting feedback from consumers/customers of products and services. These entities should then use that combined feedback to shape academic programs that meet the needs and desires of all constituents. Industry-academia partnerships could well be the vehicle that propels an industrial organization to the front of its field or the lack of such a partnership may well doom the organization to oblivion. The same could be said of such partnerships for the rescue of higher education funding. The primary goal of this study was to explore the dichotomy between the strong motivations of both industry and academia to conduct research that promotes new product development and scholarly productivity. Of equal importance, there is a need to make the collaborative effort effective. In support of the manufacturing inclusion of this study, the authors used the Manufacturing Institute, the 501(c) 3 non-partisan affiliate of the National Association of Manufacturers, whose mantra is "Making Manufacturing Strong through Education, Innovation, and Research."

Hungry for a strong manufacturing sector, Americans are nervous about their future. The third annual survey of the American public indicated that nearly three-fourths (72 percent) of those surveyed do not believe that the economy has been improving or is in better shape since 2008. Over two-thirds (67 percent) of those surveyed believed the economy remains weak and could fall back into a recession. And, Americans are nearly evenly split, 50-50, on whether the economy will show significant signs of improvement by 2015. Additionally, the public is not confident that business leaders and policy makers necessarily understand how to effectively grow and strengthen the economy. So, it is noteworthy that the recent survey of the American public's opinion on manufacturing revealed that throughout one of the most turbulent periods in U.S. economic history, Americans have maintained remarkably consistent views, year after year, on the importance of manufacturing. Americans' concern about the future is one of the basic reasons why American children's education should be prioritized in all American governmental debates.

Conclusion

As manufacturing is the backbone of most developed nations, strengthening industry-academia partnerships in the manufacturing arena will definitely improve the economics of a nation. Therefore, the involvement of industry personnel in the classroom and academic students in the industrial workplace should be encouraged. In a press report on peoples' perspective on American manufacturing, the sector revealed that America will soon be recognized as the all-time leading country in the manufacturing sector, as the competition from low-cost competitors is increasing rapidly [5]. In addition, the blog created by Galdabini [5] added the opinion of ESPN College Gameday host Lee Corso, who stated that, in his opinion, the U.S. manufacturing sector generates $1.7 trillion each year, which is equivalent to approximately 12 percent of the GDP. Manufacturing supports over 17 million U.S. jobs and approximately 12 million Americans, or nine percent of the workforce, who are directly employed in the manufacturing sector. In another article, Perry [6] clarified the differences between U.S. manufacturing and manufacturing by other nations. He also emphasized the following three points in U.S. manufacturing:

1. In 2012, the combined sales revenue of the top 500 manufacturing companies based in the U.S., including all international and national sales, amounted to $6.01 trillion. This indicated an increase of approxi-

mately 17.2 percent compared to that of 2011 sales, which was $5.13 trillion. As a matter of fact, if the entire 500 U.S. manufacturing companies were to be considered as a distinct country, the estimated revenue would be ranked as the world's number three largest economy. These 500 U.S. manufacturing companies would follow the U.S. as No. 1, China as No. 2, and be a little ahead of Japan as the No. 4 economy in the world

2. The U.S. top-ten manufacturing industries total sales revenue in 2012 amounted to $4.83 trillion, 44 percent greater than Germany's entire GDP of $3.36 trillion in fiscal year 2011.
3. The annual sales for America's single largest manufacturing company, petroleum and coal products, in 2012 was approximately $1.62 billion. This revenue was larger than the 2011 GDP of Australia, which was reported to be $1.54 trillion and as high as Canada's GDP in 2012, which was approximately $1.77 trillion.

In the same article [6], at the Greater Elkhart (IN) Chamber of Commerce, David Chavern, the U.S. Chamber Chief Operating Officer, expressed in a blog: Manufacturing jobs have dropped a lot. U.S. manufacturing jobs peaked at 19.5 million in 1979. But by 2010, the number of Americans directly employed in manufacturing fell to a new low of 11.4 million. Where did those jobs go? Mostly to a country called "productivity." Reconfigurable manufacturing systems have enhanced firms to increase their productivity, thereby increasing output and reducing payroll. These technological advancements enable manufacturing sectors to produce high-value-added products that promote innovation and growth and allow competitiveness all over the world. To develop cutting-edge products and services in a manufacturing industry at the pace that current global innovation demands and to increase U.S. productivity, academia and industry must change the way that each thinks about education and industrial relationships.

In addition to liberally educating learners, educators and learners must be engaged in hands-on activities so that students can contribute immediately to innovate at faster levels. Concepts such as active learning, where students take ownership in the design and implementation of their own learning, must be encouraged. More focused manufacturing learning may involve newer concepts such as early childhood education intervention for the sake of manufacturing. Nurturing post-secondary schools with STEM programs where students, who have a propensity for the STEM disciplines, are encouraged to pursue career paths in these disciplines early in the education process. New manufacturing programs such as advanced manufacturing and manufacturing execution systems (MES) can be taught along with more mature manufacturing concepts such as Six Sigma, Lean Manufacturing, Supply Chain Management, and Enterprise Resource Planning (ERP). A joint industry-academic comprehensive approach to this very complex problem of educating the workforce will most likely yield the best results.

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USING WEB-BASED FORMS TO AGGREGATE AND CONTROL COURSE ENROLLMENT EXCEPTIONS

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Abstract

Every semester, faculty and administrators are flooded with requests to add new sections of courses that have closed because they have reached the enrollment caps or students have not met the prerequisites. The traditional approach is to assess each request as it is received in order to determine if the request is valid and justified. Since each request is evaluated individually, there is a chance that students with a greater need than others may not be able to enroll in the course they need. Also, since literally hundreds of requests for additional courses can be received every semester, the process can become confusing and a tremendous burden on faculty and administrators, as they try to wade through legitimate requests. The recent budget shortfall has reduced the number of courses, making the problem worse, since fewer seats are available.

To help address the problem, a course special-add-request system was developed and deployed in a large department that allows students to request enrollment in closed courses using a Web form during an open enrollment request period. The system aggregates all requests and allows advisors to quickly determine the number of requests for each course and which requests are legitimate, while giving equal consideration to every request. Furthermore, faculty and administrators are no longer interrupted by course requests, as they prepare for the upcoming semesters, since all requests are submitted during an open window and assessed simultaneously by a group of advisors, who then enroll those students allowed in each closed course. Feedback on the effectiveness of the system received from faculty, students, and advisors has been very positive, since the initial deployment.

Introduction and Literature Review

Every semester, faculty and administrators are flooded with requests from students for permission to enroll in courses that have been closed because they have reached the enrollment cap or students have not fulfilled prerequisites. In some respects, this appears to be an enviable predicament. Enrollments in higher education across the U.S. have been on a consistent upward slope, increasing 37% between 2000 and 2010 [1], implying a demand greater than the supply and more revenue for degree-granting institutions. This, as most people can appreciate, is one side of a double-edged sword. Increased enrollments imply substantially greater numbers of students supported by financial aid, resulting in greater accountability. Institutions of higher education are under increasing pressure to demonstrate that public dollars are well-invested, evidenced by students successfully completing academic programs within a reasonable amount of time. Yet, criticism of higher education institutions by external entities is becoming more frequent because of low persistence and graduation rates [2]. This challenge is exacerbated by the precipitous decrease in public education funding, intensifying the affordability crisis to unprecedented levels [3]. Less money for institutions to work with results in cutting the number of courses they offer, leading to what could be paralleled with today's typical flying experience: limited seat availability, overbooked courses, and disgruntled customers. Put simply, higher education institutions are being forced to do more with less, such as ensuring graduation of more students with less revenue to spend and fewer courses to offer.

It is, therefore, not surprising that students are seeking the quickest route possible to completion, although national data may not bear this out, particularly when only 61% of full-time students complete a bachelor's degree within eight years and only 24% of part-time students complete a degree in the same amount of time [3], [4]. The fact that terms such as "swirl," "double-dipping," "intra-institutional swirl," and "major migration" [5] now hold a place in the enrollment management officer's daily vocabulary suggests that educational leaders readily acknowledge the increasingly porous and permeable boundaries between and among educational providers [6].

This also raises the possibility that a significant number of students possess the desire and determination to acquire a degree in the shortest time possible. These now commonplace terms indicate that if a desired course is not available, students are willing to shift between institutions for a single class or permanently (swirl), or enroll in two institutions at the same time (double-dipping). Likewise, students may transfer to a different program at their current institution (intra-institutional swirl, major migration) if they are having difficulty accessing coursework within a given major. McCormick [7] classified eight types of swirl. Perhaps the one most relevant here is what he calls "supplemental swirl," where students enroll at another institution for one or two terms in order to supplement or accelerate their programs.

Certainly, there are perceived benefits to this phenomenon. Students are afforded greater choice in terms of course selection, pathways to graduation, lower tuition rates, and perhaps even the opportunity to earn a degree from a more prestigious school [8]. Likewise, schools stand to benefit from revenues generated by swirling and double-dipping students. Research suggests, however, that the downsides of "credit portability" [7] outweigh the advantages. For instance, evidence indicates that students who swirl tend to have lower GPAs and, paradoxically, longer time to graduation [7], [8]. Institutions, as well, are vulnerable to a variety of challenges: assessment of need for financial aid; data collection for progression, retention, and completion rates; and, the impact from "the reality of student flow" on planning for academic programs and courses [5].

In the end, lost enrollments, or "walk away" registrations, may represent frantic and frustrated students attempting to build desired schedules [9]. These may be students who have no intention of returning, which translates into lost tuition potential and institutional investment, based on the argument that it costs more to recruit new students than to retain existing ones [10]. Further, Johnson and Muse [8] argue that lost enrollments resulting from lack of access to upper-level undergraduate courses may threaten the viability of an academic program.

Increasingly, researchers in enrollment management are pointing toward technology as the most viable solution to student attrition resulting from a lack of access to courses. The literature is replete with implications for the role of technology in the reduction of student attrition, such as enrollment management is "very much a technology-intensive, data-driven, process and enterprise" [6]; "academic officials act on the basis of fragmented and incomplete information" [9]; and, "by improving its ability to predict student enrollments and course-taking patterns, an institution will be better able to identify students most at risk of dropping out as well as estimate future revenue and capacity needs" [4].

