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TECHNOLOGY INTERFACE INTERNATIONAL JOURNAL

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

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THE TECHNOLOGY INTERFACE INTERNATIONAL JOURNAL EDITORS

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EDITOR'S NOTE: TIIJ IMPACT FACTOR AND INDEXING

Philip Weinsier, TIIJ Editor-in-Chief

IMPACT FACTOR AND INDEXING

Faculty publication in academic journals is a key criterion for appointment, tenure and promotion at most universities. Furthermore, many universities weigh the publications according to the quality, or impact, of the journals. But what metrics do authors use in choosing a journal? And, how do we, as fellow researchers and/or readers in search of journal articles, find what we're looking for? Yes, doing an Internet search generally produces results; but such results just as often are so watered down with what we are not looking for that we waste valuable time or get frustrated and give up. For the savvy readers, though, they join indexing or abstracting service organizations. Here, one can find articles focused into discipline-specific topics. Examples of such organizations include ChemAbstracts (chemistry) and PubMed/Medline (medicine).

The most well-known of these abstracting and indexing organizations are Google and Thomson Reuters/ISI, which cover a broader mix of disciplines. Here, readers and researchers alike are able to home in on what they need, while at the same time receive a measure of the relative quality of the source journal. Google provides information about journal articles cited by other articles; information that can give researchers a sense of value in terms of how other researchers are using the studies published there. Thomson Reuters/ISI, for its part, provides a ranking of journals by what it calls its impact factor (IF). For years, the scientific community has used this as a measure of the average number of citations to articles published in a given journal. It has also become a common practice to use IF as a means of ranking the relative importance of a journal.

The Thomson Reuters/ISI Web of Knowledge is a larger platform that includes multiple databases and tools such as the Web of Science—which also covers the Science Citation Index—and the Journal Citation Reports (JCR), which reports all related analytical information as well as impact factors. The Web of Knowledge indexes more than 11,000 science and social science journals. What you may not know is that besides ISI's impact factor, there are numerous other methods for ranking journals such as:

- Google Journal Metrics (using Google Scholar)
- Eigenfactor Search
- H-Index (available from Scopus and SCImago Journal Rank)
- Citations (available from Microsoft Academic Search)
- SCImago Journal Rank (SJR)

TIIJ: THE NUMBERS

The most popular ranking organization is Google Scholar Metrics (GSM), which is also available free to the public. According to GSM, the impact factor of TIIJ is 0.732 (with no self citation), placing it among the most-cited engineering journals worldwide. In publication since 1996, it is also the #4 visited engineering journal website, according to the National Science Digital Library (NSDL), one of the world's largest libraries funded by NSF.

As noted above, impact factor of a journal is but one measure of its quality; another is indexing. While almost all journals seek indexing in indexing organizations, on rare occasions the major indexing organizations approach high-quality journals on their own to sign indexing contracts. We are proud that TIIJ and its sister journals, IJME and IJERI, have been invited to join EBSCO, one of the largest leading indexing organizations.

IAJC, the parent organization of TIIJ, has also taken an aggressive approach to index the journal with other major indexing organizations in order to maximize its exposure and improve its quality and impact factor. At the time of this publication, TIIJ is indexed by 21 major indexing organizations and under review by several more—visit our website (www.tiij.org) for a complete listing.

Editorial Review Board Members

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

If you are interested in becoming a member of the IAJC International Review Board, send me (Philip Weinsier, IAJC/IRB Chair, philipw@bgsu.edu) an email to that effect. Review Board members review manuscripts in their areas of expertise for all three of our IAJC journals—IJME (the International Journal of Modern Engineering), IJERI (the International Journal of Engineering Research and Innovation) and TIIJ (the Technology Interface International Journal)—as well as papers submitted to the IAJC conferences. Please watch for updates on our website (**www.IAJC.org**) and contact us anytime with comments, concerns or suggestions

PRELIMINARY STUDY ON THE BENEFITS OF VIRTUAL REALITY TECHNOLOGY SUPPORTED BY AN INDUSTRY PARTNER TO ENHANCE MANUFACTURING EDUCATION

Julie Z. Zhang, Salih Boysan and Ali Kashef, University of Northern Iowa

Abstract

Enabling users to immerse themselves in and interact with virtual objects in a simulated 3D environment and to help reduce prototyping costs and shorten product lead time, virtual reality (VR) has become an effective tool for manufacturing industries. Due to the relatively high cost, however, VR technology has not been widely implemented in classroom settings. This paper presents a preliminary study in which VR was introduced to students in a Manufacturing Technology program through lecture, discussions and hands-on lab activities supported by an industry partner. A survey was conducted among the student participants that aimed to evaluate the effects of VR applications in enhancing manufacturing education. The data collected from the participants showed that hands-on VR technology plays a positive role in helping and promoting manufacturing design and production concepts. This study demonstrated a collaboration module on how to utilize industry resources to accommodate new technologies for manufacturing education.

Introduction and Motivation

CAD systems have been widely used both in academia and manufacturing industry communities. However, spatial location of equipment and possible interference between the operator and machinery cannot be fully determined in the CAD system due to its limited capability [1]. In addition, it is difficult for non-technical personnel to understand the CAD system results without previous training or design experience. In particular, if design for manufacturing (DFM) is not fully considered in the product design stage, low manufacturability can become a problem in the stage of production and manufacturing, although the CAD design may appear to be great. This situation could be further complicated by the project complexity, which often requires teamwork where team members may have to work on the same project though physically be separated by region or country. Enabling users to immerse themselves in a virtual world and interact with designed parts and manufacturing equipment, virtual reality (VR) provides a better solution for effective communications among technical and non-technical professionals such as design, manufacturing, application engineers and sales representatives [2]. Virtual reality is a computer-generated 3D virtual environment that allows users to have real-time interactions with objects [3], [4]. Receiving immediate feedback through multi-sensory devices in such an immersive virtual world affords users the perception that they are dealing with real entities in the real world.

VR's theoretical background is an artificial-world construction model proposed by Dr. Ivan Sutherhland that included interactive graphics, force feedback, sound, smell and taste [4]. What really differentiates recent VR technology from the early camera-based Sensorama Simulator is that VR is "an interactive and immersive (with feeling of presence) experience in a simulated world based on computer technologies. Using physical signals in the Sensorama Simulator, wind effects were produced by placing small fans near the user's head. VR, on the other hand, can generate images and collect signals by using computer simulations. VR technology has evolved over the past few decades. The quality and type of VR is a function of the number of levels of immersion. The highest level VR is a full immersive system where the user is totally immersed in the computer-generated world with the help of a head-mounted display (HMD) that provides a stereoscopic view of the scene based on the user's real-time position and orientation. The scene and user's feeling can be enhanced by audio, haptic and sensory interface.

VR is an advanced and comprehensive technology in that it encompasses computer graphics, electronic sensors, computer software and hardware, and the ability to communicate or interface with the peripheral devices. However, VR does not just belong to computer professionals; instead its scope of applications has been extended across a large spectrum [2] from scientific research/simulation to entertainment. Because of presenting a 3D graphic interface, VR technology plays a significant role in scientific visualization so that the visual representation of abstract systems such as wind-tunnel flow and thermal distribution, weather forecast, molecular chemistry models and solar systems can be expressed vividly. This makes understanding the abstract system no longer a headache. Being a super visualization tool, virtual reality has also found applications in education and training in a variety of areas like military, medical surgery, equipment operation and maintenance, and especially in the field of engineering/technology education [5-7]. Engineering education involves abstract subject knowledge, for instance in engineering design and analysis where there would be a strong need to turn pure lecture-based learning into experiential learning so that students get a deeper and more robust understanding of the concepts [8]. VR technology, allowing extreme close-up examination of an object with detailed features, motivates and engages students to proceed through an experience on their own. In addition, the interaction between users and the entities in the VR system encourages active participation rather than passivity [9].

Manufacturing is a part of the engineering discipline. Manufacturing basically comprises the following types of engineering tasks: product design, production planning, implementation and operation of the actual production system. These four tasks could benefit from the application of VR through user interactions with real-size product models in the 3D computer-generated factory layout equipped with real-size machine tools and material handling equipment. This way, design flaws could be identified earlier and manufacturing sequences could be optimized by means of virtual prototyping, thus saving substantial manufacturing costs.

Research and development on virtual reality started in the 1960s. The initial players were top research-intensive universities and federal government-sponsored research institutions since constructing a VR system needs expensive high-processing-speed computing devices. From the 1990s, the big brand-name manufacturing companies such as Boeing, Caterpillar, Ford and John Deere have been adapting VR technology for design interference detection, concept and product prototyping, manufacturing process planning and optimization, and ergonomic analyses [10-12]. Besides regular high-processing-speed computer and graphic cards, some other advanced technical components including hardware and software must be integrated and interfaced in order for the VR system to function as desired. Constructing a virtual reality system requires components such as head-mounted displays (HMD), data gloves, motion-tracking sensors, simulator joystick and rendering software systems that will generate visual, audio and other sensations to users. These components are very expensive. A high-resolution HMD could cost more than $10,000. In addition, specially trained personal must be available to support the VR system, which will make the application of this technology even more costly.

Currently, manufacturing engineering/technology education is facing many challenges in the U.S. One of these challenges is keeping manufacturing education up-to-date by investing in advanced technologies. However, the lack of educational resources cannot accommodate the emerging learning needs [13], [14]. VR technology has not been widely utilized in manufacturing technology/engineering educational institutions. Therefore, there are limited reports in the literature on its educational effect in manufacturing disciplines. Collaboration between academia and industrial partners can bridge this gap [14]. The following session presents a preliminary study that explores the benefits of VR technology supported by an industrial partner for manufacturing technology education.

Application of Virtual Reality for Manufacturing Education

The Manufacturing Technology (MT) program is housed in the Department of Industrial Technology at the University of Northern Iowa (UNI). Located in the northeast part of Iowa, UNI is primarily an undergraduate state university with approximately 13,000 students. In its over one hundred -year history, the Department of Industrial Technology has established strong partnerships with local industries. Graduates from UNI's Manufacturing Technology program provide a skilled employee pool for the local manufacturing companies. This includes the manufacturing of aircraft, large off-road equipment, wind-power devices, general industrial equipment, furniture and other consumer products.

The MT Program provides a wide range of training for manufacturing professionals by offering a variety of courses such as design, manufacturing automation, production planning and control, and quality management. The computer lab has design and manufacturing software packages such as Autodesk® AutoCAD® and Inventor®, Pro-Engineer®, Mastercam® and Vericut® to implement 2D and 3D modeling and simulation. The Production Lab has full capabilities for a variety of machining operations. Turning, milling, punching, shearing, grinding and casting operations can be conducted in the lab. Both desktop-scale and full industrial-sized CNC machines and 3D printers can be used by students to produce products or prototype designs. However, the immersive VR lab facility is still at the unreachable level at UNI due to the university's budget constraints as well as its high capital investment and operational costs. Fortunately, there are several VR labs at local industries. One particular local manufacturing company, whose main product is off-road vehicles, possesses three VR labs at different immersion levels by integrating varied sensing techniques. UNI's MT program has a long-standing collaboration with this company–some of its fulltime employees come back to school to update their knowledge and pursue a higher degree, and many of the enrolled students work part-time for this company and are offered full-time positions right after graduation. The MT students learn CAD/CAM and other computer simulations required by the program of study, but do not have an opportunity to directly experience VR simulation at UNI's lab. Based on recent technological trends and discussions in the Manufacturing Program Industrial Advisory Board meetings, the instructor added a module on VR and its application in one advanced manufacturing course.

The fundamentals of VR were introduced to a senior-level manufacturing course, including scientific definition, historical development and evolution, basic components both in hardware and software, advantages and disadvantages along with general applications. Special interests were given to the VR application in manufacturing and the successful examples that have used VR technology for new product design and ergonomic analysis. To supplement the conceptual ideas constructed during lectures, a special field trip was organized to visit one of the VR labs of the off-road equipment manufacturing company in the local community so that students could experience the immersive computer-generated virtual world. The VR lab that the class visited had hands-on activities in a three-wall immersive virtual system that utilizes optical sensors to track user motions.

The engineer in charge of the lab facilities is also interested in promoting VR technology and using it for training the company's employees. After going through the company's proprietary protocol and obtaining permission, the students enrolled in the Advanced Manufacturing Processes class were able to visit the VR lab and receive hands-on experience with the VR models and entities.

Each individual student was able to experience three different levels of virtual-reality activities. One activity was that students tried several pieces of haptic computer applications. For example, the user could feel the bouncing effect when a computer mouse pushed a computer-generated robbery trampoline and the user could feel the pressure and the sliding when a computer mouse was clicking on the spherical surface of a computer-generated solid ball. The second activity was that each individual student was able to wear the motion tracking device, stand in the three-wall CAVE system and experience and manipulate one of the 3D virtual models provided by the VR lab. The 3D virtual models included a big off-road vehicle, a wheel mounting machine for the off-road vehicle, a virtual factory layout and assemblies of engine and other components. The third activity was to manipulate a skateboard assembly model that was created by a UNI MT student. In Figure 1, a student was riding in the virtual wheel mounting machine, trying to manipulate the functions provided by the wheel mounting machine. After this field trip, a survey was conducted among the student participants based on the request from the industrial partner; meanwhile, the survey was used to test the effectiveness of this activity impacting students' perception about virtual reality and its application in manufacturing.

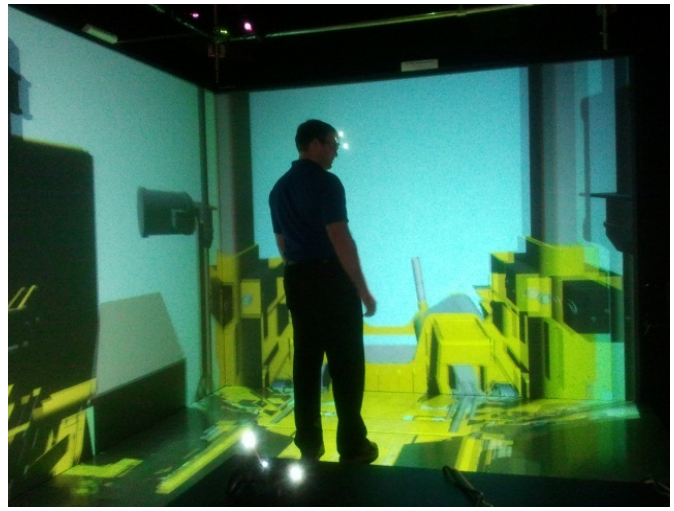


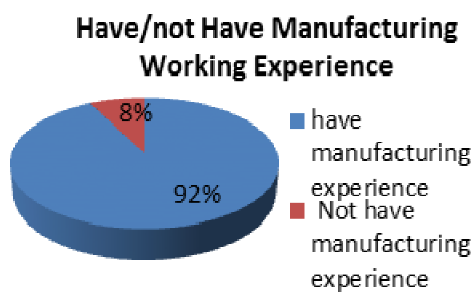
Figure 1. A Student Experienced a Three-Wall CAVE Virtual Reality System

Effectiveness Analysis of Student Perceptions on Virtual Reality in Manufacturing Education

The survey consisted of three parts: 1) general demographical questions about the student participants; 2) descriptive evaluation of student perception on VR technology and its impact on manufacturing education; 3) quantitative evaluation of student perceptions on VR technology, its application and impact on manufacturing education.

Survey Demographics

There were 13 students in this course. Of the 13 enrolled students, nine were undergraduates majoring in Manufacturing Technology, and four were graduate students who had different backgrounds in Electronic Engineering, Electronic Engineering Technology, Mathematics and Industrial Engineering. The undergraduate and graduate students took this course to meet the requirement set by their program of study. Having introductory-level courses and a CAD/CAM background for the undergraduate students, this required course would deepen their understanding on the advanced manufacturing aspects other than traditional manufacturing processes. For graduate students, this course served as an elective course to broaden their understanding of manufacturing industries in general. None of the graduate students had taken an introductory-level manufacturing course, but they were assigned to read a lot of chapters on basic manufacturing processes and operations. The graduate students had almost no experience in using CAD/CAM packages because of their non-manufacturing academic background. A vast majority of the students were working part-time or full-time and had some work experience related to the manufacturing industry. Only one student reported never having heard of virtual reality before and the rest of them indicated that they had heard this term in formal or informal settings. Five out of the 13 students mentioned that they had had a tour in another VR lab facility of this company from other class activities; however, that previous tour was not interactive. Three students had touched VR components through recreation or entertainment games. The survey demographic results are summarized in Figure 2.



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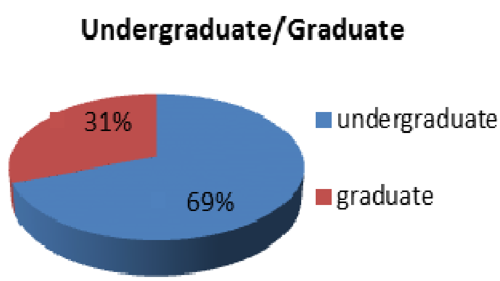

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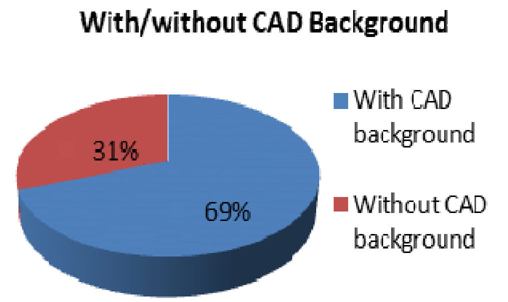

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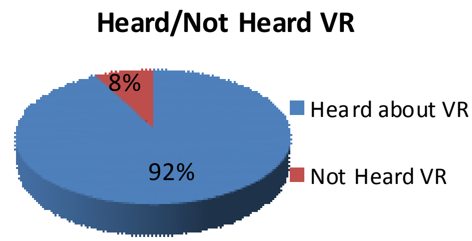

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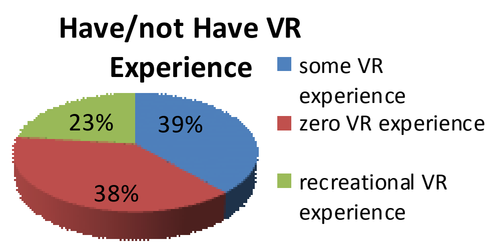


(e)

Figure 2. Demographic Information for the Survey Students

Descriptive Evaluation of Student Perceptions of VR on Manufacturing Education

The MT program at UNI and this industry would like to establish a long-term partnership, especially wanting to explore a cooperation through which the faculty and students could use the industry's VR facility for involving/working on real industry manufacturing projects in the future. Therefore the following questions were included in the survey in order to solicit ideas on how to improve VR-related activities in the future:

- Overall, how do you think the VR demo went?
- Was it a valuable experience for students?
- What would you like to change?
- Do you like to request future activities like this one?
- Any other comments?

From the students' responses, all students thought that the tour to the VR lab was very beneficial in understanding the usefulness of VR to manufacturing. They really appreciated the hands-on opportunity arranged in this tour, which provided an excellent opportunity for the students to see how such an advanced technology has actually been implemented in manufacturing design and production, particularly in the local manufacturing industry. All participants had a consensus that it was valuable to see, feel and touch this technology. After the tour, they felt it became easier to understand what VR is, why it is useful and how it is used. The students agreed that this field trip brought VR technology closer to them because it was not just a story read from the Internet, but rather a real application in the local manufacturing industry. Some of the students said "no need to change the current setup" or "keep as it is", and some recommended that they would like to see specific examples of where/how the company used this technology for evaluating or virtual prototyping a part design or an assembly design. All students thought these activities should be scheduled for future students.

The students' understanding of VR technology before and after the lecture was also evaluated. Accordingly, more questions were included in the survey as below:

- What do you learn from the VR topic and the field trip?
- Are there any changes in terms of your understanding about virtual reality before and after the VR lecture discussion and the factory VR tour?
- What specific applications in the manufacturing field do you see/think that the VR technology would be most suitable for?
- What applications in other fields besides manufacturing do you see/think that the VR technology would be suitable for?

Virtual reality appears to be a popular term because it is not only used in the academic field but also in entertainment such as 3D movies and video games. However, all students indicated that their perception and understanding of virtual reality changed to some degree. The very representative tone from the student responses is that before the field trip, students thought VR was a simulation tool similar to regular CAD/CAM software. This incorrect perception is not unusual. VR and CAD/CAM, in fact, are not even correctly distinguished in the literature [15]. Some students thought that VR would be just a more interesting way to present things or would be more like a 3D movie. After the field trip, students reported that they could "better picture what interactive VR is really like". The most impressive feature the students experienced was that they could walk through in the immersive virtual world and they could have real-time interactions with the designed product model. Students commented that both the VR technology and the tour were amazing.

The lecture, along with the field trip, broadened the students' understanding that VR technology has a wide variety of applications in scientific visualization, architecture design and engineering and technology education. From a manufacturing perspective, the biggest gain was that students had a better awareness of the fact that VR has a lot of potential in manufacturing applications such as product design, ergonomic analysis, assembly sequence optimization, etc. VR technology has been implemented and applied in manufacturing for almost two decades, but the majority of the students did not understand this technology and its application potential until they had this hands-on field trip. Due to the capability of doing virtual prototyping and testing, students clearly understood it could help prevent and catch design faults that might lead to problems in production. It is also an efficient and greener approach in that VR could possibly save companies a significant amount of money by reducing physical prototypes. One student even predicted "it will become more advanced and useful within the next 20 years". One graduate student reported that he had learned basic information about VR including definition, history and some applications. After the field trip, he comprehended better because he had the chance to physically use and test the VR hardware. His theoretical knowledge turned into practical knowledge.

Quantitative Evaluation of Student Perceptions of VR on Manufacturing Education

In the quantitative evaluation, there were two questions. The first one attempted to find out how students felt about VR's effectiveness on manufacturing technology education by using a 5-point Likert scale (5-Strongly Agree, 4-Agree, 3-Neither Agree nor Disagree, 2-Disagree, 1-Strongly Disagree). The descriptive statistics are listed in Table 1. A majority of the students strongly agreed that virtual reality made comprehension easier and was attractive to them. More than 50% of the students strongly agreed that VR technology facilitated visual thinking and induced people to be active in this environment. Due to this, it is reasonable that students felt that virtual reality made memorization easier and learning faster. Students also responded that in the VR world, they needed to concentrate more in order to orient themselves with the environment and objects. This may be caused by the fact that VR was a new technology to the majority of the participating students, and they were not used to the way it presented entities.

Students' responses to portions of the questionnaire that asked if VR "is tiring", "too involving" or "may be confusing", were in-between neutral and disagree. However, it appeared that there were more variations among students' opinions on these last three items since there were relatively larger standard deviations. The t-test of whether there was a significant difference between the undergraduate and graduate student groups revealed that the two student groups' perceptions about VR educational effectiveness were the same except on one question (virtual reality may be too involving). With the lowest overall average (2.08) for this question, the average for the graduates' response was 3 and the average for the undergraduates was 1.67. These numbers indicated that undergraduate students disagreed with this statement and the graduate students had a neutral attitude. In addition, the Pearson Correlations showed that the academic status of graduate or undergraduate did not bring correlations with their perception about VR, except that in question k there was a weak correlation, which presented the same result as the t-test.

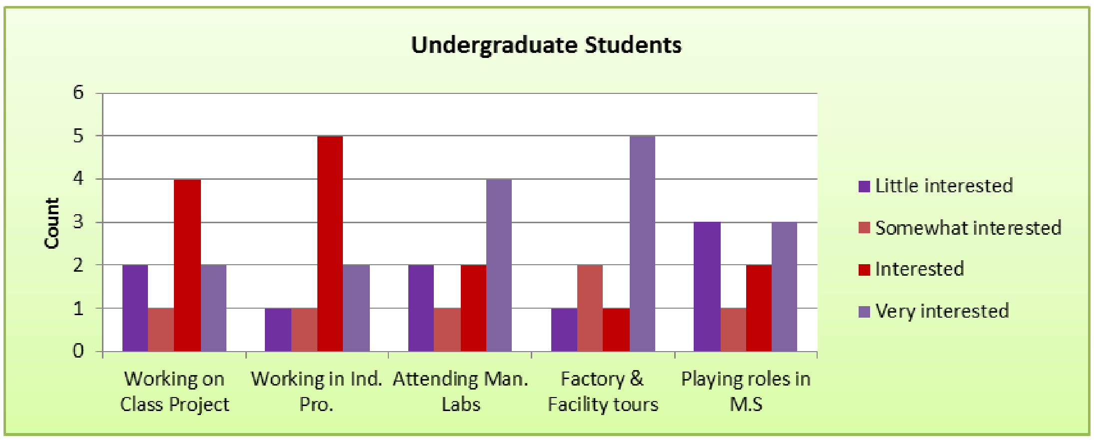
Another survey using a 5-point Likert scale (5-Very Interested, 4-Interested, 3-Somewhat Interested, 2-Little Interested, 1-Not Interested at All) investigated how VR technology could motivate student learning in different applications. The descriptive statistics results are listed in Table 2. The means for the five individual questions were about 4, which indicated that students were all generally interested in participating in these activities if they were available. There were no significant differences between the two student groups, but the standard deviations of these questions were relatively large compared with the questions presented in Table 1. A detailed examination of the response data found that the graduate students had more consistent responses, and they selected 5, 4 or 3, while the undergraduate students showed a big variation —their responses were spread from 2 to 5. The responses are shown in Figure 3. The Pearson correlations between student status and response were all below 0.5, which means that there were no clear correlations. Graduate and undergraduate students all showed an interest in using VR for manufacturing education.

Table 1. Descriptive Statistics of Student Perception of VR on Manufacturing Education

Virtual Reality…					
	Mean	Std. dev	P-values	Difference between G and UG	Pearson Correlation
a. is attractive	4.46	0.52	0.867	No	0.051
b. allows an immediate check of what has been studied	4	1.15	0.348	No	0.284
c. facilitates persons who have a visual thinking style	4.31	0.48	0.128	No	-0.444
d. induces persons to be active	4.08	1.04	0.490	No	-0.211
e. makes the comprehension easier	4.54	0.66	0.737	No	-0.103
f. requires concentration	3.92	0.86	0.644	No	-0.142
g. makes the memorization easier	3.92	0.76	0.640	No	-0.144
h. allows to learn fast	3.85	0.99	0.763	No	0.093
i. facilitates persons who have an intuitive thinking style	3.92	0.86	0.471	No	-0.220
j. is tiring	2.31	1.82	0.721	No	0.115
k. may be too involving	2.08	1.12	0.057	yes	0.562
l. may be confusing	2.77	1.24	0.555	No	-0.190

Table 2. Descriptive Statistics of Possible Ways that VR Can Motive Student Learning

	In the future, students are interested in	Mean	Std. dev	P-values	Difference between G and UG	Pearson Correlation
a.	Working on class projects in the VR environment	3.92	1.12	0.180	No	0.396
b.	Working on industrial projects in the VR environment to solve real world solve	3.92	0.86	0.937	No	0.024
c.	Attending manufacturing labs in the VR environment	4.08	1.12	0.533	No	0.191
d.	Attending VR factory or facility tours that illustrate best practices running a factory	4.31	1.03	0.401	No	0.255
e.	Playing roles in manufacturing simulations that illustrate processes and best practices of running a supply chain in the VR environment	3.92	1.26	0.122	No	0.451



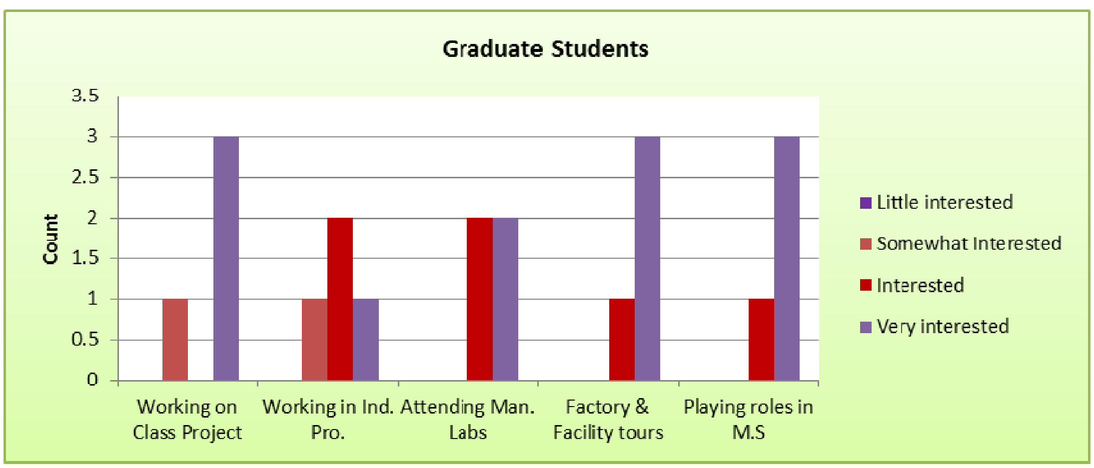


Figure 3. Graduate and Undergraduate Student Response Distribution on How VR Can Motivate Student Learning

Limitations

The limitations of this study include the capacity of the VR lab and the student sample size. The class size was limited to 13 students, which limits the generalization of the findings. The study was designed to let students have hands-on experience with VR technologies. The VR lab that the class visited and which had hands-on activities was a three-wall immersive virtual system that utilized optical sensors to tract user motions. Each student spent 15 to 20 minutes on the VR lab to experience all the facilities. As shown in Figure 1, only one student at a time could be immersed in the virtual environment due to the nature of the technology. In this respect, the capacity of the VR lab to provide hands-on experience to students was limited. When the same course is offered next time, research endeavors could include an assessment of students' perspective about VR with a larger sample size by repeating the same study questions for different groups of students.

Conclusions

The following is a summary of the conclusions from this study:

- Although it has existed and has been applied by industries for more than a decade, there is still a way to go before VR technology can be adapted to facilitate ordinary manufacturing teaching activities due to resource constraints.
- The survey results indicate that VR technology is helpful to induce learners to be active and interactive. Virtual reality's ability in easily visualizing structures makes manufacturing product design easier and facilitates better learning.
- Students were satisfied with this virtual-reality topic and with the virtual-reality lab facility tour supported by the industry partner. The lectures and hands-on activities were effective in helping students understand VR technology and its application in manufacturing.
- Virtual reality is an attractive technology to students. To manufacturing technology students, the introduction and application of VR technology does not necessarily involve a lot of computer science theory; therefore, it can be understood properly by a large audience as an auxiliary tool in manufacturing education.
- Virtual reality can promote manufacturing learning in that students are willing to try and experience class projects or real industry projects using VR technology. The knowledge of computer science may not be necessary, but CAD/CAM should be prepared if a manufacturing engineering/ technology graduate would like to apply virtual reality or work on related projects.
- It is necessary to repeat the same questions for future students who take the same course in order to verify the study's findings due to the small size of the current sample.

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Biographies

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DEVELOPMENT OF A LOW-COST MOBILE EMBEDDED HANDHELD AIRCASTING DEVICE

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Abstract

Handheld AirCasting devices represent an environmental sensing platform that allows participants, known as AirCasters, to record, broadcast and map air status updates in real-time using their Android smartphones and/or tablets. Initial development efforts in this study focused on recording variability in sound levels, temperature, humidity and carbon monoxide. The data collected and annotated by the AirCaster was uploaded to an interactive web-based map that displays both individual and aggregated routing information. Each AirCasting session allowed the user to capture real-world measurements, annotate the data to tell their story, and share the data with local and world-wide communities via the CrowdMap. The AirCasting platform also employs color-changing clothing accessories to communicate the status of the air in a particular place and time to both the AirCaster and people within the immediate vicinity.

Introduction

Air pollution in the U.S. is estimated to cause in excess of $78 billion in damages annually [1]. Of primary concerns are the human health effects of air pollution, including premature mortality and chronic illnesses such as bronchitis and asthma. Despite the tremendous economic costs and pervasive negative health impacts of bad air, air pollution often goes unnoticed because it is largely invisible. Much of what happens in our immediate environment passes without note despite the contribution that events such as recording and crowdsourcing might have on our understanding of us and our communities. AirCasting captures a spectrum of that lost reality and returns it to us as data that is consistent in its units of measurement and, therefore, easily meshed with data from other AirCasters. By making it possible for AirCasters to annotate specific environmental events in time and space, the authors supplemented the qualitative information reported through conscious human experience with the quantitative information from sensing handheld devices that observe and record aspects of our environment that are either impossible to perceive directly (e.g., pollutant gas concentrations) or difficult to quantify and communicate in a consistent manner (e.g., sound levels). AirCasting allows individuals to broadcast what is happening with their environment, crowdsource their own information with that from other AirCasters, and identify patterns and commonalities. Thus, this AirCasting device makes air pollution visible, thereby empowering communities advocating for healthy environments.