Yet, there is surprisingly little specificity in terms of utilizing technology at the course and program levels to manage enrollments; most pertain to the institutional level. In this paper, the authors make a case for managing enrollments at the course and program levels by introducing a specialized software developed specifically for reducing attrition at a four-year public institution of higher education.

Background

Every semester, courses fill up during registration periods, forcing students to contact course instructors or advisors to gain permission to register for courses they need to graduate. Also, some courses have prerequisites that restrict online registration if the prerequisites have not been met. Therefore, students must either gain the prerequisites and take those courses in subsequent semesters or get permission from course instructors to register for those courses. The number of students needing access to courses can quickly skyrocket in a short period of time. It is not uncommon for a department of 600 full-time students to have up to 200 requests for access to closed courses or additional sections of courses within two weeks of the start of classes.

The problem has worsened in recent years, since fewer sections are being offered due to budget cuts. Furthermore, sections are being cancelled just before courses begin, due to low enrollment, requiring students to look for other available courses. Often, students are forced to scramble, looking for enough courses to meet full-time load requirements, or some students run into financial aid problems, such as they are not able to pay their tuition on time and are dropped from courses. These students must then search for courses they need that are, by that time, full. All of these different problems end up amounting to a large number of student requests for new course sections or courses for which those students have not met the prerequisites.

The traditional approach to this problem is a free-for-all, where students are forced to look out for themselves. The process involves contacting the instructor for the closed course in hopes of gaining permission to register for the course. A student receiving permission would then give the permission form or email to his/her advisor, who would enroll them in the course. This approach floods instructors of popular courses with requests that come in by email, phone, and in person. Further complicating the problem is that instructors are forced to decide which requests to approve or reject. Instructors have to try to determine which students are telling the truth and which are lying in order to get into the course. Since these requests usually come in just before the start of the semester, instructors are busy preparing for courses and have little time to research each request. Therefore, some instructors take the word of the student, who claims that he/she needs the course to graduate.

Also, students who contact the instructor first have a better chance of getting into the closed course over someone else who actually needs the course. Furthermore, students who actually need a course to graduate might not be able to get into the course because the course seating capacity has been reached. This is a result of admitting students not legitimately needing the course to graduate. Another problem is that popular instructors are flooded with requests, while less popular instructors receive far fewer requests. On top of all of these problems is the fact that some students are forced to go to other schools to find a similar course and then hope they will be able to transfer that course into their program of study. It is not uncommon for students to take longer than required to complete their program of study because they are not able to get required courses when they need them.

To streamline the process and reduce the chances of such problems negatively affecting students, a committee was formed to study the problem and develop a Web-based solution to automate the process, one that allowed students to submit a request for each closed course. Each course request was dated, time stamped, and included contact information and specific reasons why the course was needed. Furthermore, students had to provide supporting evidence documenting need. In this paper, the authors outline the design, development, and the initial success of this solution to the problem.

Planning and Design Approach

To address this labor-intensive problem inherent in the traditional approach to the management of closed courses, a committee was formed to study the problem and develop a solution. The committee consisted of five academic advisors and a faculty member with software development experience. Over the course of several weeks, the committee evaluated different solutions to include a process recently implemented by another department within the college to address a similar problem. The solution that the other department implemented involved the use of Survey Monkey, a Web-based survey tool, to gather student requests for closed courses. Their existing solution was evaluated to determine if it could be implemented as is.

Unfortunately, several problems were apparent with this solution, including a lack of uniform data collection, since the survey input form required students to type in the courses they needed, which resulted in input errors such as entry of the wrong course number or section number. Another problem was the instrument's inability to determine the exact number of closed course requests submitted for each course at any given time without downloading all of the requests. This limitation made it difficult for the department chair to quickly determine if a new section of a course should be added to accommodate the requests.

As a result of these limitations, the committee decided that the most appropriate action was to develop a new solution that also uses a Web form, one that would have more features to make it easier for students to complete and afford more tools to allow the department chair to determine, at any given moment, the number of requests for each course. Also, the new solution would allow the capture of more uniform and consistent responses from students, thus reducing the chances of input errors. Lastly, the new solution would allow data to be downloaded in various formats for analysis and approval of valid requests for access to closed courses or additional sections of a course.

To ensure consistency in handling the requests, procedures were developed, approved by the department chair, and implemented. Faculty and students were provided a copy of the procedures to request enrollment in a closed course. Furthermore, a specific request period was selected to identify when requests would be accepted, when they would be evaluated by a team of advisors, and when students would be notified. The committee determined that faculty would no longer be required to accept requests and, therefore, would not be involved in the special add-course request process. This change was presented to faculty at a departmental meeting and approved for adoption in the following semester. The Web form's opening screen provided instructions and useful information such as the open request period dates, notification dates, and where to submit supporting documents.

The link to the form was emailed to students at the beginning of the course registration period and was also posted on the department's website. The new form was developed using Qualtrics, a Web-based survey generation and management tool. The form consisted of text boxes, drop-down lists, and option selection fields for data entry. Table 1 provides a list of the data entry fields used on the form. Students were also instructed to send all supporting documentation to a designated email address.

The request for courses lasted for one week each semester. At the close, the data were downloaded in Excel format and separated by advisors. Over a two-day period, advisors evaluated each request, giving priority to the earliest and most critical requests, such as requests for courses needed to graduate during the current semester. At the end of the second day, all students were notified whether their requests to take the course was approved or denied. Those who received approval to take a closed course were registered for the course. During the request collection period, the department chair and advisors were able to see the number of requests per course by viewing a live report generated from the currently submitted requests. The report enabled the chair and the advisors to better prepare for courses that required new sections.

Table 1. Data Entry Fields Used for Data Collection

Field	Type of Field	Example
Student ID	Text box	B00011110
Last Name	Text box	Smith
First Name	Text box	John
Email	Text box	Smithj@university.mail.edu
Expected Graduation Date	Text box	12-15-14
Major	Drop-down list	Networking
Advisor	Drop-down list	Mike Johnson
Credit Hours Earned	Text box	68
GPA	Text box	3.5
Credit Hours Transferred In	Text box	33
Type of Student (face-to-face or distance education)	Option buttons	Distance education selected
Prefix of Needed Course	Drop-down list	ICTN
Course	Drop-down list	3000 Networking Essentials
Section	Text box	001
DE Course (Yes or No)	Option buttons	No selected
Why course is being requested (Time conflict with another course, Need the course to graduate, part-time student needing full-time status, job, health, family commitment, re-admitted to university, course closed, other)	Multi-option selection	Job and family commitment choices selected

Limitations

There are several limitations to this study. One of these is that the scope of the Web-based solution is limited to one department. Evaluation of this new approach to course requests after implementation in several departments and universities would have produced more accurate results of the effectiveness of this solution. An additional limitation of this study is the lack of student satisfaction data, which could be used to evaluate the effectiveness and acceptance of this approach. A survey of students having completed this survey would have helped determine if this approach is truly welcomed by students and would have identified any suggested improvements to the Web-based form.

Also, the long-term effects of this approach on course management are not readily available, since this study was limited in scope and in the data collection period. Data collected over a longer period of time could be used to determine if students remained in the same programs or completed their program on time and would have produced a more accurate assessment of the Web-based tool. Another limitation of this study is the lack of evaluation of other systems and procedures implemented at other locations that address similar problems. Due to the lack of funds, this study was limited to the department's ability to develop an in-house solution. Since the university already had access to the Web-based survey tool, development of the new solution did not incur any new expenses.

Conclusions and Recommendations

Although the initial introduction of the new approach was met with some resistance by faculty who did not want to give up control of the decision to allow students into their courses, the new approach and associated procedures were adopted and implemented without any notable difficulties. During the first semester of use, a small group of students attempted to request access to closed courses using the traditional approach. They were advised of the new procedures and were able to submit their requests within the time period. The adoption of the new approach significantly reduced confusion as to how many students were added to closed courses, whether the physical seating capacity was exceeded, whether students needing access to closed courses to graduate gained access to those courses, and whether students were being honest about the need for courses because they had to provide evidence supporting their reasons for the requests. Since approximately 200 requests for closed courses were received each semester during a time period when instructors were preparing for the upcoming semester, the implementation of the new approach and Web-based data collection tool allowed instructors to concentrate on other critical course preparation tasks.

Also, the new Web-based tool enabled the department chair and advisors to quickly determine whether new sections were needed before the request period even ended. This allowed the department chair to find additional instructors and add new sections in advance, which reduced the chances of last-minute changes to student and faculty schedules. Another benefit of this approach to the management of closed courses was the improved visibility of the process. The data obtained during the closed-course request periods can now aid in determining if certain patterns of student problems in registration are evident and allow for appropriate action.

Students and faculty appear to embrace the new procedures and Web-based tool. Informal feedback from students and faculty indicated that the new approach is a sound solution to a problem many institutions likely encounter. Also, by the second semester of use, it was evident that confusion about requesting access to a closed course was reduced. This reduction in confusion could be attributed to the direct communication with students and faculty about the new procedures and Web-based tool. Despite the apparent success of this new approach, more research is needed to determine if it is effective in different departments and universities. Studies involving multiple departments and universities would help evaluate the appropriateness of this approach to a common problem, and longitudinal studies over time would also help determine the effectiveness of this approach.

Furthermore, other solutions should be developed that connect student closed-course request tools to student course registration systems. The student request process should be streamlined so that when a student attempts to register for a closed course, he/she is prompted to enter the reasons for needing the closed course and upload supporting documentation. Also, solutions should be developed that connect student advising, registration, and requests for closed courses. Student programs of study should be populated and managed with the aid of advisors. Pre-populating lesson plans will help department chairs plan for the number of sections needed for each course in advance of registration periods. This would help reduce the number of requests for closed courses and the need to cancel courses with low enrollments. While student interest in programs and other factors may affect the number of sections needed at any given time, integration of these processes through information technology is likely to lead to better visibility and management of all processes involved.

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A PROTOTYPE DISTRIBUTED FRAMEWORK FOR IDENTIFICATION AND ALERTING FOR MEDICAL EVENTS IN HOME CARE

Gary Holness, Delaware State University; Leon Hunter, Delaware State University

Abstract

The confluence of low-cost embedded sensing and pervasive Internet access and algorithms for machine perception has the potential to revolutionize home healthcare. Wireless connectivity for devices such as inertial measurement units (IMUs), heart monitors, blood O_2 sensors, and glucose monitors provides a method for valuable web-accessible continuous monitoring data that can be used as the basis of indicators for unfolding medical issues in a home care setting. A number of engineering issues were solved in developing a prototype service implementation using a widely available open source hardware reference implementation, the Arduino/eHealth Sensor, for intelligent medical monitoring targeted for home care environments. This system fits within a larger distributed framework for medical monitoring. In this study, a number of important undocumented technical issues were solved by implementing a stable medical monitoring platform, whose sensors are accessible using a typical web browser.

Introduction

Aging in place, or the ability to live in one's own home or with family throughout the senior years, is a viable model for reducing strain on long-term care facilities in addition to improving quality of life for the chronically ill. In-home care is also a viable solution for easing the impending burden on the healthcare system imposed by an aging population. The key to improved management and outcomes for care of chronic illness such as diabetes, heart disease, stroke, and Alzheimer's disease includes regular visits with home-care and allied health professionals for the measurement and assessment of vital statistics. Too often, in practice, the day-to-day management of care rests on the patient and his or her family [1]. Depending on his or her condition, a typical elderly patient managing chronic illness can expect only a handful of weekly visits from a home healthcare nurse. While family care is certainly an option, more households from the so-called sandwich generation find themselves caring for both their children and their elderly parents, while balancing a career. All of this results in decreased quality of care because subtle changes in health status are easily overlooked.

Industry trends have begun to see wireless devices such as inertial measurement units (IMUs), heart monitors, blood O2 sensors, and glucose monitors provide valuable continuous monitoring data that can be used as the basis of indicators for unfolding medical issues [2]. Armed with such tools, a patient's healthcare team (physicians, allied health, and family) would be better able to coordinate early intervention before an issue degrades into a catastrophic event. The proliferation of sensing devices and low-cost embedded systems has spurred the growth in sensory technologies and perceptual robotic systems. Today, the emergence of perceptual applications has impacted consumer applications such as face detection in digital cameras, location monitoring in smartphones, and player motion detection in video game consoles. Machine perception can provide the eyes and ears that monitor daily patient activities and vital measurements, while robotic assistants serve as the remote helping hands capable of assisting in the performance of daily activities and certain interventions.

What began in 2005 as a tool for students to experiment with embedded systems, the Arduino platform has grown into a worldwide community of relatively inexpensive controller boards, sensors, and accessories that has fueled embedded systems development in do-it-yourself, hobbyist, and research communities. Because hardware schematic software libraries are freely available through open source licensing, similar to the community of Linux and Linux-based applications, it is inevitable that Arduino-based systems and products will appear in the commercial marketplace. Experiments describe an effort to build a prototype system based on the Arduino platform purposed with building tools for medical monitoring within home-care environments.

System Platform

The Arduino platform consists of a family of processor boards differentiated by the processor speed, type, amount of random access memory (RAM), and input/output (I/O) signal lines [3], [4]. Completing the hardware development platform is an integrated development environment (IDE) consisting of a C++ like language and software library. Arduino programs are specified using well-defined function entry points that support system initialization, periodic processing, setting and reading of I/O lines, and simple interrupt handling. Arduino processor boards are customized for specific applications through daughter-boards (or shields) that connect by interfacing their signal and control lines with the Arduino processor's I/O lines. A growing community of vendors have contributed shields that add diverse capability to the Arduino processor for capabilities such as GSM communication, Wi-Fi Communication, motor control, temperature sensing, medical sensing, moisture detection, etc. A prototype was built in this study that interacted with the Arduino platform in conjunction with an eHealth Sensor available from the Libelium Corporation (http://www.cooking-hacks.com) for experimentation with medical monitoring.

This system consisted of an Arduino Uno revision 3 processor board, an eHealth Sensor Shield, a ZigBee wireless communication shield, and a Roving Networks RN-XV Wi-Fi Module (see Figure 1). The Arduino board provides processor, memory, and I/O and is programmed through a USB cable attached to a host computer running the Arduino IDE software development platform. The eHealth Sensor Shield provides signal lines and interfaces to an array of medical sensor devices including electrocardiogram (ECG), Airflow, Accelerometer (patient position information), glucometer, Pulse-Oximeter, and Galvanic Skin response (moisture/perspiration). The ZigBee shield provides wireless communication using the ZigBee radio standard (IEEE 802.15.4) and the RN-XV module implements Wi-Fi compliant (IEEE 802.11) communication using the ZigBee shield. The eHealth Sensor and ZigBee shields plug into the Arduino's signal lines in a stack (see Figure 1). The RN-XV module plugs into a socket on the ZigBee shield.

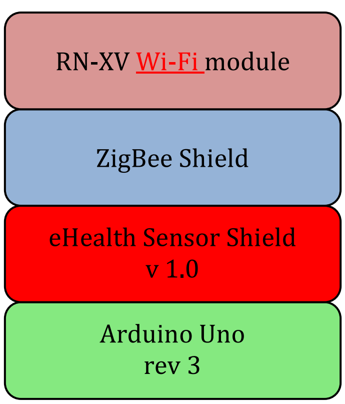


Figure 1. Arduino/eHealth Sensor/Wi-Fi Hardware Platform

The software environment consisted of an IDE for use in development of programs for the Arduino platform. Associated with each add-on shield is a software library that is added to the IDE software environment in order to extend it with libraries for controlling and interacting with the shield through program implementations. While the reported experiment employed the credit-card-sized Arduino Uno processor board for its price and availability, the longer-term goal was to target the application for smaller, more miniaturized Arduino platforms such as the stick-of-gum-sized Arduino Nano [4]. Because of limited memory resources on the ultimate target platform (Arduino Nano), care was taken in the design to reduce the software memory footprint. In order to conserve valuable limited program storage space, add-on software libraries employed in this current prototype system were limited to the eHealth Sensor library, as it was absolutely necessary for reading and controlling the medical sensors attached to the eHealth sensor board. The functions for communication were implemented through the Arduino platform's Serial library. The prototype was built using the Arduino IDE software and libraries contained in version 1.0.5. A program for an Arduino board and shield, or sketch, consists of arbitrary programs that are run from a handful of well-defined execution entry points. These consist of routines resembling standard C++. Arduino programs are executed from three specific entry points and interrupt handlers. The four entry points and their execution semantics are:

- void setup()- called once when Arduino is started and used to initialize the system
- void loop()- called periodically as Arduino is running and used to run the system
- void serialEvent()- called whenever information is available on the Arduino's UART (serial interface)
- void interruptHandler()- function name is user-selected and the execution can be triggered with a signal input rising or falling

The Arduino Uno board employs a Universal Asynchronous Receiver/Transmitter (UART) circuit for input/output (I/O) connections. The UART is used to get data from the Arduino's attached peripherals (sensors) off the board communicated to the outside world as well as getting data communicated from the outside world (Wi-Fi, USB, or serial port) onto the board.

Software Framework

The software design goal was "pluggable connectivity", where component services interact with each other for the formation of a pipeline of components that measure, store, process, and disseminate monitoring data (see Figure 2) [5], [6]. This approach gave flexibility in introducing new capabilities as well as separation of concerns for distributed application development including sensing, storage, processing, and dissemination, in a scalable approach [7].

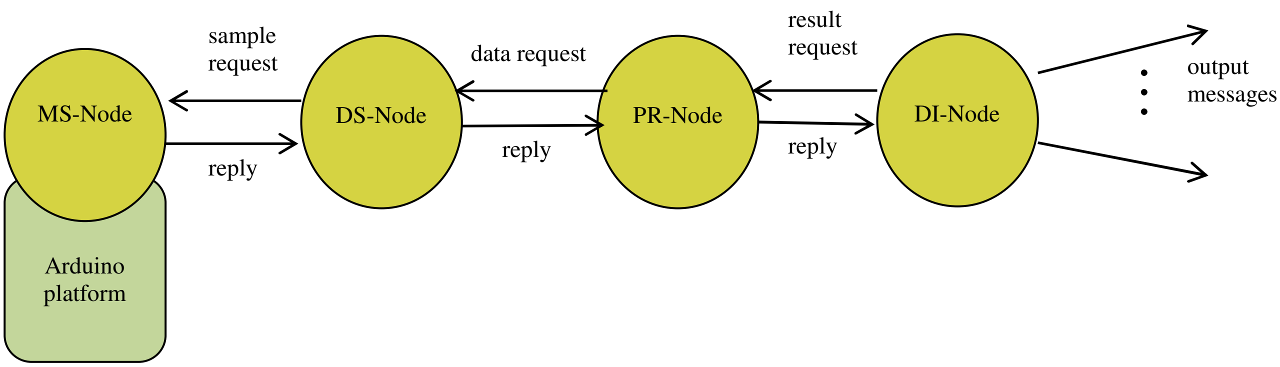


Figure 2. Pluggable Service Pipeline

The components take form as services that exchange messages in a type of pipelined architecture. The services (or nodes) include capabilities for measurement or sensing, storage, processing, and dissemination. Because nodes in the pipeline implement both client (request initiation) and service (request servicing) roles, the system is best described as a peer-to-peer (P2P) distributed processing pipeline. The measurement service (or MS-Node) consists of a web service running on an instance of the Arduino/eHealth/Wi-Fi (see Figure 1) platform hardware. The MS-Node was designed as a web-server. The choice of implementation as a web-server facilitated debugging using a standard web-browser. The web-server accepts incoming HTTP requests, parses and executes the request, and returns an appropriate response. The other nodes in the pipeline are implemented in, but not limited to, the Java programming language.