Unlike commercially available off-the-shelf chemical detection devices, the AirCasting device, with its novel design and small size, could potentially provide an advanced warning of impending danger. Comparing the AirCasting device to two commercially available off-the-shelf hazardous-vapor warning devices—the LCD 3.3 [2] and the Nose Gas Sensor [3]—the AirCasting's Bluetooth modem allows it to communicate with the world-wide web by connecting to devices such as smartphones or tablets; whereas, the LCD 3.3 and Nose Gas Sensor have no way of connecting to the web. Additionally, neither the LCD 3.3 nor the Nose Gas Sensor is small or within the price-range of ordinary consumers. This makes the AirCasting device an improvement over currently available devices for use in a chemical detection or early warning system. Also, the AirCasting device is a low-cost environmental monitoring system that ordinary consumers can afford. The current custom-made AirCasting prototype costs about $130-$150 per unit to produce; whereas, current off-the-shelf monitoring devices start around $2,000 per unit.

Microcontroller

Handheld AirCasting devices include a microcontroller. In general, a microcontroller is a small computer on a single integrated circuit containing a processor core, memory and programmable input/output (I/O) peripherals. There are many types of microcontrollers that are available on the market—PIC 18, ATMega 32, Arduino, Netduino, 68HC12, BASIC Stamp, VEX Cortex Microcontroller, NXT Microcontroller and the BasicATOM 28X, among others. In this study, an Arduino UNO microcontroller was used for this custom-designed handheld device due to its low-cost. Figure 1 illustrates the physical Arduino UNO microcontroller and 3D Arduino hardware schematic layout. The 3D Arduino hardware schematic was created using the Fritzing software program [4]. The Fritzing software program is a freeware program that is capable of making 2D and 3D schematic diagrams.

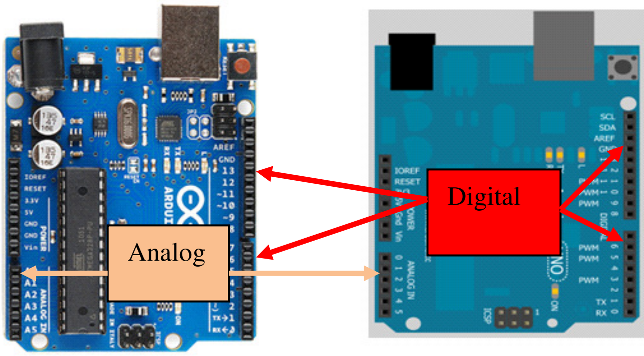

Figure 1. Arduino UNO Microcontroller and 3D Arduino Schematic Layout

The Arduino has two power pins: one for 5V and the other for 3.3V. In addition, it has a Vin pin which is mostly from the input of the power supply, and it is around 9V. Further, the Arduino has two ground pins along with a reset pin.

The Arduino UNO has I/O pins labeled on the right side of the microcontroller (see Figure 1). There are 14 digital pins, and of the 14 pins of which 6 provide the pulse width modulation (PWM) output. PWM can be used as digital or as PWM itself. PWM pins act like a variable analog output that can be outputted. Standard digital inputs and outputs, on the other hand, mean simply turning on/off an LED. In other words, digital means on or off, yes or no. These pins not only serve as an outputs but inputs as well.

The Arduino UNO also has 6 analog input pins labeled on the left side of the microcontroller (see Figure 1). The analog inputs are generally used for sensors with analog outputs such as temperature, humidity or gas (CO, CO_2, NO, NO_2, etc.). The Arduino UNO has one set of communication pins (TX/RX). Communication pins are used for serial inputs and outputs for wireless communication between devices. Some examples of devices that use these communication pins are Bluetooth transceivers or ZigBee transceivers, which are useful and practical in educational capstone projects. Heng et al. provide some examples of capstone projects [5].

Sensor Calibrations

The low-cost mobile embedded handheld AirCasting device has three different types of sensors: A temperature sensor (LM335A), a humidity sensor (HIH-4030) and a carbon monoxide (CO) gas sensor. The signal data acquisition from the three sensors is raw analog data. The raw data must be calibrated with respect to that sensor. For instance, the calibration for the raw analog value of the LM335A temperature sensor would be as follows:

```
float Kelv = (((analogRead(A2) / 1023.00) *5) *100;
// Kelv = Kelvin
float Cel = Kelv – 273.15; // Cel = Celsius
float Fah = (9.00/5)*Cel + 32; // Fah = Fahrenheit
```

Note that the analogRead( ) function reads the voltage applied to one of the analog pins from the Arduino UNO in Figure 1. In this case, the analog pin is A2. This analogRead ( ) function returns a number between 0 and 1023 [6], which represents voltages between 0 and 5 volts (V). Also, the factor of 100 in the Kelvin equation comes from the fact that the LM335A works like a Zener diode with a breakdown voltage proportional to the absolute temperature at 10mV/°K [7].

Unlike the calibration of the LM335A, the Honeywell corporation provides a chart [8] on output voltage versus relative humidity, as shown in Figure 2.

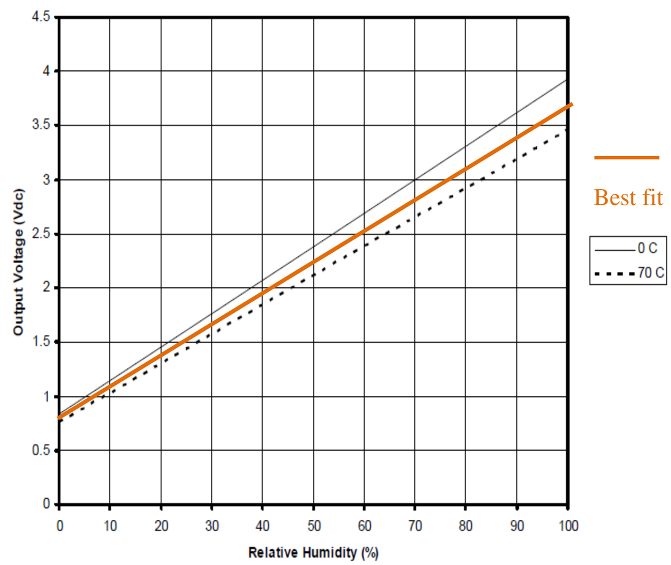

Figure 2. Output Voltage versus Relative Humidity

Based on Figure 2, the best linear fit and linear equation can be used to calibrate the relative humidity value from the raw analog value.

```
float MaxV = (3.27-(0.006706*Cel));
float RelativeHumi = ((((analogRead(A0)/1023.00)*5)-0.8)/MaxV)*100;
```

Note that the maximum voltage (MaxV) value drops to 0.006706 for each degree Celsius over 0°C. The voltage at

0°C is 3.27. This is corrected for zero percent voltage offset, which is approximately 0.8.

Similar to the calibration of relative humidity, the calibration for carbon monoxide (CO) is based on the sensitivity characteristics of the gas concentration chart. For instance, the gas concentration chart [9] in Figure 3 is used as part of the calibration for the CO concentration in PPM (parts per million).

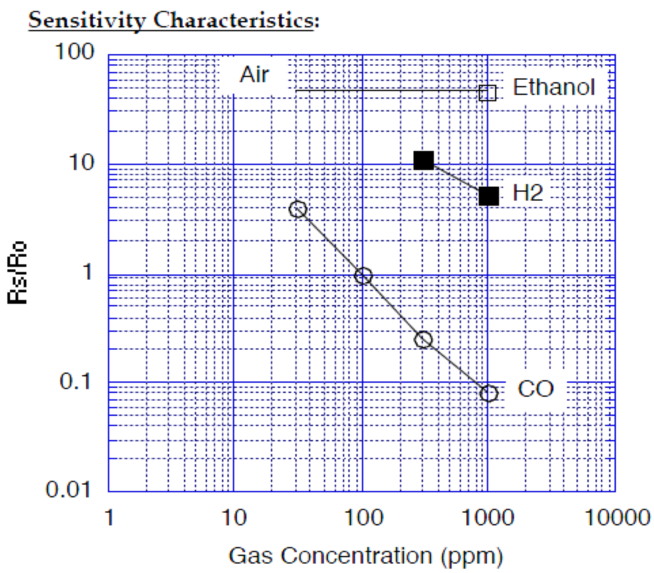

Figure 3. CO Concentration in PPM

The Y-axis in Figure 3 indicates the sensor resistance ratio, Rs/Ro, which is defined as follows:

Rs = Sensor resistance of displayed gases at various concentrations

Ro = Sensor resistance in 100 PPM CO

Figure 3 represents the typical sensitivity characteristics of the CO concentration level which increases as the sensor resistance decreases. As the value of the sensor resistor, Rs, decreases, the voltage across Rs decreases because the fixed resistor and the sensor resistor are connected in series. This is illustrated in Figure 4. Another way of looking at Ro in Figure 3 is the level of exposed gas to the sensor in a confined space. For instance, if 100 PPM were poured into the container in a confined space, what would the Rs sensor read? It may read 98 PPM or 102 PPM. Using the voltage-divider concept, the formula for defining the sensor is as follows:

$$Rs = \frac{Vc \times R_L}{Vout} - R_L \tag{1}$$

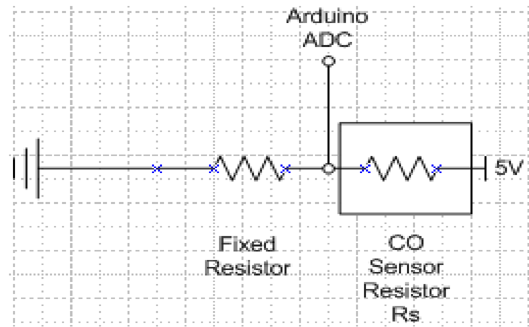

Figure 4. CO Sensor Resistor

From Equation (1), Vc is the voltage input, 5 Volts, from the Arduino UNO microcontroller. R_L is the load resistance (in this case, 39kΩ was used) that was connected to the CO gas sensor. Vout is a voltage signal from the CO gas sensor, which varied depending on the PPM CO concentration. The value of Rs in Equation (1) changes according to the amount of CO gas present—as seen in Figure 3; the typical detection range for the CO gas sensor is 30 to 1000 PPM. If the resistance value of Rs is the same as Ro, then 100/100 = 1, which correlates to 100 PPM in Figure 3. In theory, Ro represents the X axis in Figure 3, if conditions are perfect.

Hardware Schematic of the Handheld AirCasting Device

Using the Fritzing software program, the overall schematic layout for the handheld AirCasting device was designed, as illustrated in Figure 5.

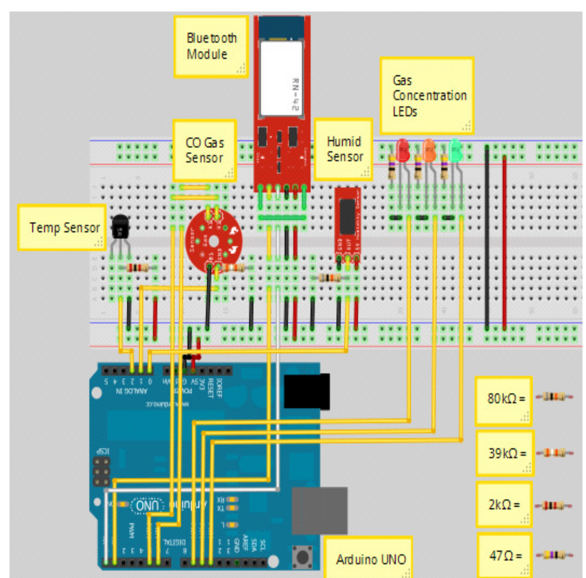

Figure 5. Schematic Layout of the Handheld AirCasting Device

From Figure 5, the yellow, red, and black wires are used as data signal communication, voltage and ground, respectively. The signal lines for the three sensors (temperature, CO gas and humidity) connect to the Arduino analog pins A2, A1 and A0. The red and black lines are connected to the Arduino 5V and ground pins, respectively. The yellow and white wires from the Bluetooth module are used as the transceivers and are connected to Arduino pins TX (transmitter – yellow wire) and RX (receiver – white wire). The use of a Bluetooth module provides the wireless communication lines between the AirCasting device and a smartphone or tablet. Also, the three color LEDs indicate the level of CO gas concentration. The green, orange and red LEDs indicate the least, medium and highest CO concentrations, respectively, making the AirCasting a unique mobile handheld device.

Prototyping of the Handheld AirCasting Device

Based on the hardware schematic layout of the handheld AirCasting device in Figure 5, the physical prototytpe for this device was made. Figure 6 shows the progress stages in designing the AirCasting device.

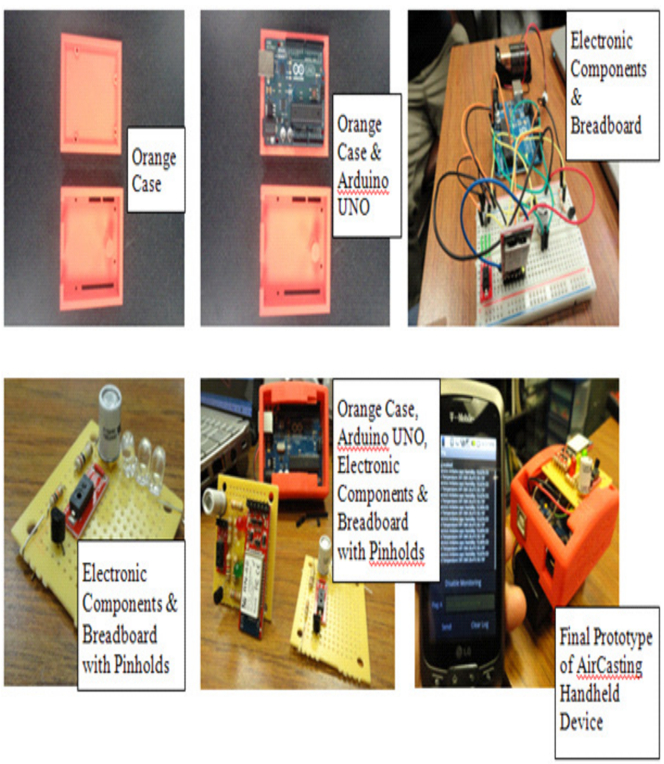

Figure 6. Design Stages of the Handheld AirCasting Device

The custom-made AirCasting device cover (orange case) is used for holding the Arduino UNO microcontroller and electronic components (sensors, resistors, LEDs and Bluetooth) along with the breadboard. First, a computer model of the AirCasting device was created using Autodesk Inventor software. Figure 7 is a computer rendering of the device. Then, a phyical prototype was made using a 3D rapid prototyping machine, as shown in Figure 7. The electronic components were soldered on the back side of the breadboard. After all of the electronic components were soldered on the breadboard, the completed breadboard was mounted in the orange case. This completes the design stages of the AirCasting prototype.

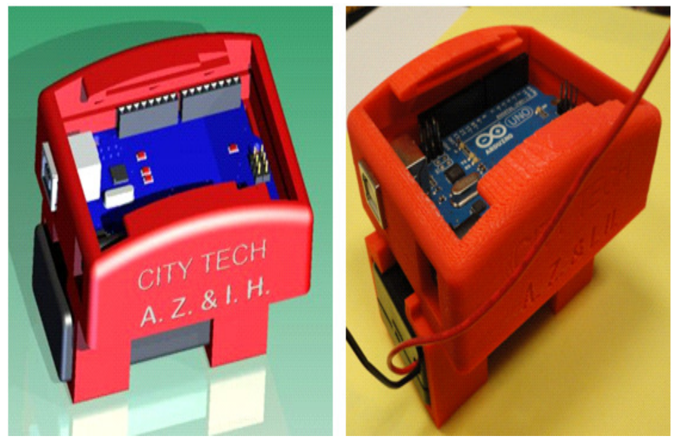

Figure 7. Computer Rendering and Physical Prototype of the Handheld AirCasting Device

Software Design of the Handheld AirCasting Device

Following is a discussion of how the software program communicates and interfaces between the AirCasting device and mobile smartphones or tablets. The source code was written in Arduino Sketch to communicate and interface with the electronic components, such as the temperature sensor, humidity sensor, CO gas sensor and LEDs, as shown in Figure 6. Upon the success of interfacing with the sensors and LEDs in Arduino Sketch, the Android library MeetAndroid was imported into the Arduino library folder so that the data acquisition could be sent from the Arduino Serial Monitor to the Amarino Application (App) progam. The Android library MeetAndroid is part of the Amarino driver device that must be imported into the library folder of Arduino Sketch. The Amarino progam [10] is a freeware program that incorporates a plug-in mechanism which allows programmers and developers to integrate their events into Amarino. This, then, provides a gateway to communicate with smartphones or tablets based on the Android open-source operating system. Figure 8 illustrates the details of communication between Arduino Sketch, the Amarino App, AirCasting App and Android operating system.

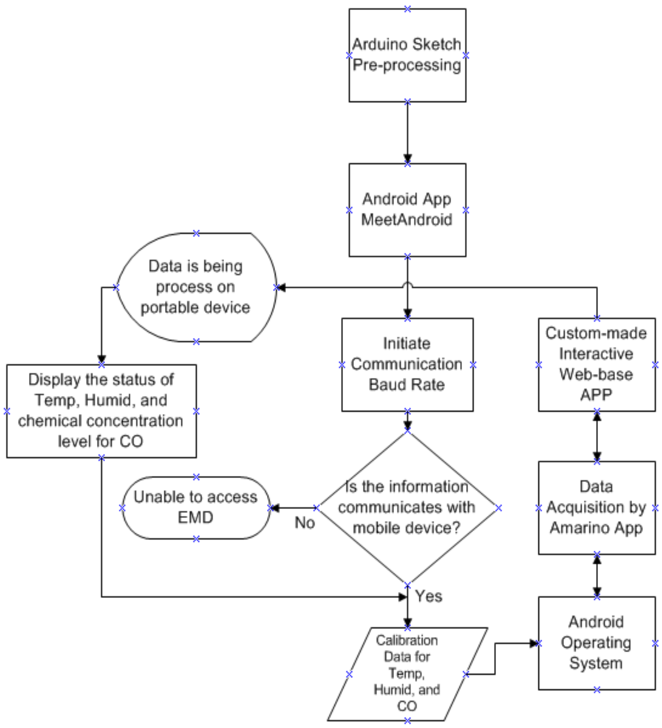

Figure 8. Flowchart of the Handheld AirCasting Device

Since the Amarino program is capable of acquiring the data acquisition from the AirCasting device through Arduino, the AirCasting App was developed to retrieve the data from Amarino App. This AirCasting App is an interactive web-based map that displays both individual and aggregated routing information on sound levels, temperature, humidity and carbon monoxide. It is written in the high-level Java and XML programming languages. The source codes of the AirCasting App are too long to be included here. Instead, the block diagram of the AirCasting App is introduced in Figure 9.

The system in Figure 9 is composed of two main parts: an Android App and a Ruby-on-Rails [11] backend. The main purpose of the Android App is to gather environmental data which is subsequently stored in the backend. It also allows the user to view data gathered and stored in the backend. The web application's purpose is twofold: it exposes an API which the Android App can use to submit data, and has a web user interface for a more comfortable way to browse the data.

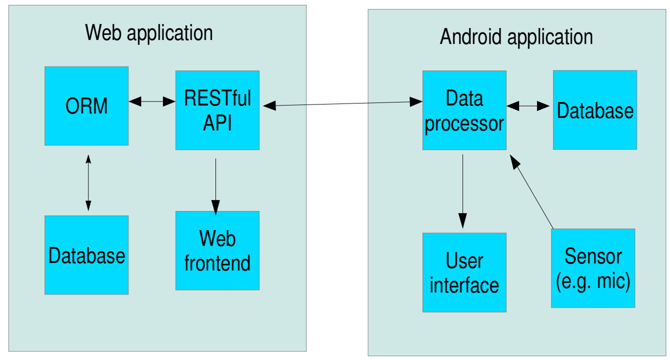

Figure 9. Block Diagram of the AirCasting Application

Android Application

The Android App (see Figure 9) accesses an environmental sensor connected to the phone (thus far, only the built-in microphone) and stores measurements obtained from that sensor (in the case of a microphone, sound volume levels). The measurements are annotated with the time and location where they are taken and form a sequence called a session. The users can add their own notes (to sessions) to indicate that some special events have occurred while measuring. Sessions are stored in a database on the phone so that the user is quickly able to access their data. Using the API, the application will also upload sessions to the backend when network connectivity is available. The application's user interface allows the user to view both their local data and aggregated data obtained from the web application's API.

Web Application

The most important part of the web application is the API it exposes. A RESTful HTTP approach [12] was used in this study and all data were transmitted as JSON [13] for maximum simplicity. The most important functionalities of the API are:

- Uploading sessions
- Accessing raw session data - this is used, for example, when the user is viewing a single session
- Accessing aggregated data - this is used to generate a "crowd map" represented with color-coded averaged data overlaid on top of a map

The API uses an Object Relational Mapping (ORM) [14] layer to write and read data from a database; thanks to this, the sessions from various users are kept in one place and aggregate data may be calculated. The web interface is functionally very similar to the user interface available in the Android App; it uses the data exposed by the API and renders it for the user. The complete source codes for the AirCasting App are available on the following AirCasting website: http://aircasting.org. The sample of the AirCasting App for sound levels can be seen in Figure 10.

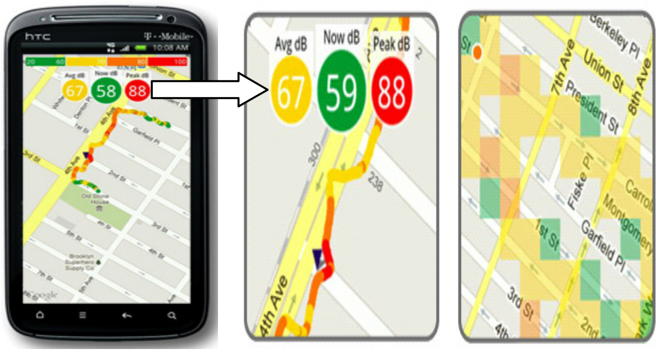

Figure 10. AirCasting App for Sound Levels

AirCasting Device: Testing and Results

Several tests of the AirCasting device were performed at different locations to record temperature, humidity and CO. The test was done by using a laptop, a Xoom tablet and a TMobile Android smartphone. The preliminary results, an average of the tests, are shown in Table 1.

Table 1. Testing and Results

Average	Temp (F)	Humid (%)	CO (PPM)
Indoor Tests	80.5	18.3	13.7
Outdoor Tests	42.3	31.5	8.1
Inside Passenger's Car	57.3	22.1	22.2
Behind Car's Exhaust Pipe	85.7	107.6	81.5

Several tests were conducted and hundreds of data points were recorded on four different scenarios by using a laptop, a tablet and a smartphone. Each scenario was then averaged, as displayed in Table 1. Of the four different scenarios, the worst case was placing the AirCasting device behind the car's exhaust pipe while the car engine was running. In this case, the average temperature, humidity and CO were approximately 85.7°F, 107.6% and 81.5 PPM, respectively. Note that the wind factor was about 7 to 10 miles per hour while these tests were being performed outside. This is why the results of the temperature, humidity and CO were a bit low due to the wind factor.

Conclusion

The handheld AirCasting device is about crowdsourcing cybernetic systems. Seemingly, every day brings to market a new portable device that is capable of augmenting human sensory experience by tapping into phenomena that are beyond the limits of human perception. On any given day, the air may be considered bad in a particular place; or our asthma may be flaring up. But sensing and communicating the quality of the air or the state of our bodies in precise and universal terms only becomes possible with the aid of scientific instruments. Previously, these instruments either did not exist or were too expensive or bulky to be purchased and carried on or in the human body. Currently, though, portable environmental sensors, tracking devices and biomonitors are rapidly becoming ubiquitous. The output from these cybernetic systems is innately social as data-basing and crowdsourcing are fundamental to the way they record information and evolve through technological iterations. By creating a platform that crowdsources data from thousands or potentially millions of cybernetic devices, a handheld AirCasting device becomes an analytics engine capable of picking out emergent patterns in human environments and biology.

Acknowledgements

This research was partially supported by a grant from the New York Hall of Science (NYSCI) and by a grant from the National Science Foundation (NSF ATE No 1003712). The authors appreciate greatly the support from the New York Hall of Science (NYSCI) and NSF. In addition, the authors would like to thank Raymond Yap (former City Tech student) who was involved in making the AirCasting device.

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Biographies

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MICHAEL HEIMBINDER is a community organizer, educator, and information designer. HabitatMap's community mapping and social networking platform is a direct testament to Michael's dedication to creating online platforms that engage the public and facilitate the sharing of news and information using geographic information systems. Since launching HabitatMap in 2006 he has worked with dozens of community based organizations and schools to create planning and advocacy maps that publicize the issues they care about most. In addition to running HabitatMap, Michael is Vice-Chair and Project Manager of the Newtown Creek Alliance, where he has made community knowledge sharing the keystone of the organization's successful efforts to clean up the Creek and improve quality of life in the surrounding neighborhoods. He is also a member of the New York State Environmental Justice Interagency Task Force Mapping Work Group and an advisor to the Organization of Waterfront Neighborhoods where he consults on solid waste management issues in New York City. Michael is a graduate of Colorado College and received his M.A. in International Affairs from the New School for Social Research.

PAWEL OBROK works for Lunar Logic Polska as part of web development team. He works on the programming aspect of AirCasting App and website to receive and display air quality data.

AN EXPERT SYSTEMS APPROACH TO HIGHWAY CONSTRUCTION SCHEDULING

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Abstract

In this study, the authors conducted a study for a Midwestern state department of transportation (DOT) to determine ways to improve the accuracy of the engineer's estimate of time required on highway construction projects. The goal of the project was to assist design engineers in developing more realistic construction schedules for a wide variety of projects. Expert input was obtained through interviews with highway contractors, resident engineers (REs), engineering design consultants, DOT design and construction engineers, and from records of completed projects as captured in RE's diaries and other project documentation. The results of the data collection were used to create 12 scheduling templates containing the pay items that controlled the completion of the project (controlling items). The templates were incorporated into software that was developed as part of the study. Schedules developed using the templates were validated in testing by DOT design engineers and technicians using record data from completed projects.

Introduction

Construction scheduling is a complex process that requires an intimate knowledge of construction methods, materials, and equipment and production capability for the individual work activities required to complete a project. Experience teaches construction schedulers how to assess the impact of weather, labor relations, subcontractor qualifications and crew productivity, material availability and other factors, and which work activities can be done concurrently. Contractors typically identify all project work activities, their duration and the relationships among them in order to find the activities that define the project's critical path.

Engineers who prepare plans, specifications and estimates (PS&E) for state departments of transportation are responsible for establishing the contract time allowed for completion of the work. Their estimates of time are typically based on pay items—major components of the work that are related to the specifications and form the basis for measurement and payment but may not represent individual work activities. While many DOT engineers have significant scheduling experience, new hires may have less field experience on which to base their selection of pay items that control the progress of the work (controlling items). One Midwestern state DOT identified the loss of institutional knowledge as a potential problem and requested research to examine ways to improve engineers' scheduling capabilities, including the proper selection and ordering of work items.

One solution to the problem would be to capture the experience of the retiring engineers who had years of estimating and scheduling experience. Chu and Hwang [1] stated many knowledge-based systems have been proposed with the knowledge from a single expert in the given field of study. However, since experts may have different experiences and knowledge in the same area, it would be advantageous and necessary to elicit and integrate knowledge from several of these experts to develop an effective expert system.

Expert systems provide a means for retaining institutional knowledge. Through the use of expert interviews, a knowledge-based model or template was created. A novice may then use the tool to solve current problems. Ismail et al. [2] proposed a computer-based expert system capable of using data from interviewed runway pavement engineers to detect pavement distress, diagnose causes of failure and recommend the most cost-effective repair strategies. Several studies have been done in the area of cost estimation to help improve estimating strategies and improve cost control and time and budgetary constraints [3-4]. Similar studies have been found inside the field of highway construction [5-7], but they focus on building parametric cost models rather than scheduling systems. A recent study used a reliability-based approach to help identify structurally deficient bridges and help prioritize the need for their repair or replacement [8]. And while other studies have identified a need for improved highway scheduling techniques [9-10], including the creation of typical models [11], no studies were found that created highway construction scheduling templates using common controlling pay items.

Researchers, acting in consultation with a project technical review panel (TRP)—made up of seven subject-matter experts from a Midwestern state's DOT and the Federal Highway Administration (FHWA)—conducted a study to determine ways to improve the accuracy of engineers' estimates of time required on DOT projects. The goal of the project was to assist design engineers develop more realistic construction schedules for a variety of typical DOT projects by capturing expert input from a variety of sources, including highway contractors, resident engineers (RE), consultants and the records of completed projects as recorded in the RE's diaries and other project documentation. Additional inputs included historical weather records, DOT standard specifications, recurring special provisions and design memoranda. This expert knowledge was used to create highway construction scheduling templates that contain the controlling items of work for twelve common highway and bridge construction projects. The development, testing and implementation of these schedules are discussed here.

Methodology

The research team obtained expert knowledge by interviewing construction professionals to determine best practices in planning the sequence and estimating of the duration of a wide variety of typical highway construction operations. DOT engineers and engineering consultants who routinely prepare plans, specifications and estimates (PS&E), and resident engineers who have experience administering DOT contracts were also interviewed to illuminate designers' strategies in project planning and scheduling. Using PS&E from typical road construction projects in the subject state, the research team documented the method of approaching the initial project planning from both the engineers' and the contractors' perspectives in preparing templates for planning and scheduling activities that lead to a probable schedule duration.

The researchers interviewed personnel at highway construction firms in two states, consultants, and DOT design engineers and resident engineers. Personnel from seven highway construction firms were interviewed regarding the procedures used in developing construction estimates and schedules, productivity rates on key items of work such as earthwork, concrete paving and asphalt paving, and factors that affect productivity either positively or negatively.

The engineer's perspective on construction scheduling was obtained by interviewing designers at a large consulting firm that performs work for the DOT and drawing upon the research team's professional engineering and scheduling experience. In addition, the seven engineers who were members of the TRP were instrumental in providing information to the researchers, including plans, specifications and estimates of time required for projects of varying complexity, and initial schedules and resident engineer's daily reports for a variety of completed projects.

Eight DOT resident engineers were interviewed during a half-day group working session to determine the potential for using project documentation as an additional source of information regarding controlling items of work, measurement of quantities of work put into place, typical sequencing of work, and the type and amount of equipment and manpower on the job each day. Another significant source of information was the project documentation found in the state's Construction Record System (CORS) database. The researchers were able to use the CORS data on completed projects to develop information on typical construction sequencing and productivity for those pay items that controlled the progress of the work (controlling items).

Results

Contractor Perspective

None of the contractors who participated in the study reported creating detailed or formal construction schedules as a separate exercise from the bidding process. Instead, the project's duration develops as a function of several key variables that are addressed while bidding, including, but not limited to:

- Quantity of major items of work to be self-performed by the bidder
- Availability of subcontractors to perform designated items of work
- Proximity of project to home office or other ongoing projects
- Availability of equipment and labor needed to perform the work
- Likely competitors for the work
- Backlog of work by the bidder
- Amount of time allowed in the contract documents

The bidding process is typically conducted in a short time frame in comparison to the time devoted to developing the plans, specifications and engineer's estimate. When projects are put out for bid, the contractor has a relatively short amount of time—typically on the order of one month—in which to examine the projects on the upcoming letting, determine which projects are a good fit for the firm, and make the decision to bid. For those projects selected, the contractor may have less than one week to perform the bid calculations and assemble the bid documents and schedule.

A commonly reported process was that a primary estimator works with a group of key personnel to outline the parameters of the project and begin working on the estimate. Because each project is unique, team members rely on experience and good communication to help identify important items that will affect the estimate. The primary estimator reads the bid documents, paying particular attention to the special provisions to identify unique requirements or restrictions. Environmental requirements and the soils report or soil boring information provided in the plans are considered key pieces of information. The estimator must have complete familiarity with the specifications, how each bid item is measured for payment, and what is included as incidental to each bid item.