In order to minimize the run-time memory footprint, the MS-Node server internals were organized as a finite state machine (FSM) that directly accesses the Arduino's UART serial interface rather than relying on communication libraries (such as the WiFly library). When issued an HTTP request, the web-service returns an HTTP response containing sensor readings for each of the attached medical sensors. The added benefit of supporting HTTP in the MS-Node is its accessibility from any standard web-browser or client. The storage process consists of a data storage peer that retrieves measurements periodically from the MS-Node. The DataStorage peer (or DS-Node) is configured at run-time in this prototype by specifying the MS-Node IP address on the command line at run-time. The processing peer (or PR-Node) inputs data samples from the DS-Node, runs a processing computation on the data, and produces a result. In this current example prototype, the PR-Node implements a simple average. Future versions of the PR-Node will consist of algorithms for predictive modeling. Finally, the Dissemination peer (DI-Node) inputs results from the PR-Node and delivers them to users. The PR-Node in the current prototype implementation outputs information to the console. Future versions of the PR-Node will send outputs through email, SMS Alerts, or social media. Details of the Measurement Node follow.

The MS-Node is implemented using the subset of C++ supported by the Arduino 1.05 programming environment, while the DS-Node, PR-Node, and DI-Node are implemented in the Java programming language. Each node type that accepts incoming requests (server role) implements a standard TCP/IP server. Each node type that initiates requests (client role) implements a standard TCP/IP client. Default values for TCP/IP connections in Java were used for the DS-Node, PR-Node, and DI-Node. The MS-Node made use of the Arduino's server-side TCP/IP idle timeout for connection management. The prototype implementations perform the following high-level actions:

MS-Node:
1. accept a measurement request
2. obtain readings from medical sensors attached to the Arduino
3. compose a response
4. return a response

DS-Node:
1. initiate a request to the MS-Node for sensor reading
2. parse the HTTP response and extract sensor measurements
3. store record in memory
4. respond to data requests

PR-Node:
1. initiate a request to the DS-Node for historical measurements (default of 10)
2. parse a response
3. compute an average
4. store the computed result (current average) in memory
5. respond to processed data requests

DI-Node:

1. initiate a request to the PR-Node for the computed result
2. parse the response
3. print the computed result to the console

Measurement Node

The MS-Node implementation takes the form of a finite state machine that parses incoming requests arriving over the UART/Serial interface of the Arduino platform. In the current prototype implementation, the FSM implements a parser that extracts the filename from an HTTP get request [8]. Currently supported is a request for the index.html file. In response to this request, the MS-Node composes an HTTP response message containing a web-page (HTML text) with readings from all sensors attached to the Arduino platform. Future implementations will support requests for individual web pages corresponding to the individual sensors. These will include the non-invasive medical sensors because experiments received institutional review board (IRB) approval to run human subject trials for non-invasive experiments only. Noninvasive medical sensors included a Pulse Oximeter (spo2.html), temperature sensor (temp.html), electrocardiogram (ecg.html), blood pressure sensor (bp.html), airflow sensor (air.html), and accelerometer/position sensor (pos.html). The grammar describing the HTTP request implemented by our FSM parser follows:

HTTPRequest → Operation HeaderLine "\r\n"
Operation→ OP Resource Version "\r\n"
OP→ "GET"
Resource→ <file-path>
Version→ "HTTP/1.1"
HeaderLine→Name ":" Val "\r\n" |
Name ":" Val "\r\n" HeaderLine
Name→ <valid-header-type-string>
Val→ <valid-header-value-string>

The FSM Parser was implemented as a standard left associative linear recursive (LALR) parser with 1-token look ahead [9].

Prototype, Experiments, and Experiences

The MS-Node was tested on a standard Wi-Fi network that was open (no authentication) for ease of connectivity. The MS-Node was also tested using authenticated access (WEP, and WPA). A pipeline of processing from MS-Node to DS-Node to PR-Node to DI-Node was made through a series of TCP/IP connections. The focus of this experiment was to build the basic plumbing for the distributed framework (nodes), where the majority of the effort was focused on a more complete implementation of the MS-Node. This choice was made because the MS-Node involved a hardware-software codesign.

Configuring the Wi-Fi connectivity was performed by connecting to the Arduino Platform using a terminal over the serial port and entering configuration commands. Because the Arduino-to-host interface was USB, software was installed to map USB devices to serial ports. This allowed the use of unmodified terminal emulation software to connect to the Arduino. An important detail uncovered through substantial reverse engineering and trial and error not described among vendor documentation for the ZigBee Shield is that, in order to connect to or upload programs, the shield must be set to USB mode. When in USB mode, the interface between the ZigBee Shield and the Arduino UART/serial is redirected to the USB port mapped to the serial port of the attached host computer for downloading programs to the Arduino. What this means is that, while programming and testing the system, inputs to the Arduino's serial interface will come from the host computer's Serial-mapped USB port. Likewise, outputs from the Arduino's serial interface will be sent to the host computer's serial-mapped USB port. Care was exercised in ensuring that the ZigBee Shield's jumper connectors were set such that the board was placed in USB mode. Once in USB mode, from a terminal emulation program, the network parameters of the ZigBee Shield/ RN-XV Wi-Fi hardware were configured. This was accomplished through the following commands (text following // are comments):

```
$$$                     //put ZigBee Shield/RN-XV
                        //into command mode

set ip protocol 1\r     //TCP/IP allowing
                        //incoming/outgoing connections

set ip localport 80\r   //local TCP port is 80 (for HTTP)

set wlan ssid SSID\r    //set network name to SSID
                        //of experimental network
                        //substituting SSID for your own
                        //network's SSID

set wlan auth 0\r       //no authentication

set wlan join 1\r       //join automatically after power up

set comm idle 1\r       //close TCP connection server
                        //side after 1-sec idle

set comm remote 0\r     //turnoff automatic greeting msg
                        //for TCP connection
```

join Robots\r	//join network now
show net\r	//display networking //configuration parameter values
save config\r	//save settings to filename //"config" to be read at boot
exit\r	//exit command mode

Another important undocumented point is that once you have configured the communications shields (ZigBee/RN-XV), they must be removed before loading the web service program to the Arduino. Failure to do so will cause your uploaded web service program to overwrite any ZigBee-specific configurations if there are any programmatic Wi-Fi commands in your Arduino sketch.

At the end of any TCP/IP connection between a client and the server it is important to close the server-side connection. There was a serious issue concerning closing the TCP connection on the server. To do so required programmatically switching the Arduino to command mode by sending a "$$$" control character sequence without a <CR-LF> at the end of the string. Once in command mode, the string "close\r" with a single <CR> at the end of the string closes the connection and then and "exit\r" command must be given to programmatically exit command mode on the Arduino.

The problem stems from the method that Arduino uses for its UART/serial interface. When running as a web Server, the ZigBee/RN-XV is also (similar to the board's USB port that to the host) interfaced to the Arduino through its UART/serial interface. This means that incoming data over Wi-Fi passes through the UART to the serial interface. Reading the serial interface on the Arduino accesses this data. Responses from the Arduino communicated to the outside world are sent through its serial interface to the UART on to the ZigBee/RN-XV and out over Wi-Fi.

The problem with switching to command mode, closing the TCP server-side connection, and exiting command mode programmatically is that these are achieved by a special print command, namely Serial.println(), which binds formatted outputs to the serial interface. The same print function results in data being sent through the serial interface. The resulting issue is that the control commands appear in the server's output at the end of the HTTP response message (see Figure 3). Because these commands do not belong in the formal definition for a valid HTTP response, the client/browser on the other end of the TCP web connection interprets them as an ill-formed HTTP response.

Figure 3. Closing TCP Connection via Command Mode Pollutes HTTP Response

Depending on the browser type or client, the response is interpreted as invalid. A method for closing server-side TCP connections that do not have this problem was uncovered through reverse engineering then developed and tested. The method used the TCP idle timer for closing server-side connections instead of programmatically closing them using the ZigBee/RN-XV's command mode (the method published in technical documentation is to use command mode). After testing, this approach was found to be very reliable for closing server-side connections (see Figure 4).