Potential weather conditions are considered key in development of the project estimate. The estimator typically visits the National Oceanic and Atmospheric Administration (NOAA) or other weather reporting service website to determine the likely number of rain days per month during the project period.

Other team members verify the plan quantities, with particular attention to the items that involve the largest quantities, such as earthwork or paving. Verifying plan quantities is not the same as estimating. For example, to determine the price per foot to install a pipe culvert, the estimator must consider and price such things as the size of pipe and its depth, survey layout of the pipe, the need for trench shields, trench bracing or trench dewatering, granular backfill, and protection of adjacent utilities, among other factors. Plan quantities for this example would only include the linear feet of pipe and not provide for additional items and logic.

Depending on the size of the project, an experienced person typically visits the site and confirms key physical constraints such as stream crossings, access roads with weight or height restrictions, location of overhead utility lines or other obstructions that may impact crane or other equipment operations, traffic conditions, type and size of trees to be removed, soil, groundwater and potential flooding conditions, location of potential borrow or waste sites, equipment staging areas and other conditions. Resources such as Google Earth or other mapping utilities may be used to supplement or substitute for a site visit, depending on the complexity of the project.

Additional constraints are identified, such as requirements for night work, air and water quality permits, relative location, prices, billing terms and production capabilities of key material suppliers, noise, dust, or other daily or seasonal restrictions on construction operations, protection of endangered species or other environmental restrictions on construction operations and others. While some firms indicated use of a checklist of general items, most acknowledged that an understanding of the extent and potential impact of various constraints is developed through experience.

Depending on the firm's capabilities, the major items of work to be self-performed versus subcontracted are identified and estimators begin to work on obtaining subcontractor bids and material quotes. One of the most time-consuming functions is examining each pay item and identifying all the work activities required to execute that item. Most work activities require equipment, labor and material. As each work activity is identified, the estimator begins to "build" the crews required to complete the work. Crews are typically built around major functions such as long- and short-haul earthwork, pipe installation and paving. The equipment needed to perform each work activity is determined and production rates are computed based on fundamentals such as creating a mass diagram, determining haul distance, estimating loading time for trucks and scrapers, and finding total cycle time for travel. Resources such as the Caterpillar Handbook are used to determine the capability of equipment, but historical records and "rule of thumb" production rates are also used to get quick estimates of time required.

Contracting firms typically do not have a person whose primary job title is "scheduler." The project schedule is developed as an outgrowth of the estimating process as the office personnel (project manager and senior estimator) and field personnel (key superintendents and foremen) reach consensus on how the project will be built (methods), how the project will be executed (order of operations, application of available resources, concurrent and sequential activities), and how long the project will take (schedule). This consensus is typically developed in a pre-bid meeting in which the key personnel validate the estimate and make the final decision to commit to the numbers.

Most estimators keep track of concurrent activities mentally unless a project is complex. Creation of a bar chart schedule helps visualize the possible concurrent activities and identify the critical path and the early finish date or number of days likely to be required for the project, but formal schedules are not widely used unless required for submittal. Instead, the single most important factor in determining the construction schedule is how much time is allowed in the contract documents, and whether there are incentives for finishing sooner. This insight returns the burden for realistic construction scheduling to the engineers who create the contract documents and establish the contract time.

Determination of Contract Time

The engineer is charged with determining a reasonable time to complete the project. Contract time can be stated in terms of working days, calendar days, a completion date, or some combination of these. Calendar days and working days are defined in the state's standard specifications. Calendar days are every day shown on the calendar. Working days are calendar days with the exception of Saturdays, Sundays and holidays that are recognized by the contractor's entire workforce statewide, from May 1 through November 30. The period December 1 through April 30 is the winter exclusion period for this state during which time the contractor may perform work as long as specified restrictions regarding temperature or weather conditions are not violated, without working days being charged against the contract time. This practice of the winter exclusion is typical of northern states, although the beginning and ending dates vary by state.

As described in the state's design manual, the number of days required for each item is obtained by dividing each quantity by its respective production rate. The production rates are published in the manual for some major work activities. Engineers are encouraged in the manual to determine a logical order of work activities and to consider which activities can be performed concurrently. The designer determines the total days required and days not affecting time limit and creates the estimate of time required. A bar or arrow diagram comprised of major pay items is used to help determine the critical path and activities that will be controlling versus those that will not affect the early completion date.

Controlling Items and Scheduling Templates

A key aspect of the research was the development of scheduling templates that synthesized the knowledge gained from the diverse expert sources. The results of the research indicated that many highway projects share the same controlling items and that many common construction activities do not affect the overall project duration. A decision was made in consultation with the project TRP to develop project templates using only controlling items. In order to standardize the terminology used to describe these controlling items, the terms used for the production rates given in the state design manual were selected. Terms describing the construction of "bituminous" pavement were updated to Hot Mix Asphalt (HMA) pavement to reflect current terminology used in the state's supplemental specifications, recurring special provisions and construction inspection checklists. Terms describing sub-tasks in bridge construction were also added.

Table 1 shows the final list of 49 controlling items selected to form templates covering the construction of the most common types of highway projects in the state, as determined by the project TRP. Table 2 shows the 12 project types for which scheduling templates were developed.

The templates were incorporated into software that was developed as part of the study. Users input values or accept defaults for parameters such as the anticipated start date, projected number of working days per month, and the winter exclusion period of December 1 through April 30. Historical temperature and rainfall records can be selected to allow users to study the impact of various start dates, the likely project-specific weather throughout the calendar year, and other project-specific constraints such as protection of bat habitats or restrictions on road closure dates. An example template and associated schedule for Roadway Reconstruction are shown in Figure 1.

The 12 suggested templates may be modified by deleting unnecessary controlling items or by adding controlling items from the list in Table 1. Because the templates are constructed using only controlling items, the user can quickly generate a project schedule and estimate the project completion date, number of working days and number of calendar days. Assumptions can be easily changed to study the impact on the completion date. A complete list of the controlling items contained in each template is given in Appendix A.

Each template will generate a bar chart project schedule showing only the controlling items. Concurrent activities that may be required to complete the project but are not likely to impact project completion date are not shown. The use of standard templates allows the designer to easily modify the base parameters and study the impact on the number of working days and completion date.

Conclusion

The goal of the project was to develop scheduling templates to assist designers in the creation of more realistic construction schedules for typical highway construction projects. The knowledge input for the software tool included contractors, design engineers, resident engineers, consultants, historical project records and published research on highway construction scheduling. The research approach was to focus on controlling items for a set of typical highway construction projects. Scheduling templates for 12 types of road and bridge construction projects were developed from a list of 49 controlling items that were selected in consultation with subject-matter experts based on an examination of historical project records. The templates created during this study will allow a more standardized approach to highway construction scheduling, thereby providing design engineers across the state with standard project templates. The software tool provides flexibility for designers to modify templates and to create and share new templates developed over time.

Table 1. Controlling Items for Development of Scheduling Templates

Borrow Excavation	PC Concrete Pavement
Bridge Approach Pavement	Pipe Under-drains
Checkout / Acceptance	Place Abutment
Class A Patching	Place Bridge Deck
Class B Patching	Place Pier Cap
Class C / D Patching	Place Pile Cap
Concrete Curing	Place Columns
Concrete Structures	Precast Box Culverts
Concrete Superstructure	Precast Concrete Beam Erection
Curb / Gutter – Drainage	Precast Concrete Bridge Deck
Deck Slab Repair (Partial Depth)	Process Lime Stabilized Soil
Driving Piles	Raised Reflective Pavement Markers
Earth Excavation	Removal of Existing Concrete Deck
Earth Excavation (Shoulders / Widening)	Removal of Existing Substructure
Fabricate Bridge Deck Formwork	Removal of Existing Superstructure
Fabricate Bridge Deck Reinforcing	Seeding
Gravel or Crushed Stone Base Course	Stabilized Sub-base
Gravel or Crushed Stone Shoulders	Steel Plate Beam Guardrail
HMA Pavement	Storm Sewers (Dependent on size, depth)
HMA Shoulders	Strip Reflective Crack Control
HMA Surface Removal	Thermoplastic Pavement Marking (Hand)
HMA Pavement Removal	Thermoplastic Pavement Marking Symbol
Mobilization	Traffic Control
Paint Pavement Marking (Hand)	Tree Removal
Paint Pavement Marking (Truck)	

A follow-up study could attempt to collect the opinions of users to help improve the current set or create additional sets of templates. In addition to improving the tools for existing users, other state DOT designers could be questioned about the use of controlling items in creating such templates. Another national study could be completed to validate the model in regards to the contractor's perspective. In addition to the templates, researchers could re-examine their state's winter exclusion periods. Perhaps these periods are outdated and do not reflect technological advances in materials and equipment.

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Table 2. Scheduling Templates Developed

1. Roadway Rehabilitation	**4. Intersection Reconstruction (Continued)**	Checkout / Acceptance
Mobilization	Earth Excavation (Shoulders / Widening)	**9. Bridge Rehabilitation:**
Traffic Control	Stabilized Sub-base	Mobilization
Class C / D Patching	HMA Pavement	Traffic Control
HMA Surface Removal	Thermoplastic Pavement Marking Symbol	Class C / D Patching
HMA Pavement	Seeding	HMA Surface Removal
Pipe Underdrains	Checkout / Acceptance	HMA Pavement
HMA Shoulders	**5. Interchange with Bridge Replacement:**	Paint Pavement Marking (Hand)
Paint Pavement Marking (Truck)	Mobilization	Checkout / Acceptance
Checkout / Acceptance	Traffic Control	**10. Bridge New Construction:**
2. Roadway Reconstruction:	Earth Excavation (Shoulders / Widening)	Mobilization
Mobilization	HMA Pavement	Traffic Control
Traffic Control	Replace Structure - Series	Bridge Substructure - Parallel
Earth Excavation (Shoulders / Widening)	HMA Pavement	Precast Concrete Beam Erection
HMA Pavement Removal	Paint Pavement Marking (Truck)	Precast Concrete Bridge Deck
Gravel or Crushed Stone Base Course	Seeding	Steel Plate Beam Guardrail
HMA Pavement	Steel Plate Beam Guardrail	Earth Excavation (Shoulders / Widening)
Pipe Under-drains	Checkout / Acceptance	Process Lime Stabilized Soil
HMA Shoulders	**6. Grading:**	Stabilized Sub-base
Paint Pavement Marking (Truck)	Mobilization	Bridge Approach Pavement
Seeding	Tree Removal	HMA Pavement
Raised Reflective Pavement Markers	Precast Box Culverts	Seeding
Checkout / Acceptance	Earth Excavation	Paint Pavement Marking (Hand)
3. Roadway New Alignment:	Checkout / Acceptance	Checkout / Acceptance
Mobilization	**7. Bridge Repair and Deck Overlay:**	**11. Patching & Resurfacing – PCC:**
Tree Removal	Mobilization	Mobilization
Earth Excavation	Traffic Control	Traffic Control
Process Lime Stabilized Soil	HMA Surface Removal	Class A Patching
Gravel or Crushed Stone Base Course	Deck Slab Repair (Partial Depth)	Strip Reflective Crack Control
HMA Pavement	HMA Pavement	HMA Pavement
Pipe Under-drains	Thermoplastic Pavement Marking (Hand)	Thermoplastic Pavement Marking (Hand)
HMA Shoulders	Checkout / Acceptance	Raised Reflective Pavement Markers
Paint Pavement Marking (Truck)	**8. Bridge Reconstruction:**	Checkout / Acceptance
Thermoplastic Pavement Marking Symbol	Mobilization	**12. Patching & Resurfacing – HMA:**
Seeding	Traffic Control	Mobilization
Raised Reflective Pavement Markers	Earth Excavation (Shoulders / Widening)	Traffic Control
Checkout / Acceptance	HMA Pavement	Class C / D Patching
4. Intersection Reconstruction:	Replace Structure - Series	HMA Surface Removal
Mobilization	HMA Pavement	HMA Pavement
Traffic Control	Paint Pavement Marking (Truck)	Thermoplastic Pavement Marking (Hand)
HMA Pavement Removal	Seeding	Raised Reflective Pavement Markers
Storm Sewers (Dependent on size and depth)	Steel Plate Beam Guardrail	Checkout / Acceptance

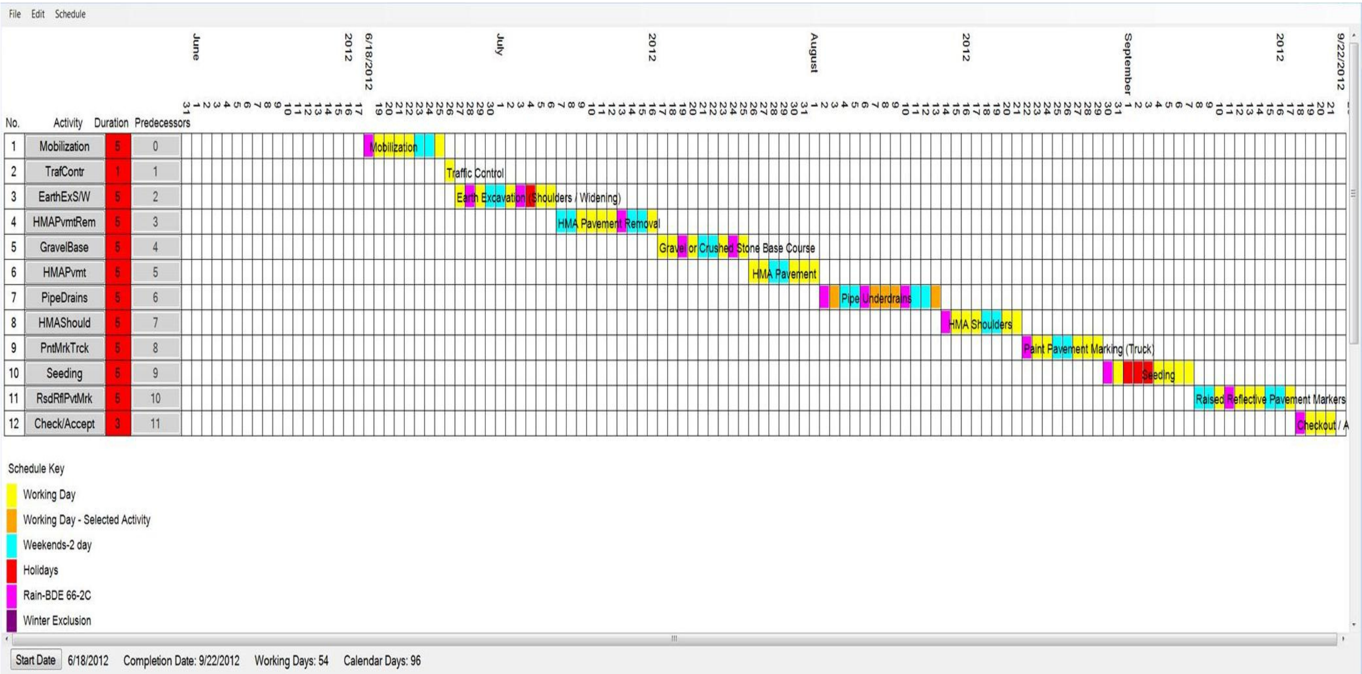

Figure 1. Scheduling Template for Roadway Reconstruction

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THE HISTORICAL IMPACT OF BUSINESS AND ENGINEERING EDUCATION ON THE INDUSTRIAL DISTRIBUTION DISCIPLINE

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Abstract

Industrial distribution as an educational discipline is relatively new. Its origin came during the industrial revolution when manufacturers discovered that engineers generally made poor technical sales representatives. While engineers were competent in technical content, they often had no interest, or no ability, in selling the product to the end user. The interpersonal skills of engineers were often lacking the necessary components to be successful in a sales environment. Business school graduates, however, had an entirely different challenge. Manufacturers of technical products found that business graduates lacked the ability to understand the products and explain to customers the technical aspects of these products. Industry demand called for a cross between these two educational disciplines, sort of a hybrid engineering/business education, hence, the beginning of societal and educational demand for the industrial distribution discipline. In 1956, Texas A&M University accepted the challenge of creating a degree that combined the technical skills of an engineer and the relationship skills of the business professional into what is now known as a technical sales professional. This degree was called industrial distribution and combined coursework from both engineering and business curricula. This study examined the histories of both of these degrees and how the content and the blending of said content from each of these disciplines allowed for the formation of the industrial distribution degree.

Introduction

Just as most disciplines within higher education originated from societal need, industrial distribution, as a post-secondary discipline, developed as the need for a more technically competent sales force evolved soon after World War II (WWII). As manufacturing of technical products increased and the need to get these products to end users grew, the distribution model of conducting business continued to evolve. The history of industrial distribution is not a well-researched topic. Porter and Livesay [1] point out in their book, *Merchants and Manufacturers*, that "changes in the distribution played at least as important a role in the story of our economic past as did changes in production" [1]. The attention of most historians, however, has been primarily directed at developments in manufacturing. The origin of the distribution of manufactured products in the United States dates back to the early beginnings of the country when products were manufactured by skilled tradesmen, and then bartered, traded or sold to local end users.

After WWII, distributors provided a way for manufacturers to have a presence in most communities and markets. They would provide the end user with a place to purchase products in a sort of one-stop shop. This became very advantageous to both the manufacturer and the end user. As distributors developed and became specialized in specific products and markets, they realized the difficulty of finding and developing technical sales people. If these distributors hired graduates with the soft skills necessary for a professional salesperson from business colleges, they often lacked the ability to learn and retain the technical information required. Conversely, if these distributors hired trained engineers, it was found that although the engineers did very well in the technical area, they lacked the necessary people skills required to develop the personal relationships needed in the sales arena. This dilemma initiated the demand to develop a specialized degree that combined the people skills and the technical skills needed to become successful technical sales people. Texas A&M initiated such a degree in 1956 and they called it industrial distribution. This degree became the provider of technical sales personnel for the industrial distribution industry. Texas A&M's degree has been recognized as an educational leader in industrial distribution. Several other schools followed in developing this degree, including the University of Nebraska at Kearney, Purdue, Alabama Birmingham, East Carolina University and others.

This paper summarizes the history of both business education and engineering education so that the reader might be able to understand how the need for a specialized degree in industrial distribution evolved.

Business Education in the United States

According to Moreland [2], business involved money lenders, the legal fraternity, merchants and entrepreneurs for many centuries. From the early beginning of the United

States, the guild and apprenticeship systems, many of which were originally developed in other countries, were an integral component of the trade system. During this same time, bookkeeping instruction began to take root as it made its way from Europe to the New World.

Business Education Comes to the New World

Small business in the U.S. has evolved since the very early arrangements by the British to promote export trade with the newly established American colonies. As the settlers came to the New World, the New England colonies gave birth to home industries that grew into village and town industries. Labor and skills became more specialized. The sole proprietors and leaders of these small businesses were often journeymen skilled in a trade, such as shoemakers, gunsmiths, bakers, weavers, tailors, tanners, powder makers and others [3].

During the early days of the U.S., schools, teachers and books were scarce as education was considered private, and the skilled trades were passed along without formal education. The Massachusetts General Court passed the first act in 1647 requiring all settlements of 50 families or more to provide elementary school and towns of 100 families or more to provide secondary schools to prepare boys for college [2]. The curriculum was largely classical, however, and not considered important.

Evolution and Improvement of Business Education

Although not widely recognized or supported until the mid-eighteenth century, bookkeeping was first offered in Boston in 1709 and in New York City in 1731 [4]. Because these cities were centers of trade, bookkeeping, mathematics and other classes such as navigation and surveying were offered. In 1749 Benjamin Franklin urged schools to adopt "commercial and productive" classes [4]. As a result, the curriculum diversified, and classes such as commercial arithmetic and bookkeeping were offered [4].

Perhaps the most influential education leader of his time, Horace Mann (1796-1859) wrote "Why should algebra, which not one man in a thousand ever uses in the business of life, be studied by twice as many as bookkeeping which everyone, even the day labourer, needs?" [2]. On the other hand, Charles Eliot, president of Harvard from 1869 to 1909, reflected the academic view. He was instrumental in developing the elective system and established the first graduate school of business administration. Business education grew as the demand for it increased.

Private colleges began to open to meet the demand for educated business workers. Bartlett's Business College located in Philadelphia opened in 1834, and Dolber's Commercial College located in New York City opened in 1835 [5]. Most notable, however, is Duff's Mercantile College, which began in 1840 and was incorporated in 1974. Still in existence today, the school is currently known as the Everest Institute, Pittsburg campus.

More schools continued to open during the last half of the 19th century. Until the early 1860s, only males attended business schools. However, during the Civil War, the federal government experienced a shortage of male clerks, and suddenly women entered the business world through the Treasury Department [4]. In 1867, the U.S. Office of Education was created as a part of the Department of the Interior. In 1953, it became part of the Department of Health, Education and Welfare.

Another large contributor to the growth of business education in college was the Morrill Act, passed in 1862 [5]. This Act granted states a designated number of acres for the purpose of establishing schools of agriculture, mechanical arts and business. Higher education for business now had a permanent place in the college arena. In 1881, the Wharton School of Finance and Commerce, University of Pennsylvania, was founded and became the first successful school of business. Other four-year institutions began opening schools of business by the end of the 19th century. Joliet Junior College, established in 1902, was the first post-secondary 2-year institution with a business curriculum.

While many federal legislative acts contributed to the growth of business education, perhaps one of the most significant contributions was the Smith-Hughes Act of 1917, later known as the Vocational Act of 1917. This legislative act promoted vocational programs in agriculture, trade and industry, and home economics. In 1963, the definition of vocational education was broadened to include business. Vocational (career) education was later championed by Carl D. Perkins, which ushered in the era of Perkins legislation beginning with the passage of the Carl D. Perkins Vocational Education Act of 1984 [5].

During the mid-1800s, as business moved from an agrarian society to an industrial society, management became an issue because no common body of knowledge existed for instruction in management [6]. James Montgomery of Scotland prepared one of the first management texts ever written. Because Montgomery was so highly regarded as a manager, he was brought to the U.S. in 1836. He prepared a comparative study of management in different economies. The focus was on organization, methods and the recognition of human problems as industry expanded. This beginning gave way to scientific management thought, and then to efficiency and the modern era of management theory and practice.

In the early beginnings of marketing, students were educated as economists. From Adam Smith's concept of "the economic man bent upon a constant effort to better his condition" [7] through competition and the idea of the consumer in economic theory in the 19th century, marketing evolved to sales, advertising, research and marketing management. By 1976, marketing included quantitative aspects, marketing systems, environmentalism, comparative marketing, international marketing, logistics and marketing and society [7].

Business Education Curriculum Development

While the origin of management in the curriculum is unclear, some evidence points to engineering students as the first recipients of a series of lectures at Stanford University in 1896 by John Richards on works administration [6]. One of the first management textbooks to hit the shelves of business schools came in 1911 when Frederick W. Taylor published his first textbook on scientific management, entitled "The Principles of Scientific Management".

With the addition of distributive education (i.e., marketing) in the early 20th century, the curriculum expanded. Ohio State University was one of the first schools to include marketing in the curriculum [7]. The first classes included Distribution of Products in 1905, Commercial Credit in 1909 and Salesmanship in 1916. By 1921, the curriculum included business communications, marketing, marketing problems, wholesaling, retailing, credits and collections, salesmanship, advertising, advertising practice, exporting and importing, and research in marketing. In 1937, Congress passed the George-Deen Act that provided funds for teachers to teach classes in distributive subjects such as sales, marketing and wholesaling. This step allowed marketing education to expand. The concepts of differentiation and socialization were added between 1960 and 1970.

From its roots in money lending, trade guilds, and apprenticeships, today's business education curriculum has grown to include many facets of business administration including accounting, economics, information technology, finance, management, sales, supply chain and marketing. Figure 1 is a representation of some of these post-secondary business school disciplines offered today.

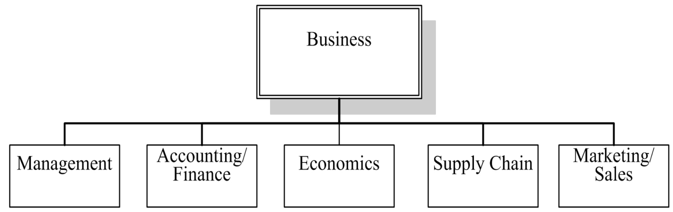

Figure 1. Typical Business School Disciplines

Business curricula did a very good job at developing the soft skills and the business operations skills needed in the distribution industry. However, the need to understand technical information and be able to assist customers with technical information was lacking. Distribution still needed people that had the ability to learn technical products. Engineering, on the other hand, did a great job of preparing people for the technical side of the business. The soft skills needed by engineering graduates to be quality sales people were lacking, due in part to the kind of training received in school.

The Beginning of Engineering Education in the United States

On a parallel course to that of business education, engineering education in the United States was beginning to evolve and take shape during the infancy of the country. This engineering education was heavily influenced by the European settlers of this country. During the early 1700s, several European countries, including France, Germany and England, had significant epistemological influence on science and engineering. Russia was also one of the earlier entrants into the field of engineering and technical education. The early European system of engineering education evolved from a complex system of guilds and apprenticeships, as well as societal demand for more theoretical solutions to basic needs. The early adopters of engineering and technical education came from many different backgrounds, and this historical setting would shape the future of the profession for many years to come [8].

During the early years of American industrialization, there was a strong relationship between the political and economic framework of the country. Financial rewards were built-in to stimulate the manufacturing foundations of the new country. Manufacturing of basic items such as clothing, tools, food and other supplies was a major engineering concern for America during the late 1700s due to the non-importation law implemented in 1774. Further, as the country gained its independence from England and continued to grow, basic infrastructure was needed. There was a significant need for engineers to design and build roads, canals and bridges [9]. Societal demand would drive increased opportunities for engineering and, perhaps more importantly, an increase in more technically engineered products.

Shop Cultured Engineering Education

During the late 1600s, amongst the English colonies in America, apprenticeships were growing. Several colonies even passed local laws regulating the apprenticeship programs. At the same time, there were efforts being made to introduce the idea of manual arts into formal education. This system of apprenticeship and manual arts instruction was the primary system of education for lower- and middle-class youth of the middle ages. As the country continued to grow and develop, this foundation of hands-on training would play a pivotal role in the development of a more scientific approach to some of the pressing needs of society.

School Cultured Engineering Education

With increased demands for technical experts in warfare, transportation, bridge building and canal design, interest in a more theoretical approach to industrial education was renewed. While several universities had been established in the U.S. during the 1700s, it was not until the year 1802, when the United States Military Academy (West Point) was created, that this country had its first official engineering program at the university level [8]. It was originally established as a school for both officer training and a national school for civil engineering. Other higher education institutions would soon be involved in engineering education; Norwich University, Gardiner Lyceum and The Rensselaer School are all considered some of the early pioneers in engineering education in the United States.

Meanwhile, the U.S. Congress passed the aforementioned Morrill Act in 1859 (and later signed into law by Abraham Lincoln in 1862). The Morrill Act would federally fund a system of agricultural and engineering colleges in each state. Also known as the Land Grant Act, it was a significant step in the progress of engineering and technology education in the United States. The purpose of these land-grant universities was to "teach such branches of learning as are related to agriculture and the mechanic arts, in such manner as the legislatures of the States may respectively prescribe, in order to promote the liberal and practical education of the industrial classes in the several pursuits and professions in life" [10].

Due in large part to the Morrill Act, there were over 85 engineering schools by 1880 [8]. This increase in engineering universities also increased the number and variety of engineering programs offered. Mechanical, mining, architecture, chemical and civil engineering programs began to emerge as separate and distinct fields of study. It was during this time that the profession of engineering education began experimenting with the notion of technology education. Figure 2 represents typical engineering programs offered today. Yet it would be several decades before engineering technology, as well as associated disciplines such as industrial distribution, would be recognized as separate disciplines.

The Influence of the Grinter Report

In 1952, the Committee on Evaluation of Engineering Education of the American Society of Engineering Education (ASEE) appointed L. E. Grinter and his committee to make recommendations regarding the direction engineering education should take in an attempt to keep pace with rapid developments in science and technology [11]. In 1955, this committee published a report entitled *Report on Evaluation of Engineering Education,* commonly known as the "Grinter Report". This report continues to be widely known and recognized as a driving force in engineering curriculum design and organization. However, in the little-known preliminary Grinter report, this committee proposed the need for two types of engineering programs: 1) a general professional program whose graduates would participate in the engineering problem-solving area to satisfy the needs of industry, and 2) a scientific professional program that would be based more in math and science. This preliminary program for a dual-path engineering approach was summarily rejected by the ASEE Board of Directors. The final Grinter Report did not include this dual-path approach, but instead only included the scientific professional program [12].

Despite industry demand for a recognized hands-on, experiential learning program (or some sort of general professional), academia was slow to adopt this new discipline. Industry, however, continued to demand students who were competent in the more practical application of engineering principles. Over time, engineering technology programs emerged to fill the gap.

The Emergence of Industrial Distribution Programs

The aforementioned early baccalaureate business, engineering and engineering technology programs in the U.S. did not include curricula specifically designed to train students in interdisciplinary study. However, due to increasing demands from industry to provide increased numbers of better trained and qualified students to market, sell and apply technical products, several higher education institutions started responding to these needs by the mid-1950s to 1960s. Industrial distribution programs began to emerge on the higher education landscape to fill this need in industry.

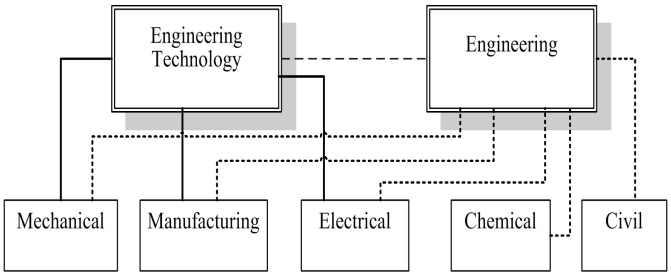

Figure 2. Post-secondary Engineering and Engineering Technology Disciplines

Industrial Distribution

To understand the industrial distribution industry, it is necessary to have some historical perspective on the industry, its culture, behaviors, evolution and environment. During WWII, many countries within the European region were devastated. Their ability to rebuild was compromised by the destruction of manufacturing plants. Europe's ability to rebuild, as well as its economic recovery, was highly dependent upon a good trading relationship with the United States. Within the U.S., wartime production facilities quickly converted to post-war, consumer-driven production, driven in large part by European markets. The European market included a high demand for industrial products. This change in market economy would mark the emergence of industrial distribution as a distinct field within industry and, in later years, a distinct discipline within academia.

While distribution of products was happening pre-WWII, it was the incredible industrial growth that took place during post-WWII that allowed industrial distribution (I.D.) to formalize and to be recognized as a distinct field. Professionals within the industrial distribution industry helped to streamline, or improve, post-WWII production and distribution of products. This was done by helping to reduce inventories, improve marketing strategies, and radically changed how logistics and transportation was being handled for industrial products [13].

Industrial distribution is simply a channel through which manufacturers of industrial products can take their products to market. An inherent advantage of the I.D. industry is that as manufacturing plants continue to change locations—for example, many companies that sent manufacturing to China over the last two decades are now bringing that same manufacturing back to the United States—the need and role of the industrial distributor has not changed. That role is to provide technical sales, marketing and service of these manufactured products to the end users of said products. Corey et al. [15] succinctly state the importance of industrial distributors: "if farms and factories are the heart of industrial America, distribution networks are its circulatory system."

Today, as evidence of the progress the I.D. industry has made, several universities throughout the United States offer bachelor's degrees in industrial distribution or other similar disciplines (e.g., Texas A&M University, Purdue University and the University of Nebraska at Kearney).

Despite little scholarly research on the industry, the wholesale distribution industry represents a significant force in the U.S. economy. Fein [14] estimates that the wholesale distribution segment of the U.S. market is over $4.2 trillion, represents approximately 7% of the private U.S. gross domestic product (GDP), and employs nearly one out of every 20 workers in the U.S.. The top ten wholesale distribution industries are represented in Table 1.