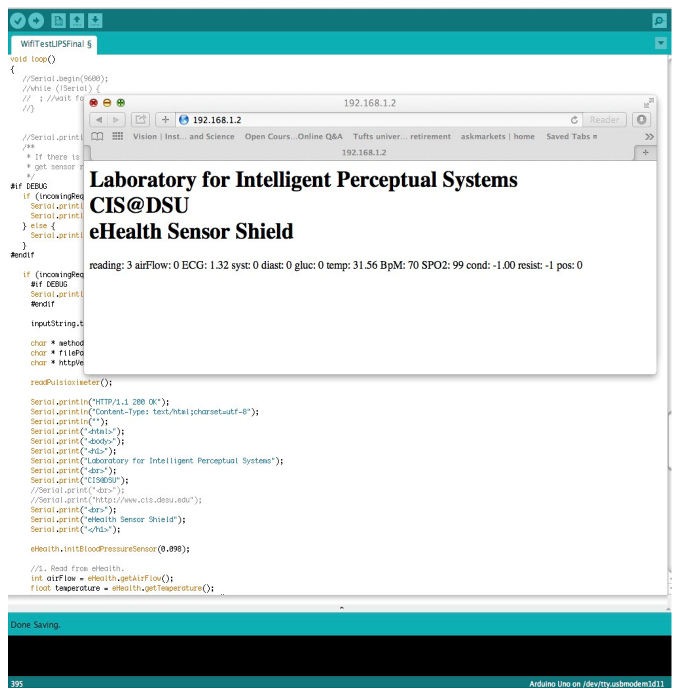


Figure 4. Using TCP Idle Timer Reliably Closes Server-side TCP Connection

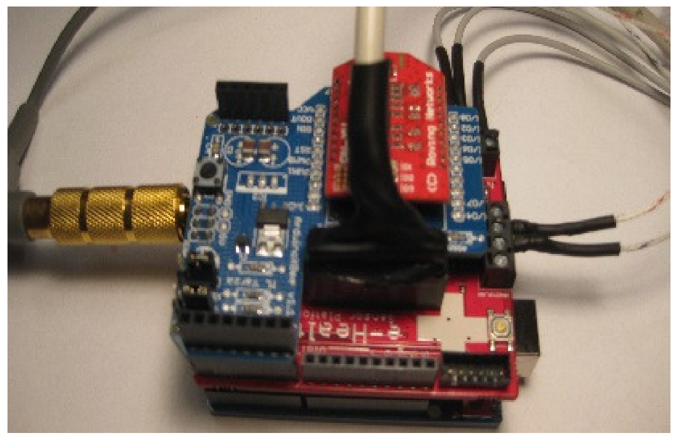
Because inbound data arrive through a serial interface it was important to store inbound messages on the server in a buffer before operating on them with the parser. The serialEvent() routine is a built-in interrupt handler for the Arduino platform. It is triggered whenever data are available to the serial interface via the Arduino's UART. This trigger was used to fill a buffer with the character data from the incoming HTTP request. When attached to the ZigBee/RV-XN/Wi-Fi shield, incoming data over the Wi-Fi network reached the Arduino processor through the UART. From the UART, data were stored in buffers accessible using the Arduino's serial interface. Programmatically, HTTP responses are implemented by sending data through the Arduino's serial interface. Such outbound data then pass through the UART to the ZigBee/RV-XN/Wi-Fi shield and out to the requesting client as an HTTP response over the network. Browser interaction with the MS-Node was tested using both Safari on MacOS X, Firefox on MacOS X, and Firefox on Ubuntu Linux 12.04 LTS. Wireless connectivity (Wi-Fi) was tested using a Cisco Aironet 1142 router operating in open mode (no authentication) and an ActionTech MI424 operating in open mode and authenticated (WEP 128) mode.

Discussion

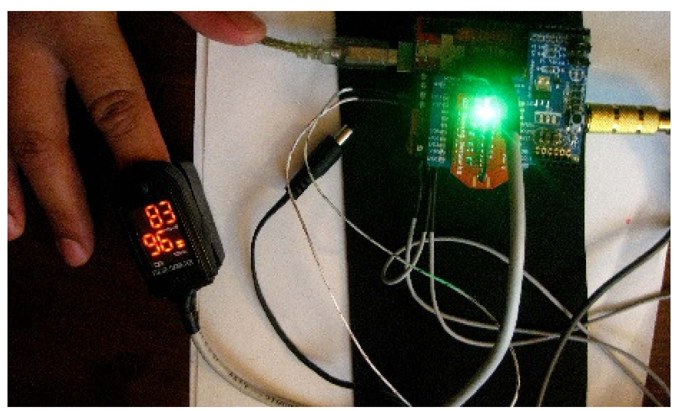
The experiments validate a prototype implementation (see Figure 5) and successful solutions to a number of important undocumented practical issues for the Arduino/eHealth Sensor/ZigBee RN-XV hardware stack that participates within a larger distributed framework intended for medical monitoring for home care environments. The prototype takes form as a web-service Measurement Node (MS-Node) that responds to a HTTP GET request and responds with properly formatted HTTP responses as well as simple DS-Node, PR-Node, and DI-Node peers that implement a peer-to-peer distributed processing pipeline. The HTTP response of the MS-Node contained information sampled from health sensors interfaced to the Arduino platform. Many months were invested investigating, reverse engineering, and hacking the platform in order to resolve issues largely undocumented in vendor's technical documentation as well as the worldwide Arduino development community. Particularly, the research addressed critical issues of how to get the platform to connect automatically to the network. The most reliable approach was to manually configure the platform, store the configuration and retrieve and apply it under program control.

A pure programmatic solution to configuring the hardware to attach to the network was not reliable. This stemmed from timing issues concerning contacting a local Wi-Fi access point, the electrical noise in the environment around the system, and a relatively low power antenna on the ZigBee module. Also, using command mode to close TCP connections (the only documented method in the vendor documentation) polluted the server's HTTP response message with the command string sequences. Using the TCP idle timer provided the perfect method for reliably silently closing the server-side TCP connection.

(a) SP02, Temperature, ECG, and Airflow Sensors (left to right)



(b) Arduino Platform, eHealth Sensor, and ZigBee/RN-XV Platform Stack



(c) System in Operation Platform, System Operation

Figure 5. Prototype System in Operation

Future versions of the distributed framework will include implementation of more sophisticated processing capability for the PR-Node, including a library for linear interpolation, Gaussian Processes, and pattern recognition for streaming data. Moreover, the storage node (DS-Node) in future implementations will include database-backed persistence. Finally, the dissemination node (DI-Node) in future implementations will include targeted wide-area communication through mechanisms such as integration with the Twitter APIs.

The Arduino platform is relatively stable and future experiments will add features for retrieving individual sensor readings by implementing access to multiple server file system objects, one for each sensor. The platform is a promising system that participates easily within this distributed pipeline framework. Further information about the project may be found among the web pages for the Laboratory for Intelligent Perceptual Systems at Delaware State University (http://www.cis.desu.ed).

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Biographies

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INFORMATION SECURITY RISK AWARENESS BASED ON CATEGORIES

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Abstract

Almost 80 percent of computer users are affected by some type of security threat, due to unawareness about security. Different studies show that it is understood that most businesses do not receive enough information security consulting from within and/or outside the organization. In addition, it was found that most businesses are not sufficiently involved in information security standards to be able to implement them in their organizations. Billions of dollars are spent yearly on computer security, because it ranks as the world's number one concern. It has also been reported that awareness of information security is the key to understanding various information security threats and to perceiving vulnerability related to these threats.

The increasing utilization of information technology is affecting the status of information security and is gradually becoming an area that plays an important role in everyday life. The term "information security" is more commonly used to describe the tasks of protecting information in a digital format. Information security threats are events and actions that present a danger to information assets. Information security is included in organizations, the public, sociopolitical, computer ethical, and institutional educational dimensions. For this reason, information security should be taken very seriously; the rules should be read and followed. This project involved the collection of various risk factors that could result in great losses to businesses, industries, institutions, and their employees, if information is breached. The focus of this research was based on prior literature reviews identifying the factors that contributed to security risk of industries, educational institutions, and employees. The research developed the security awareness risk model (SARM), which includes risks as well as losses and outcomes.

Introduction

Security's role is much more important today than it was years ago. Billions of dollars are spent yearly on computer security, because it ranks as the world's number one concern. Although bundles of money are spent on security, the number of attacks is continuing to increase. It has been reported that the lack of compliance with an information security policy is due to unavailability of the policy [1], [2]. It has also been reported that awareness of information security is the key to understanding various information security threats and to perceiving vulnerability related to these threats. However, an understanding of threats alone seems not to be enough to motivate action [3], [4]. Information security is a critical issue that many firms currently face; while increasing incidents of information security breaches have generated extensive publicity, previous studies repeatedly exposed low levels of managerial awareness and commitment, a key obstacle to achieving a good information security posture. In fact, it has been reported that a reason why information system security incidents and abuses continue to plague organizations is that employees are the weakest link in ensuring information systems security: they constitute an insider threat to their organizations [5], [6].

Computer users should be aware of the risk factors involved in security and should be knowledgeable of the steps that can be taken to reduce the risk of becoming a victim to security breaches. Receiving or sending incorrect data could result in security problems such as system crashes that can severely damage or erase valuable data. Fraud and theft are two common risk factors that are often undetectable. It is important to use passwords and security codes to ensure that those who have access to certain information have permission and are trustworthy. Viruses, worms, and Trojan horses are malicious codes, uninvited software that can damage information. It is vital to maintain certain spyware and security protection software to limit the chance that information will fall prey to this type of program. Employees are still involved in risky behaviors that put businesses at risk, despite the security policies, standards, awareness strategies, and tools currently in place. Security-related behavior in the workplace has recently been a major focus in the information systems literature [7], [8].

Positive and negative security-related behavior in the workplace is a major focus in information systems literature. Studies reported security-related behavior to be inconsistent and sometimes contradictory, when relating the effects of some factors such as sanctions [9]. Employees violate policies, creating threats to businesses or organizations, due to unawareness. Some threats are created intentionally and some unintentionally. In this current study, the author developed the security awareness risk model (SARM) to identify the factors that provoke security risks and losses for businesses, industries, educational institutions, and employees.

Security Awareness Risk Model (SARM)

The focus of this study was based on prior literature reviews identifying the factors that contributed to security risk of industries, educational institutions, and their employees on the basis of the risk model, presented in Figure 1. Several factors associated with security have been reported in different studies. These factors were implemented in these previous studies on protecting information in digital format involving losses and outcomes. The security awareness risk matrix (see Table 1) includes the risks as well as losses and outcomes.

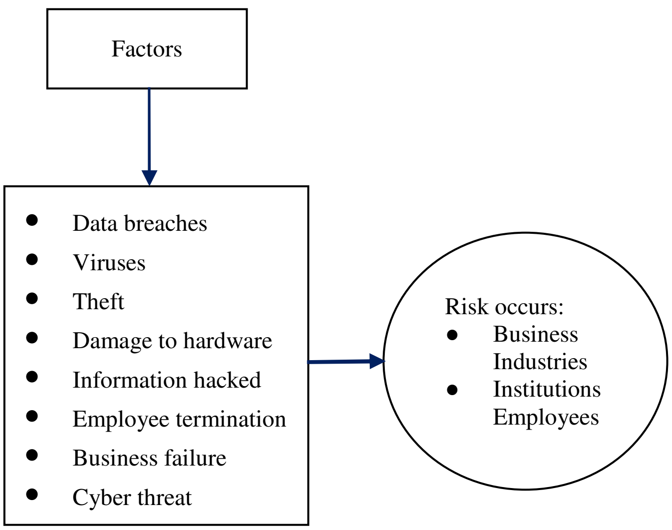

Figure 1. Security Awareness Risk Model (SARM)

Results

All of these factors are based on the categories (see Table 2), and associated risks or threats are linked with losses of personal information that may damage the infrastructure of industries and reputation of institutions. Even though information collected from industries, educational institutions, and their personnel is protected by the United States Information Security and Federal Information Security and Data Breach Notification Laws, this information may be breached [10], [11].