Table 1. U.S. Wholesale Distribution Industry Revenue

Major Industry Sector	2005 Revenue ($B)
Grocery and Foodservice Wholesale Distributors	$ 510.30
Oil and Gas Products Wholesale Distributors	$ 509.80
Pharmaceutical Wholesalers	$ 362.80
Industrial Distributors	**$ 338.30**
Motor Vehicle and Motor Vehicle Parts Distributors	$ 324.10
Electrical and Electronics Wholesalers	$ 323.30
Miscellaneous Durable Goods Distributors	$ 238.40
Other Consumer Products Wholesale Distributors	$ 222.90
Computer Equipment and Software Distributors	$ 182.80
Agriculture Products Wholesale Distributors	$ 179.90

Industrial Distribution Education Today

Industrial distribution programs today continue to struggle with their own identity. Throughout the United States, I.D. programs are housed in Colleges of Education, Business, Technology and Engineering. Over the years, proposals have been made within the educational community to merge, marginalize, abolish, rename, reconfigure or otherwise change I.D. programs. One of the challenges for these I.D. programs is to mitigate the effects that these subordination attempts have had on the discipline. Today, I.D. programs are often confused with Supply Chain Management. While I.D. is integral to the supply chain process, as illustrated by Figure 3, I.D. has a more specific role in the manufacturer's supply channel.

Products and technology play an instrumental role in the I.D. model. For example, I.D. personnel utilize management information technology to interface with supplier manufacturing operations, sales and marketing, logistics and engineering functions, which allow for effective and efficient communication and operations. Despite the evolution of products and technology over time, the specific role of industrial distributors remains the same. The business model of industrial distribution continues to include a strong emphasis on technical sales and may include other aspects of operations and customer service.

It has been shown that the trend for higher education is to place more emphasis on theory rather than practice [16]. While the need for content-rich curricula is demonstrated in many educational disciplines (such as chemistry, biology, physics, etc.), the requirement for hands-on experiential education could never be so important as it is in industrial distribution where the integration of theory and practice is critical for the thorough understanding, safety and professional progress of students.

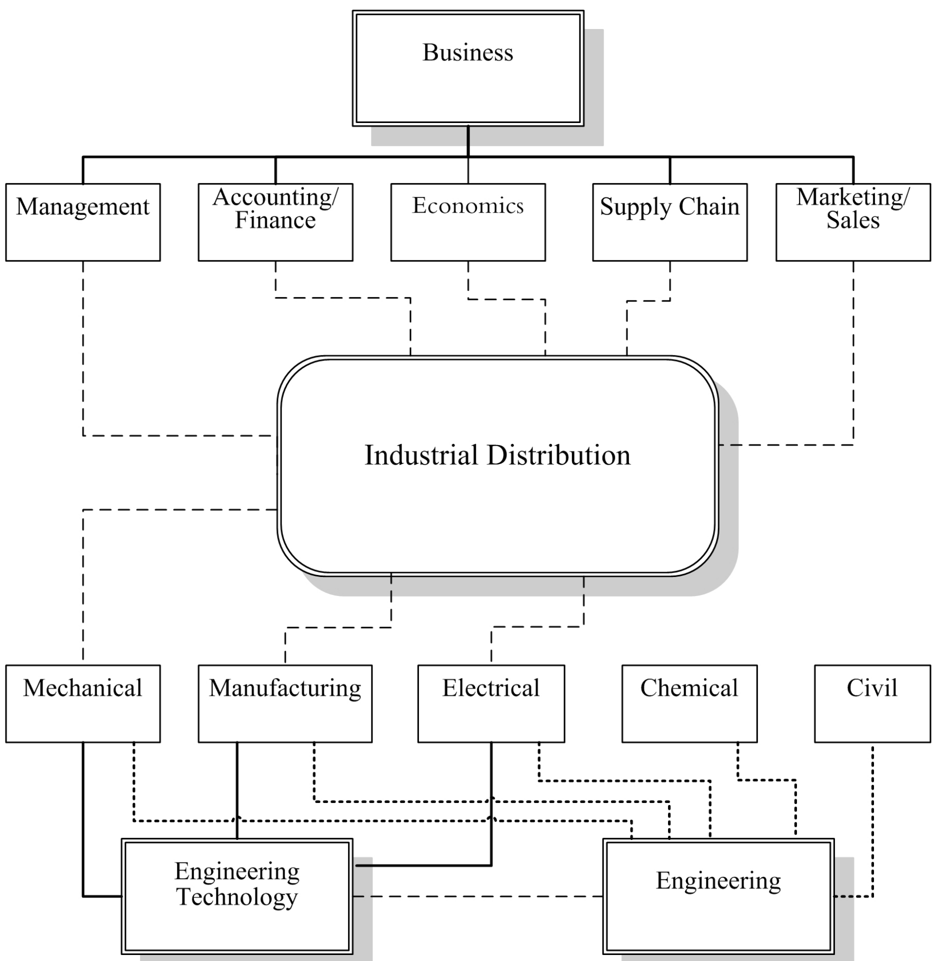

Figure 3. The Integration of Business and Engineering Disciplines

Conclusion

The need for a specialized degree in industrial distribution was originally driven by industry and continues to be a discipline in high demand. As these programs began to prepare technical sales people, it was found that they were successful because they had the soft skills of sales personnel, the knowledge of business operations, and the ability to learn and understand technical products and applications.

Industrial distribution, as an academic discipline, continues to evolve as the needs of industry change. Many industrial distribution programs have moved away from a technical sales emphasis to a logistics/supply chain emphasis. While the need for logistics and/or supply chain management may be important for many industries, it has not, nor should not, supplant the need for technical sales people. With the increase of technical products, the need for people with a combination of sales skills and technical skills is greater than it has ever been. Industrial distribution needs to continue to focus on this mission.

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Best Practices and Success Factors in Online Education: A Comparison with Current Practice in Technology-Based Programs

Neal Callahan and Martin Jones, Missouri State University; Richard Bruce, The Builders' Association

Abstract

This paper reports findings concerning the current and future prospects for online education and the established best practices in online education at the post-secondary level. Best practices conveyed by major learning commissions and institutional leadership organizations are identified and reported. Commonalities of best practices between these groups are identified and referenced in order to develop a common set of best practices that are representative of these major educational commissions and organizations. Generalized best practices are then broken down into specific success factors that have been shown to effectively support the various areas of online education. The current progress of technology-based programs toward these established best practices and success factors is then assessed through a survey of technology faculty. Survey results are analyzed and recommendations are made specific to technology-based programs.

Introduction

Technology-based programs in higher education face both challenges and opportunities as they prepare to compete in the global environment and economic realities of the new decade. Enrollment in many technical programs has suffered as manufacturing continues to move to developing countries and U.S. manufacturers slow plans for expansion. One bright spot in this environment has been online education. Online education has grown dramatically over the past decade and is now becoming a crucial strategy for many colleges and universities. This rapidly developing delivery method allows programs in higher education to expand beyond traditional geographic limits and affords working students more flexibility. These added capabilities and incentives are often enough to persuade prospective students, who cannot attend traditional classes, to begin or continue their studies using the online delivery format. This added pool of students is particularly promising for technology-based programs looking to increase enrollments and better serve their students who need specialized training, while working full time or living in a remote location.

This paper identifies best practices in online education as promoted by major learning commissions and institutional leadership organizations, and develops a set of commonly accepted areas of best practice and supporting success factors. A survey of technology faculty is administered to assess agreement with these best practices and success factors in technology-based programs. Limitations and solutions concerning laboratory exposure in technology-based online programs are identified and discussed.

Background

As the Internet came into widespread use in the 1990s, colleges and universities began to develop online courses and a few totally online programs began to emerge. By the year 2000, online course offerings were in rapid growth as institutions were developing their capabilities in this area. According to a study supported by the Sloan Consortium, the percentage of students in higher education taking at least one online course increased from 9.6% in 2002 to 25.3 % in 2008 [1]. This explosive growth over the last decade indicates that online education has grown into the mainstream and is now a major consideration for most colleges and universities.

By 2010, virtually all institutions with any interest in online education had already begun offering online courses. Larger institutions with deeper resources and infrastructure have been particularly interested in developing online capabilities. According to Allen and Seaman [1], these large institutions are responsible for most of the current growth in online education.

Several current factors are driving the interest and demand for online education to even higher levels. The economic crisis that began in 2008 resulted in serious budget shortages in many states, which seriously limited funding to higher education. At the same time, demand for college education increased [1]. Similarly, Basken [2] found that the poor economic conditions expanded enrollments at many colleges because individuals felt compelled to improve their skills to better compete in a tough job market; those unemployed individuals were, then, available to take courses. Federal programs such as the Workforce Investment Act, which provides tuition, textbooks and gas money for the unemployed, deliver a strong incentive for some to continue their education [3]. As demand for education has driven up enrollments, expansion of physical facilities at many institutions has not kept pace. Limited physical space combined with limited budgets for expansion has focused administrators' attention on online education as a means for meeting demand without requiring expensive building projects [4].

As demand for online education grows, so does the capacity for delivering it. Internet availability, bandwidth and processing speed continue to increase rapidly. Specialized software for collaboration and course instruction has become commonplace, making online communication, data sharing and course management a reality even for those with limited technical skills [5].

As online education takes its place as a major delivery method for college education, it brings both promise and challenge that must be dealt with in order to achieve its full potential. Surveys indicate that students value the convenience and flexibility of online courses and that online instructors and materials can be very effective. However, students also indicate that the quality of interaction and feedback, lengthy reading assignments, and issues with technology are problems that can limit the value of online education [6]. Young [7] found that online students highly valued three attributes in online courses: effective instructor facilitation and communication, a challenging high-quality course and the opportunity for collaboration and interaction. Beyond specific teaching and interaction factors tied to coursework, an institutional approach to online learning that involves training, support services and proper planning and coordination of programs is also needed for a successful online strategy [8].

The opportunities and challenges of online education have been considered and investigated for well over a decade, at the writing of this paper. Leners [9] identified benchmarks for online education based on recommendations from two major higher education organizations. Over the years, major learning commissions and institutional leadership organizations have done extensive investigations and research concerning the success of online education. Four organizations—the Institute for Higher Education Policy, the Sloan Consortium, the Higher Learning Commission, and the Alliance for Higher Education Competitiveness—have conducted extensive research and made specific recommendations concerning best practices in online education. A review of each of these organization's findings is presented here.

The Institute for Higher Education Policy

The Institute for Higher Education Policy (IHEP) is a non-profit organization whose mission is to promote access and quality in postsecondary education. The National Education Association (NEA) and Blackboard Inc. sponsored the Institute for Higher Education Policy to research benchmarks for successful online education. The study involved an extensive literature review concerning currently recommended benchmarks combined with site visits to six institutions identified as leaders in distance education. Based on the literature review and interviews at the six institutions, final recommendations were given concerning benchmarks for online education [10]. Here is a summary of those results:

- Institutional Support - A centralized system is in place for distance education that includes electronic security measures and a reliable and failsafe technology delivery system.
- Course Development - Guidelines and minimum standards are in place for course design, development and delivery.
- Teaching/Learning - Instructor feedback and student interaction with faculty and other students is effectively facilitated.
- Course Structure - Students are provided with written course objectives and expected learning outcomes, an orientation to online education and library resources.
- Student Support - Students are provided with information concerning admissions, required materials, library services and technical assistance.
- Faculty Support - Faculty are given assistance in transitioning to online teaching and in online course development and are assessed during the process.
- Evaluation and Assessment - Educational effectiveness and program administration are assessed through a variety of standard-based methods. Intended learning outcomes are reviewed regularly.

The Sloan Consortium

The Sloan Consortium is an association of colleges, universities and organizations that supports the development and improvement of online education. The consortium was created through funding from the Alfred P. Sloan Foundation [11]. The Sloan Consortium conducts research and encourages collaboration to develop effective practices in online education and to make higher education more accessible [12]. Recommendations made by the Sloan Consortium are summarized here:

- Student Satisfaction – Students are successful in learning online and are pleased with their experience. This includes interaction with instructors, peers and support services.
- Learning Effectiveness – The quality of online learning should be comparable to that of traditional programs, meeting or exceeding industry standards for learning outcomes.
- Scale – Institutions should achieve capacity enrollment and deliver the best value to learners while continually improving services and reducing costs.
- Access - Anyone who is qualified and motivated has access to such studies.
- Faculty Satisfaction – Faculty satisfaction with online teaching reflects institutional commitment to building and sustaining environments that are personally rewarding and professionally beneficial.

Higher Learning Commission

The Higher Learning Commission (HLC) is a major accrediting agency in the United States that accredits degree-granting post-secondary educational institutions in the North Central region, and is one of two commission members of the North Central Association of Colleges and Schools (NCA). The HLC also offers services, training and publications to help advance the cause of higher education. In cooperation with the other five regional institutional accreditors, the HLC has issued a report outlining best practices for online education [13]. Following are the highlights of the HLC report:

- Institutional Context and Commitment – Electronically offered programs are consistent with the institution's mission and an institutional structure is in place to fully support technical, administrative and oversight requirements.
- Curricula and Instruction – Qualified academic professionals assure that the rigor and breadth of online programs are consistent with the standards of the degree being awarded. A coherent plan is developed for students to access all necessary courses and technology to complete the program. The design of online courses reflects the importance of student/faculty interaction.
- Faculty Support - Participating faculty and the institution have considered issues of workload, compensation, intellectual property rights and the implications of program participation on the professional evaluation process. Faculty are provided appropriate technical support and training in the area of online education.
- Student Support - The administration has committed the administrative, financial and technical support necessary to enable admitted students to complete the program in the publicized timeframe. The institution promotes a sense of community among online students.
- Evaluation and Assessment - Overall program effectiveness is continually evaluated through a variety of student and faculty metrics including their ability to meet intended program outcomes, their competence and satisfaction and the program's cost effectiveness.

Alliance for Higher Education Competitiveness

The Alliance for Higher Education Competitiveness (A-HEC) is a non-profit organization that promotes value through innovation by collecting, analyzing and disseminating information to institutions of higher education. A-HEC has released a paper based on surveys and interviews with twenty-one higher education institutions that are considered to have demonstrated successful online education techniques. The paper identifies best practices, innovations, major challenges and future priorities for online education [14]. The major recommendations of the paper are:

- Executive Leadership and Support - The institution maintains a program focus concerning online education and places importance on clear policies and the quality of teaching and learning.
- Faculty and Academic Leadership - Full-time faculty have significant involvement in online education. Faculty members are given incentives for participation and protection of intellectual rights.
- Student Service - A dedicated staff is maintained to assist distance learners in program advising, help-desk support, web-based enrollment, orientation to online education and retention.
- Technology Infrastructure - A highly reliable 24/7 infrastructure is in place that matches technologies with appropriate pedagogy.
- Course and Instructional Quality - A standard course structure and content management procedure is in place. The course design template promotes student/faculty interaction, lecture archiving and team activities.
- Financial Resources - The institution commits sufficient financial resources and seed funds to start and maintain the program.
- Training - Faculty receive required training and orientation including web-based training. Faculty men-

toring and support from curricular designers is also available.

- Marketing - Marketing and retention plans are in place and strategic partnerships are encouraged.

Analysis

The recommendations of the four organizations studied are remarkably similar. Although each organization has its own style and perspective concerning best practices for online education, several areas of emphasis are clearly common to all groups evaluated. Five areas of significant focus for all four organizations are:

- Institutional Leadership
- Teaching/Learning Quality
- Student Support
- Faculty Support
- Evaluation/Assessment

These commonalities are supported by critical success factors that promote specific actions for improving online education. These success factors were extracted from the summarized best-practice listings presented earlier and from their supporting documentation. Table 1 identifies the five major areas of focus along with critical success factors below each major area. The promotion of each critical success factor is indicated by an "X" under the corresponding organization's column.

Survey of Faculty in Technology-Based Programs

A survey of faculty in technology-based programs was developed in order to compare faculty perceptions of online education with respect to the critical success factors identified by the four organizations listed in Table 1. While the survey incorporated most of these critical success factors, the scope of this paper is limited to the discussion of those success factors identified by all four organizations.

The survey was administered via SurveyMonkey.com, and members from the Association of Technology, Management, and Applied Engineering's (ATMAE) university-members listserv and professional-members listserv were invited to participate in the survey. There were a total of 80 members who began the survey. The first question on the survey asked, "Have you taught or are you currently teaching an online course." If the response was "No" then the respondent was not allowed to answer any subsequent questions on the survey. There were fifty respondents who completed the survey, representing about 11.8 % of the members on the two listservs.