Recommendations

Most of the discussion in the literature focuses on prevention techniques by using technical countermeasures; therefore, organizations should optimize their limited resources. In this study, the author investigated various risk factors, due to noncompliance standards of security, unawareness of the policies, and ignorance of business security risks.

In future work, how security strategies are developed and utilized in organizations will be explored. Therefore, personal interviews and surveys will be conducted to validate the various risk factors that could result in great losses for those areas indicated in Table 1. All participants in the focus groups will be related to the positions such as security manager, IT manager, security consultant, security research, and development director, and they will be required to have more than four years' of experience. Moreover, detailed recommendations will be shared with them after compiling

Table 1. Security Awareness Risk Matrix

Category	Reported Factors	Risk / Threat	Losses / Outcomes	Prior Literature
Lack of awareness	Employees causing problems to businesses Cybercrime attempts	Employees could be terminated Businesses could fail Data breaches Personal information could be hacked	Businesses will become victims Revenue compromised Spending increases Security failure Drive repair Head crashes	[3, 12, 13]
Security-related behavior	Policy violation Computer abuse	Viruses Theft Damage to hardware	Profits compromised May be sued Student enrollment decline	[6], [9]
Lack of compliance	Security rule compliance is not being met Failure to change passwords Failure to update security patches Failure to backup	Information could be hacked Employees could be terminated Businesses could fail	Decreasing of employees and business	[1, 5]

the data to improve awareness of security risks and increase the usage of security mechanisms in the organization.

Table 2. Security Awareness Risk Matrix: Categories

● Lack of awareness: — vulnerable to cyberattacks and malicious information technology (IT) — vulnerable to cyber threats — loss of revenue — facilitate exploitation, revenge, economic, political, or social harm and disruption — damage to IT assets — possible perpetrators of malicious IT recovery costs — related cost of avoiding cyberattacks
● Lack of compliance: — individual responsibilities — facilitate exploitation, revenge, economic, political, or social harm and disruption — damage to IT assets — possible perpetrators of malicious IT recovery costs — related cost of avoiding cyberattacks
● Security-related behavior: — avoidance behavior — safeguard resources — facilitate exploitation, revenge, economic, political, or social harm and disruption — damage to IT assets — possible perpetrators of malicious IT recovery costs — related cost of avoiding cyberattacks

Conclusion

Privacy policy information is a priority and policies are constantly being upgraded and revised in order to maintain confidence and trust. Protecting computerized information is a major concern and reality today. This project involved the collection of various risk factors that could result in great losses for those areas indicated in Table 1. One is not always aware of how this information can be violated and the resulting ripple effects that can occur. All parties and entities involved should become aware of and engage in secure behavior, and comply with security policies. These steps should be taken to safeguard and avoid misuse, abuse, and destruction of computer digitized information. More educational security awareness programs should be introduced and included in everyday practices, thereby resulting in a greater compliance with security rules. Due to the seriousness and sensitivity of information security, it is very important that industries, institutions, and employees understand and comply with all security policies and provide a safer and more secure working environment by implementing their own SARM.

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Biography

SYED RAZA is currently a Computer Information Systems instructor at Trenholm State Technical College. Recently, he completed his leadership montgomery training. During his training, he was involved in different community services and addressed issues in higher education and business industries. He also has over 15 years' of experience as an educator and software engineer. Dr. Raza may be reached at sraza@trenholmstate.edu

RISK MANAGEMENT FRAMEWORK IN CLOUD COMPUTING SECURITY IN BUSINESS AND ORGANIZATIONS

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Abstract

In this paper, the authors present an overview and the benefits and security challenges of cloud computing. The main problem is that several security risks and problems occur when using cloud computing on both sides: users and providers. These problems can decrease the level of trust between the users and providers. Also, as more security incidents occur, more people are worried about using the cloud. In terms of providers, they need to be able to detect and deal with security risks and problems before and after they occur. Thus, a risk management plan for dealing with a few security issues is proposed from the cloud provider's perspective. The two main goals of this study were to increase confidence between the users and cloud provider and to increase the use of cloud computing at all levels.

Introduction

Cloud computing technology has rapidly developed. Widespread application is anticipated in social, business, and computing aspects. Cloud computing changes the Internet into a new computing and collaborative platform. It is a business model that achieves purchase-on-demand and pay-per-use on a network. Many competitors, organizations, and companies in industry have jumped into cloud computing and implemented it.

Despite all of the advantages cloud computing provides, such as convenience, reduced costs, and high scalability, there are a number of enterprises, individual users, and organizations that still have not deployed this innovative technology. Several reasons have led to this problem; however, the main concern is related to security, privacy, and trust. In 2009, Rittinghouse and Ransome [1] performed an international classification of diseases in which they examined 244 IT executives/CIOs and their line-of-business colleagues about their opinions of cloud computing usage. They found that security is the greatest challenge to using the cloud [1]. Low trust between users and providers is reported in the literature. It is important to note that choosing cloud computing assumes a high degree of trust between the organization and its provider, as the provider will be trusted with sensitive information and security details. In an attempt to solve this problem and increase the investment and adoption of this technology, the authors provide here a comprehensive cloud computing, risk management framework based on previous work. This framework can be applied in small and large enterprises, organizations, and companies.

Cloud computing has become popular in the IT industry. Among various virtual ways to deliver computing resources and services is the cloud computing provider, which is one of the best self-services of the Internet infrastructure. Cloud computing is a virtual server available over the Internet that enables the user to access computing resources and services, regardless of time and place. Well-known cloud computing providers include Amazon Web Services, Microsoft Windows Azure, and Google's Google App Engine. The two main purposes of using cloud computing are to maintain data and get applications. In fact, cloud computing has improved rapidly and is used widely, especially in the business field. However, there is no agreement on the definition of cloud computing. Vaquero et al. (as cited in Qaisar and Khawaja [2]) defined cloud computing as:

> A large pool of easily and accessible virtualized resources (such as hardware, development platforms and/or services). These resources can be dynamically re-configured to adjust to a variable load (scale), allowing also for an optimum resource utilization. This pool of resources is typically exploited by a pay-per-use model in which guarantees are offered by the infrastructure provider by means of customized service-level agreements. (p.1324)

Moreover, the National Institute of Standards and Technology (NIST) defines cloud computing as "a model for enabling convenient, on-demand network access to a shared pool of configuration computing resources that can be rapidly provisioned and released with minimal management effort or service provider interaction" [3]. In the 1960s, John McCarthy introduced the fundamental concept of cloud computing. He believed that "computation may someday be organized as a public utility." The term cloud came from the telecommunications world, where telecom companies started offering high quality virtual private network (VPN) services at a much lower cost [4]. By using VPN services, these companies can switch traffic to balance utilization of the overall network. Now, cloud computing extends this to cover servers and network infrastructure.

Cloud computing has numerous advantages for providers, adopters, and users. Gupta et al. [5] reviewed a number of empirical studies on the usage and adoption of cloud computing by small and medium enterprises or small and medium businesses (SMBs) and found that cost reduction, avoiding natural disasters, sharing and collaboration, trust in cloud providers, reliability, security breaches, and service disruption are the most important parameters. They stated that "One of the biggest advantages of moving to cloud computing is the opportunity cost of freeing up some of the IT administrative time, which can now be applied to the business aspects of growing the core business of SMBs." Jadeja and Modi [4] provided five benefits of cloud computing: easy management, cost reduction, uninterrupted services, disaster management, and green computing. In addition, Brohi and Bamiah [6] revealed that cost reduction, easy scalability, and increased productivity are the main advantages of applying cloud computing [4]. Accordingly, cost reduction, ease of use and convenience, more productivity, reliability, sharing, and collaboration are the highlighted benefits of applying cloud computing.

As with any new concept, cloud computing is facing several critical issues, the most important of which is security. Tan and Ai [7] said that the "Gartner survey showed that more than 70 percent of respondents said they do not intend to use the cloud computing at recent, the main reason is afraid of the data security and privacy." They also stated that a large number of Google users' files were leaked in March. Aleem and Sprott "interviewed 200 Information and Communications Technologies professionals worldwide. Respondents' most cited concern regarding the use of cloud computing was security, as reported by 93.4 percent of interviews" (as cited in Hutchings et al. [8]).

Brohi and Bamiah [6] stated that "According to a survey conducted by International Data Corporation (IDC), 53% of organizations in the Asia-Pacific region are already using some form of cloud computing services, and the remaining 47% of the organizations have plans to adopt private or public cloud services in the next 12 months." Additionally, they revealed that the survey results indicate that cloud computing is not a highly adopted technology; however, the growing contributions by researchers and IT industries will increase the use of cloud computing globally. As the number of security incidents continues to increase, more people are worried about using the cloud. Many studies and researchers have addressed cloud computing threats and other problems.

Threats

Although many cloud computing users tend not to worry about doing backups, keeping hackers out of their data or providing more virtual storage space, there are still various risks that users might not realize. Security is a significant problem. Cloud computing contains important and sensitive data such as personal, government, or business data, that attract hackers' attention. Therefore, the cloud computing system must be protected more carefully than the traditional system. The traditional security mechanisms cannot protect the cloud system entirely [9]. Some of the main security problems include data security, user data privacy protection, cloud computing platform stability, and cloud computing administration [9]. In 2008, "the U.S. information technology research and consulting firm Gartner issued a 'cloud computing security risk assessment' report, mainly from the vendor's point of view about security capabilities analyzed security risks faced by the cloud, listing seven major security risks that the cloud computing technology exist" (see Table 1) [3]. Cloud-computing threats can be divided into two types: network and security.

Table 1. Seven Top Security Risks

Risk	Description
Privileged user access	Sensitive data processed outside the enterprise brings with it an inherent level of risk
Regulatory compliance	cloud computing providers who refuse to external audits and security certifications
Data location	The customer probably don't know exactly where your data is hosted
Data segregation	Data in the cloud is typically in a shared environment alongside data from other customers
Recovery	A cloud provider should tell what will happen to the data and service in case of a disaster
Investigative support	Investigating inappropriate or illegal activity may be impossible in cloud computing
Long-term viability	Data should remain available even after such an event

As cloud computing users, we lose control over physical security. So how can we ensure that data will not leak and privacy can be protected? In order to understand available solutions, the types of attack that we might experience should be highlighted. Several security threats can occur in cloud computing:

Browser Security: Once a user requests a service from the cloud server, the user's Web browser plays a significant role. Even if the Web browser uses SSL, sniffing packages on an intermediary host can get decrypted data [2]. Also, the attacker uses decrypted data (credentials) as a valid user on a cloud system. Web Services Security is a method for eliminating the browser threat by using XML Encryption and XML Signature to guarantee confidentiality and integrity to SOAP messages [2]; for example, Kerberos, standard usernames, passwords, and X.509.

Unsecure Interfaces and Application Programming Interfaces (APIs): Cloud users are provided with set of software interfaces or APIs to manage cloud services. Unsecure APIs, which allow software applications to interoperate with each other by passing login information between them, are among the top cloud threats [7]. According to Peerson and Yee [10], "From authentication and access control to encryption and activity monitoring, these interfaces must be designed to protect against both accidental and malicious attempts to circumvent policy". The big concern with this threat is that third parties often build upon these interfaces to offer value-added services to their customers, which increases the security risks.

Cloud Malware Injection Attack: This attack works against cloud services, applications, or virtual machines [7]. Attackers can create their own malicious service by using functionality changes or data modifications for specific purposes [2]. Then, they upload this service into the cloud system by tricking it. The cloud system automatically redirects valid user requests to the malicious service implementation then that code is executed. To prevent cloud malware injection attacks, it is necessary to use the hash function, store a hash value on the original service instance's image file, and compare this value with the hash values of all new service instance images [2].

Flooding Attacks: This attack exploits some cloud features, which increase and initialize new services in order to maintain user requirements and requests. The attacker requests a huge amount of particular service; this means that cloud computing would not be capable of supplying service to normal user requests, because the system works against the attacker's requests [2]. A denial of service (DoS) attack is one type of forceful flooding attack. According to Qaisar and Khawaja [2], installing a firewall to detect and filter fake requests is a countermeasure for flooding attacks.

Data Protection: Data protection is very important and complicated for a cloud consumer, because it is hard to ensure that the data are handled in a lawful way [2]. For this attack, the consumer should be aware of whether or not the data are handled correctly. In addition, data compromise can occur due to unauthorized party access, loss of an encoding key, or deletion or alteration of records without a backup of the original content [10].

Incomplete Data Deletion: The significant risk that a cloud consumer might experience is incomplete data deletion. The reason is that there are many replicas of these data in other servers, maybe as backup. Also, the majority of operating systems do not delete data accurately or completely. Jamil and Zaki revealed that "Adequate or timely data deletion may also be impossible (or undesirable from a customer perspective), either because extra copies of data are stored but are not available, or because the disk to be destroyed also stores data from other clients" (as cited in Qaisar and Khawaja [2]). Additionally, Qaisar and Khawaja suggested using VPN and query for securing and completing removing of data from cloud servers that have replicate data.

Locks In: The last security issue is locks in. It is related to data, application, and service portability. There is little offered in the way of tools, procedures, or standard data formats that could ensure data, application, and service portability [2]. Therefore, the cloud customer cannot move from provider to another or shift the services back to an in-house IT environment [2].

Network Threats

There are six network issues related to cloud computing:

Denial of Service (DoS): DoS attacks are not new; they can make cloud computing resources and services unavailable to the users [7]. Frequent overflow requests sent to the server by the attacker to affect server functionality that provides the services. As a result, the server is unable to respond to the regular users. According to Qaisar and Khawaja [2], to avoid cloud computing DoS attacks, it is important to reduce user/attacker privileges based on their behaviors when they are connected to a cloud server.

Network Sniffing: This is a way of analyzing network traffic for hacking unencrypted data that are transmitted through the cloud network. To illustrate, if the user does not use encryption techniques during communication with the cloud server, hackers can capture data such as username and password. Therefore, an encryption technique is an effective method for eliminating network-sniffing threats [2].

Man-in-the-Middle Attack: During data transmission between user and cloud server, there is a potential threat called "Man in the Middle Attack." According to Hutchings et al. [8], data that are transmitted without encryption may be hacked or stolen; thus, they recommend encrypting and compressing the data during transmission by installing a secure socket layer (SSL) to prevent man-in-the-middle attacks.

Port Scanning: Attackers use port scanning to discover exploitable communication channels/ports between the user and cloud server. The attacker's goal is to find an active port and exploit vulnerable cloud services [2]. Thus, one main component of network security structure is the firewall. Both user and cloud server need to employ firewalls to detect and filter authorized traffic.

Structured Query Language (SQL) Injection Attack: This is a technique that uses a special character/string to gain unauthorized access to or retrieve information from a cloud database [7]. For example, if the attacker types 1==1 as an argument value of query in the form field, it may retrieve an entire database table.

Cross Site Scripting (XSS): This is an attack method for obtaining sensitive user data (credentials) or the user's session. The attacker uses a malicious script Web application to redirect the user to the attacker's target [2]. The script will be activated when it is read by an unsuspecting user's browse or by an unprotected application. For example, consider a login or payment page that is hosted on the cloud.com domain: if the attacker discovers XSS vulnerabilities in the domain, the attacker can use Java scripting to steal a user's information. Hutchings et al. [2] stated that "Cross site scripting attacks can provide the way to buffer overflows, DoS attacks and inserting spiteful software in to the web browsers for violation of user's credentials".

Risk Management Framework (RMF)

In this paper, the authors recommend RMF for cloud computing providers, regardless of their types and models, based on the NIST risk management guide and McGraw's security risk management. From a business perspective, cloud computing providers were basically found to provide products and services for their own profits. Among various ways to deliver computing resources and services, cloud computing providers' underlying mission is that every user can use available applications and get services easily, regardless of location and the device operating system. Their basic business goal is to deliver highly secure and reliable applications and services. Also, the providers aim to gain costumers trust and loyalty.

Cloud computing providers have encountered dangerous security risks and problems. These security risks would negatively affect confidentiality, privacy, reliability, and integrity of a provider's services. Therefore, a specific RMF process dealing with security risks and problems is recommended. The basic idea of RMF is simply identify, rank, track, and understand software security risk as it changes over time. This framework can be used widely and flexibly because it can fit with small and large enterprises. Also, the advantage of using RMF is that it "is not specific to security risks; it can be applied in non-software situations" [11]. However, the main goal of using RMF with cloud computing providers is to consistently track and handle risks and threats.

It is significant to define risk management and its purpose in general. Stoneburner et al. [12] defined it as "the process that allows IT managers to balance the operational and economic costs of protective measures and achieve gains in mission capability by protecting the IT systems and data that support their organizations' missions". The explicit goal of applying risk management in any organization is to minimize negative impacts on organizations and fulfill a need for a sound basis in decision making.

Tanimoto et al. [13] analyzed cloud computing security problems in detail, based on the risk breakdown structure method and the risk matrix method. They provided risks extracted from the user's viewpoints. Xie et al. [14] suggested a risk management framework for cloud computing, which consisted of five components: user requirement self-assessment, cloud service providers desktop assessment, risk assessment, third-party agency review, and continuous monitoring. The framework presented in this paper is different from that given by Xie et al. [14] that involved users, providers, and third parties. In this current study, the authors emphasize the business angle; that is, the marriage of business and technical concerns is the central driver of this risk management plan. Also, increasing the adopters and users of cloud computing is one goal of this framework. This RMF consists of six stages, discussed in detail in the next section.

A continuous risk management process is a necessity in cloud computing. Also, continuous monitoring process is required through ongoing risk identification, implementation, and assessment. The risk management plan should be well planned and collaborative between and among different departments. So, sufficient time must be given for planning, collaboration, and communications. Figure 1 shows that monitoring is needed all the time to ensure that what was expected is actually working. This needs to be performed at consistent time intervals set in the risk management documentation. Sometimes it is necessary to place a watch on areas, and at other times it will be prudent to change a certain process. If the process has been changed, it is added to the risk management documentation. Some organizations prefer to outsource the monitoring, while others will keep the monitoring in-house. When monitoring cloud services, it might be logical to form a team between several different companies for better mobility in the documentation.

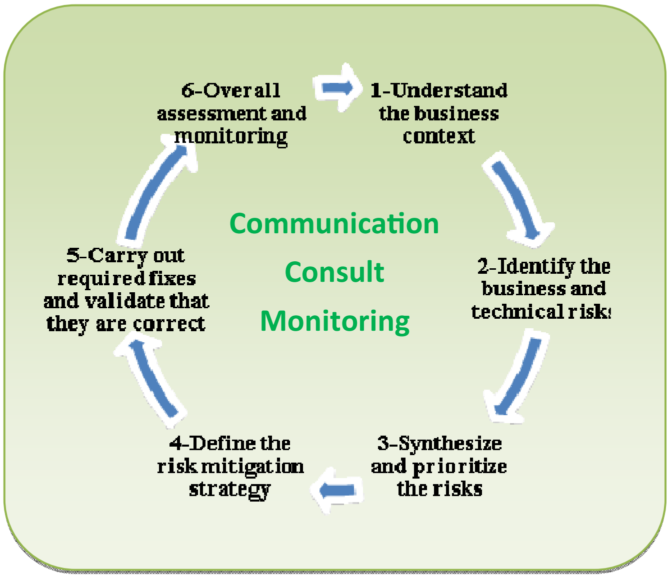

Figure 1. RMF for Business and Enterprise Consists of Six Fundamental Activity Stages

Also, in the middle of Figure 1, it states communication and consulting. This implies that all stakeholders should be kept informed of what the risk management documentation states and, if it changes, all of those stakeholders will need to be contacted. This is why outsourcing of monitoring is currently popular in the cloud. Small businesses lack the resources to deal with constantly talking with stakeholders, while monitoring their systems.

Risk Management Framework Stages

The RMF consists of six fundamental activity stages: (1) understand the business context, (2) identify the business's technical risk, (3) synthesize and prioritize the risk, (4) define the risk mitigation strategy, (5) carry out required solutions and validate that they are resolved, and (6) overall assessment and monitoring of the system.

Understand the Business Context

This includes describing the business's goals, priorities, and circumstances in order to understand what software risks and which business goals are paramount. Different information, including quantitative and qualitative data, will be gathered. System analysts should develop several questions for interviewing and surveying different people (e.g., manager, IT management, clients, developers, and employees). Also, they are encouraged to develop research projects to examine the overall system and reduce it to a reasonably small set of components. Also, choosing relevant critical areas to focus on is necessary, especially if an area needs immediate attention. NIST's rough guidelines for ranking business goals can be used; Table 2 provides a guideline for ranking goals in a way that effectively meets standards required by federal regulations. This ranking places business goals under three broad headings of high (H), medium (M), and low (L), depending on the extent of its impact on the project, the employees, and the company at large. The goal is ranked high if it is crucial to the existence and continuity of the project. Failure of such goals has the potential to halt the entire project and directly affect the company. Medium-ranked goals are crucial to the existence of the project, and their failure may adversely affect many employees and also impact some higher-ranked goals. Failure of a lower-ranked goal can affect just a small portion of the company's revenue, and the impact may be felt by just a small portion of the company's employees.

Table 2. Guidelines for Business Goals Rankings from NIST

Rank	Definition
High	These goals are critical to the existence of the project (and possibly the company). If not met, there is a real risk that the project will cease to exist and the company will be directly impacted.
Medium	These goals are very important for the existence of the project (and possibly the company). A large number of employees may be affected if these goals are not met. A failure to achieve a medium-ranked business goal may result in a negative effect on high-rank goals.
Low	These goals affect only a small portion of the company's revenue. A small number of employees may be affected if these goals are not met.

Creating a risk management plan's directions, committees, goals, requirements, timeline, and scope is required in the beginning. The goal for doing this is to ensure that everyone on the committee is aware of his/her responsibility, role, and time. Also, it would make the committee's time and efforts to be used more effectively and directly.

Identify the Business, Technical Risks, and Vulnerability

Business risks can impact business goals. For example, they can affect business reputation, revenue, and productivity. The identification of business risks helps to define and identify the most effective technical and managerial methods for measuring and mitigating these risks. In terms of technical risks, they are hard to find because they are often not actionable. They can be related to a system behaving in an unexpected way, violating its own design structures, or failing to perform as required.

When identifying business and technical risks, three fundamental sources of threats should be taken into account: natural (e.g., floods, earthquakes, tornadoes, etc.); human, including unintentional acts and deliberate actions such as network-based attacks; and, environmental threats such as long-term power failures, pollution, and chemicals. Also, these sources can be divided into adversarial incidents and non-adversarial incidents. Adversarial incidents are these initiated by the adversary such as hackers or cyber-criminal organizations, while non-adversarial incidents occur due to environmental problems such as earthquakes, floods, system faults, or those initiated unintentionally by operators.

In this stage, technical, management, and operational vulnerability should also be investigated. Applying vulnerability sources, the performance of system security testing, and the development of a security checklists can help identify system weak points. After identifying risks and vulnerability, a ranking of risk indicators, impact of risks, and the likelihood of identified risks must be created (see Tables 3 and 4). Risk indicators are signs and important tools within operational risk management that can be used to monitor, measure, and determine risk status over time. The level of impact and the likelihood of occurrence would allow the analyst to evaluate the impact of business risk on different business goals [11] (see Table 5). In addition, this step involves discovering and describing technical risks and linking them to business goals.

Table 3. NIST Risk Likelihood Description

Business Impact Value	Definition
High	1. Very costly loss of major tangible assets or resources 2. Significant violation of, or harm or impediment to, an organization's mission, reputation, or interest 3. Human death or serious injury
Medium	1. Costly loss of tangible assets or resource 2. Violation of, or harm or impediment to, an organization's mission, reputation, or interest 3. Human injury
Low	1. Loss of some tangible assets or resource 2. A noticeable effect on an organization's mission, reputation, or interest

Table 4. NIST Business Impact Scale

Likelihood Value	Definition
High	The threat is highly motivated and sufficiently capable; controls to prevent the risk from occurring are ineffective.
Medium	The threat is motivated and capable, but controls are in place to impede its successful materialization.
Low	The threat lacks motivation or capability; controls are in place to prevent, or at least significantly impede, the risk from occurring.

Table 5. Level of Risks

Quality Values	Semi-quantitative Value	Description
Very High	10	Very high risk means that a threat event could be expected to have multiple severe or catastrophic adverse effects on organizational operations, organizational assets, individuals, other organization, or the nation.
High	8	High risk means that a threat event could be expected to have severe or catastrophic adverse effects on organizational operations, organizational assets, individuals, other organization, or the nation.
Moderate	5	Moderate risk means that a threat event could be expected to have serious adverse effects on organizational operations, organizational assets, individuals, other organization, or the nation.
Low	2	Low risk means that a threat event could be expected to have limited adverse effects on organizational operations, organizational assets, individuals, other organization, or the nation.
Very Low	0	Very low risk means that a threat event could be expected to have negligible adverse effects on organizational operations, organizational assets, individuals, other organization, or the nation.

Synthesize and Prioritize the Risks

In any system, a large number of risks will always exist. However, prioritization should be performed. In this stage, the process must consider the most important business goals and identify which goals are immediately threatened. To understand and manage risks, analysts must establish relationships between the business goals, business risks, and technical risks [11]. It is helpful to draw visual relationships between these three items. It is possible that an individual technical risk may impact multiple business goals at different severity levels [11]. Additionally, analysts are strongly encouraged to prioritize these goals and risks in meaningful business terms (see Table 5). In the third stage, synthesize and prioritize the risks by producing a ranked set, analysts can develop the technical risk severity by examining how each technical risk impacts business goals. To determine the severity level, likelihood of technical risk occurrence and business impacts must be assessed. So, based on all of the information gathered thus far, the management team is now able to create an outline for a risk mitigation strategy.

Define Risk Mitigation Strategy

A coherent strategy should be created for mitigating the risks in a cost-effective manner. All suggested mitigation strategies must take into consideration: cost, implementation time, likelihood of success, completeness, and impact over the entire body of risks. Coherent strategies should be created, taking into account their effectiveness. Also, the management team should answer the question of "How can the identified risks be managed?" [11]. Different mitigation methods should be proposed in order to choose the best and the most effective one that make sense economically and is applicable to many risks. The method that provides large risk coverage at a low cost should be considered. Also, several issues should be taken into account when selecting mitigation methods such as legislation/regulation, organizational policies, and impact of method implementation on operations. After that, a completed risk analysis report should be ready to present to the management team for peer review.

Carry Out Required Fixes and Validate Correctness

This stage involves carrying out validation techniques, which provides confidence that risks have been properly mitigated and that the strategy is working. Also, the mitigation strategy should be tested to make sure it is effective. It involves implementing the process and applying validation techniques. Validation plan and instruments are different from one project to the other, based on risks identified and methods chosen to address them.

Overall Assessment and Monitoring

After carrying out the required solution, the teams of experts meet to continually evaluate and assess the outcome of the solution. Based on observations, the team decides whether the risk assessment meets the plan or not and what they should do next in each situation. If the assessment meets the plan, they can document the type of attack/threat and any effective solutions. They can then think of solution vulnerabilities and ways to fix them. Besides, alternative solutions can also be devised to increase readiness, should the current solution fail for a similar attack. The experts can also evaluate the performance of the solution to see the effectiveness in meeting the goals of the business partners as well as securing client confidence.

If the solution failed, the experts can assess why it failed and develop fixes. They can evaluate the extent of the damage and come up with effective ways of counteracting any aftermath of attacks. They can also develop effective ways of restoring the confidence of their clients, should the attack affect their data security or privacy information. This team of experts forms the backbone of cloud computing, because their innovative thinking does not only provide robust mechanisms for combating known threats but also provides the platform for developing more effective and dynamic RMF. Since humans are potentially the most dangerous threat source, a team of humans performing continuous monitoring and creating combat procedures is indispensable to any reliable risk management framework.

Conclusion

In recent years, cloud computing has gained much popularity in the IT industry. Cloud computing is a computing resource with deployment and service models that enable users to get computing resources and applications from any location via an Internet connection. The powerful characteristic of cloud computing is that no special devices or software are required for the service. A user only needs the Internet and a remote server to use cloud computing services.

Cloud computing brings us both opportunities and challenges. Reduced costs, speed of deployment, scalability, fewer requirements for operating IT functions, and other environmental benefits such as less physical space, are among the advantages cloud computing provides. However, a large number of organizations and users in general do not use or adopt this new technology, mainly because of security concerns and low trust. To prevent serious problems occurring with the security of cloud computing, the authors provide here a risk management framework that can be applied for this purpose. The main goals are to raise trust between providers and users and to increase the number of users and adopters of cloud computing. To accomplish this, the authors have provided a comprehensive cloud computing risk management framework based on previous work. This risk management framework consists of six stages: 1) understand the business context, 2) identify the business technical risk, 3) synthesize and prioritize the risk, 4) define the risk mitigation strategy, 5) carry out required solutions and confirm that they have been resolved, and 6) overall assessing and monitoring of the system is a novel idea for effectively combating threats both from adversarial and non -adversarial sources. The first five steps are the well-known risk management stages, but in this study a more robust approach to each of them was adopted. In this paper, the authors highlight the details of these approaches used in the first five steps as well as explain the sixth step.

To clarify these steps, a scenario explaining a step-by-step approach to applying this risk management framework to a hypothetical cloud computing provider was outlined. The advantage of this risk management framework lies in its flexibility, because it can fit with small and large enterprises. Besides, the "RMF is not specific to security risks; it can be applied in non-software situations" [11].

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