Table 1. Major Focus Areas and Critical Success Factors

	Organization			
Area	IHEP	SLOAN	HLC	AHEC
1.0 Institutional Leadership				
1.1 Secure, dependable technical infrastructure	X	X	X	X
1.2 Program focus instead of course focus	X	X	X	X
1.3 Online supports overall mission of institution	-	X	X	X
1.4 Adequate funding is provided	-	X	X	X
2.0 Teaching /Learning Quality				
2.1 Facilitate interaction with faculty and other students	X	X	X	X
2.2 Students are provided written course objectives, outcomes and expectations	X	-	-	-
2.3 Program rigor is consistent with traditional programs	X	X	X	X
2.4 Feedback to students is constructive and timely	X	X	X	X
2.5 A sense of community is valued and promoted among online students	-	X	X	-
3.0 Student Support				
3.1 Students are provided an orientation to online education	X	X	X	X
3.2 The institution provides students with full support services including registration, advising, library, services, financial aid information, etc.	X	X	X	X
3.3 Students are provided adequate technology and technical support	X	X	X	X
4.0 Faculty Support				
4.1 Faculty are provided with significant training and technical support for online courses	X	X	X	X
4.2 Faculty are rewarded or given some form of incentive for teaching online	-	X	-	X
4.3 Workload parity between online and traditional delivery is considered	-	X	X	-
4.4 Faculty intellectual property rights are considered	-	X	X	X
5.0 Evaluation/Assessment				
5.1 Intended learning outcomes are emphasized in evaluation and assessment	X	X	X	X
5.2 Feedback from learners is taken seriously and used for continuous improvement	-	X	X	X
5.3 Educational effectiveness is assessed through standards-based methods	X	-	-	X

The survey did not ask about Area 1.1, "Secure, dependable technical infrastructure", since it was assumed that nearly all institutions would provide this. Although beyond the scope of this paper, the survey did ask demographic questions such as faculty rank and university type.

Respondents were given a six-point Likert scale from which to respond to statements based on the critical success factors given in Table 1. In left to right order, the choices were "Strongly Agree", "Agree", "Neutral", "Disagree", "Strongly Disagree", and "Not Applicable". For the purposes of this study, data presented here are shown based on combining responses of "Strongly Agree" and "Agree" into "Agree". Similarly, "Disagree" and "Strongly Disagree" were combined into "Disagree". "Neutral" and "Not Applicable" data not are not explicitly stated or discussed in detail in this paper. Only survey results for those areas identified by all four organizations are presented in Table 2.

As seen in Table 2 for each success factor area, a higher percentage of technology faculty agreed with the common recommendations of the four organizations. However, the percentage difference between those who agree and those who disagree varies greatly between the various survey questions. Several survey questions resulted in a relatively high level of agreement (60% or more) when compared with the recommendations of the four organizations. The questions resulting in relatively high levels of agreement listed below align with typical expectations for traditional courses.

- Interaction is facilitated between faculty and students and among students
- Program rigor is consistent with traditional programs
- Feedback to students is constructive and timely
- The institution provides online students with full support services including registration, advising, library services, financial aid information, etc.
- The assessment of online courses and programs emphasizes defined learning outcomes

The survey does indicate several areas of more limited faculty agreement with the recommendations of the four organizations (50% or less of faculty agree). These survey questions are:

- My institution focuses on overall online programs rather than specific online courses
- The institution provides appropriate student orientation to online education
- Students are provided adequate technology and technical support
- Faculty are provided significant training and technical support for online courses

These survey questions, which resulted in less agreement with the four organizations' recommendations, focus more on overall program issues such as training for the online environment, technical support, online orientation and development and administration of a complete online program.

Table 2. Selected Survey Results of Technology Faculty on Best Practices for Online Education

Area	Statement	Response	
1.0	Please rate your level of agreement with the following statements concerning your institution's leadership in online education:	Agree	Disagree
1.2	My institution focuses on overall online programs rather than specific online courses	39.20%	33.30%
2.0	Please rate your level of agreement with the following statements concerning your experience with online education:	Agree	Disagree
2.1	Interaction is facilitated between faculty and students and among students	60.80%	15.70%
2.3	Program rigor is consistent with traditional programs	72.60%	13.70%
2.4	Feedback to students is constructive and timely	74.50%	9.80%
3.0	Please rate your level of agreement with the following statements concerning your institution's support of online students:	Agree	Disagree
3.1	The institution provides appropriate student orientation to online education	39.30%	37.30%
3.2	The institution provides online students with full support services including registration, advising, library services, financial aid information, etc.	68.00%	6.00%
3.3	Students are provided adequate technology and technical support	50.90%	19.60%
4.0	Please rate your level of agreement with the following statements concerning your institution's support of faculty teaching online:	Agree	Disagree
4.1	Faculty are provided significant training and technical support for online courses	47.00%	26.50%
5.0	Please rate your level of agreement with the following statements concerning your institution's evaluation and assessment of online courses:	Agree	Disagree
5.1	The assessment of online courses and programs emphasizes defined learning outcomes	62.70%	15.70%

Challenges Specific to Technology-Based Programs

Research indicates that the lack of program focus in many technology-based online education efforts is, to some degree, tied to the challenges of including a laboratory component. The laboratory experience is considered to be critical for many technology-based programs. The value of hands-on activities compared with simulated or remote laboratory exercises has been debated by academics for some time. Ma and Nickerson [15] reviewed research on laboratory education and concluded the following:

- Interest in the effectiveness of virtual versus traditional laboratory exercises has increased, probably due to advances in technology and cost pressures relating to physical laboratories.
- There is a long-running debate concerning the effectiveness of virtual versus traditional laboratories with advocates and detractors for each type.
- Further research is needed to identify the correct mix of technologies that will allow the appropriate balance between the sense of reality developed with hands-on experiments and the conceptual understanding that can be achieved in virtual laboratories.

With the level of controversy and challenge associated with developing online laboratory activities, it is no wonder that technology-based programs, administrators are reluctant to offer complete programs online. Some faculty members and students will prefer face-to-face interaction, and some situations require this in order to meet learning requirements. Hands-on laboratory experience cannot be duplicated through online delivery, in many cases. However, if the will and need exist to develop an online program that integrates laboratory exercises, innovative approaches exist that can be realistic options.

Achieving a quality laboratory experience can be difficult to incorporate using web-based tools. Some programs have focused on simulation software and/or web cameras to achieve lab experiences from a remote location. Others have focused on creating web-based tools to compliment the on-site laboratory experience. In this scenario, some lab experience is provided online that complements on-site experience where students travel to the school once during the class for condensed lab activities. This allows online students to complete a lab-based course online and travel to the lab site on a limited basis.

The Industrial Engineering School at the Spanish Open University in Madrid, Spain, has completed extensive work in developing a web-enhanced approach for distance education students taking lab-based Industrial Engineering courses. In this approach, lab work is developed around three phases: pre-lab, lab and post- lab. The pre-lab is carried out online by students using simulation software and collaboration exercises with other students.

Students conduct experiments, analyze data and interact with other students in this phase in order to become familiar with lab processes and become better prepared for the live lab. Once during the course, in the lab phase, students travel to the laboratory in blocks for lab exercises that are conducted over two or three days. In the post-lab, students use the online system to work collaboratively with other students to reflect upon and discuss the on-site lab [16].

Others have concentrated on further developing access to labs via the Internet. Pastor et al. [17] developed a platform to enable students to perform experiments in real time on actual lab equipment using cameras and the Internet. The system uses a standardized language for the specification of systems, making it easier to share the technology with other institutions once it is developed. With this system, the researchers found it possible to reuse common code to support fast and easy integration of various control systems.

Leva and Donida [18] developed laboratory exercises online based on National Instruments' LabVIEW environment. Students participated in control system experiments via the Internet. The labs included theoretical abstract models, simple physical situations and real physical apparatuses including a speed controller with flexible transmission.

Couture [19] evaluated a simulation-based virtual physics lab that was developed to teach experimental physics. Findings from this study indicate that students value a realistic simulation environment that closely matches actions required in the real world. Other researchers [20-22] are experimenting with the creation of Virtual Labs for their technology students.

Based on the literature available, there appears to be several approaches for incorporating online laboratories into technical programs; these include:

- Online lab activities complimented by condensed on-site labs once per course.
- Online labs incorporating simulation software to provide a realistic experience.
- Specialized software and web cameras to allow remote control of actual laboratory equipment.

Developing laboratory exercises for online courses definitely requires extra effort and thought, and can be a roadblock to developing a program approach to online education in technology-based programs. The above options provide solutions that can assist in moving toward a more program-focused approach.

Conclusions

Online delivery of courses and programs has become a significant factor in post-secondary education. Online education offers great advantages in convenience and flexibility that can clearly improve accessibility for students in a variety of situations. With almost two decades of experience in online education, best practices have been developed and identified that can assist in delivering a quality online experience. The best practices identified in this paper indicate that online delivery should maintain interaction with the instructor and among other students, and include the same level of support, advising, assistance, financial services and information sharing as the on-site environment. Best practices also indicate that institutions should look at online education at the program level in order to ensure that Internet courses are developed with a coherent strategy that serves the needs of the students.

The survey of technology faculty indicated that basic classroom expectations are being delivered with online courses. This includes rigor, interaction among students and with faculty, feedback, non-technical support and assessment. However, the survey of faculty did indicate less agreement with the recommendations of the four organizations from the perspective of the overall program. Less than a majority of faculty agree that their institutions have a program focus when it comes to online education. There may be a strong focus on delivering a good online course, but less attention is given to developing an entire online program that completely serves off-campus students. The survey also indicated limitations concerning student orientation to the online environment and technical support and training for students and faculty.

Technology-based programs are challenged by the need to integrate laboratory coverage when developing online programs. Different approaches to laboratory integration such as limited campus visits, simulation and remote-control interaction have been successful in specific situations. Additional development in the area of online laboratory integration is needed in order to assist technology-based programs in moving toward a program approach in online education.

Online education has come a long way on college campuses over the last 15 years. Although some faculty members are becoming more comfortable with the rigor and effectiveness of online teaching, others still have strong concerns about the quality and effectiveness of online compared with face-to-face interaction. Work still needs to be done in developing a program approach to online education, where entire programs and supporting training and orientation are at the same level of priority as delivering quality individual courses. Some disciplines or individual courses that require complex equipment, or that depend on face-to-face interaction, may not be suited for online education.

Limitations and Future Research

This paper addresses online education issues from the perspective of learning commissions/organizations and technology faculty, but is limited by the absence of student input. As ultimate participants, the opinion of students is a primary concern in assessing performance of online education. Future research is needed to better understand the students' perspective with regard to common best practices that have been identified. Based on the faculty survey results shown in this paper, there may be a gap between the needs of online students and the technical and programmatic support available. Since the sample size of fifty faculty members participating in the survey is relatively small, the results should only be viewed as an indication and not as conclusive evidence. Future research should include a larger sample to further evaluate this indication. A gap analysis could be made by administering a survey to students, as described in this paper, in order to obtain their perception of the criticality of the common success factors identified by the four major educational organizations.

The laboratory component of technology-based programs was identified in this paper as a major challenge in achieving a program approach to online education. Input from students and further input from faculty concerning how best to deal with laboratory requirements in technology-based programs is needed. Some students and faculty members prefer both face-to-face courses and laboratories, and many situations may require face-to-face formats in order to achieve the level of exposure and experience required. A more detailed analysis of options for integrating laboratory exercises into online programs should be investigated. This analysis should include student perceptions concerning online laboratories and possible options for accommodating students who prefer or need face-to-face participation. Future research should also include investigation and analysis concerning which laboratory integration methods are best for specific applications.

Future research should also consider the demographics of the faculty surveyed. Although demographic data were collected, the limited sample size of this survey does not provide strong indications in this area. Age, rank and area of discipline could be an important indicator of faculty perception concerning online education.

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Creating a State-Wide Transfer Program for Engineering Technology and Technology Management Students

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Abstract

The primary purpose of the Western Kentucky Pipeline for 2+2+2 Engineering Technology and Technology Management (ET/TM) students program is to significantly increase degree production and workforce preparation in central and western Kentucky through the construction of a long-term sustainable, reproducible model bridging program of cooperation between Western Kentucky University (WKU), Murray State University (MSU) and the Kentucky Community and Technical College System (KCTCS). The program will significantly increase industrial and technology education opportunities, technology enrollment and two- and four-year degree completion. Additionally, this project supports the Kentucky Council on Postsecondary Education's (CPE) goal to double the overall number of undergraduate degrees granted. Kentucky's "2020 Goals" represents a united P-16 effort to improve student achievement, compared with national norms. This program will establish and demonstrate a model that may be replicated throughout the Commonwealth. Other states may find elements of the model useful.

Introduction

Technology revolutionizes and advances all aspects of modern life. While the strategic importance of attracting and retaining more students to STEM disciplines cannot be overstated, it must be stressed that engineering technology (ET) and technology management (TM) are critical fields in the overall endeavor—fields in which new innovations are applied to real-world problems in order to improve the quality of life for our citizenry. Our recruitment and retention approach is centered on conveying this exciting impact of technology. Despite this crucial role in our standard of living, technology is frequently misunderstood by society—it is primarily perceived to be related to computers, electronics and the Internet [1]. Popular media generally promote the engineer and scientist over the knowledge and applied skills of the technologist, and advanced technology programs are often an afterthought for students interested in science and engineering. Early exposure to advanced technology for students ultimately prepares them to obtain a position of leadership in business, industry or workforce development in support of innovation and global competitiveness.

In order to increase the number of talented students entering ET and TM, three broad themes need to be addressed. First, students need to see the excitement of this field, recreating the charisma of science and technology that was so evident during the twentieth-century "Space Race." Second, once attracted to the field, student motivation should be maximized by underscoring personal buy-in and ownership of projects by students. Finally, streamline inter-institutional transfers in order to ensure that students remain committed to achieving a baccalaureate or higher credential in this field.

This paper outlines an approach to create just such an environment for the fields of Engineering Technology and Technology Management. The approach is novel, exciting, engaging and straightforward. The purpose is to outline a statewide or regional ideological plan to increase degree production and workforce preparation. The example provided will highlight the development of a long-term sustainable and reproducible program of cooperation in central and western Kentucky between two comprehensive universities and state community and technical college systems. It will show how such an approach would improve the preparation of the workforce by transforming and opening industrial technology education opportunities to students in regions of Kentucky where the talent pool remains largely untapped. The goal is to significantly increase the industrial and technology education opportunities, technology enrollment and two- and four-year degree completion. This paper proposes a model that could be implemented in Kentucky. Other states may find elements of the model useful.

According to Maurizio [2], the integration of secondary and post-secondary technical education increases the visibility and desirability of technology programs and promotes first-generation college success in this area. The pipeline approach has been demonstrated to increase student retention, decrease overall program costs while increasing services, improve overall program delivery and provide significant economic benefits [3].

The Kentucky Example

The targeted service region is comprised of thirty-eight counties of western Kentucky with very low rates of post-secondary education; only five counties have 15% of the population with a baccalaureate degree or higher [4]. This would particularly target first-generation college students, students in rural or underserved areas, and non-traditional students with potential and talent but with financial challenges. All seven of the community college partners are within one hundred miles of either the partnering universities, where students can continue to pursue coordinated four-year degree programs in ET and TM. Additionally, this supports the statewide goal enunciated by the Kentucky Council on Postsecondary Education (CPE) to double the overall number of undergraduate degrees granted. Kentucky's "2020 Goals" represents a united P-16 effort to improve student achievement, as compared to national norms [5].

The community and technical college system in Kentucky is the largest provider of postsecondary education and workforce training in the state, and the proximity of many of its campuses supports reasonable expectations for students to seamlessly commute or relocate to the receiving universities to continue their studies. Current enrollment in the community and technical college system is 98,000 students, with approximately 600 technology students transferring to the partnering universities each year. The number of STEM degrees conferred by these universities combined has increased every year and now exceeds 600 per year. Current university ET and TM degree production represents approximately 23% of the total STEM degree production, an increase of 7% since 2005.

Program Goals

The overarching goal is to create a vibrant, seamless pipeline in ET/TM disciplines from secondary school to baccalaureate success. The specific goals would be to:

1. Increase ET/TM involvement of secondary and post-secondary teachers and school counselors.
2. Increase the number of associate degrees awarded by partnering community colleges.
3. Increase the number of community college transfers into ET/TM disciplines at the partner universities.
4. Double the number of baccalaureate degrees awarded in ET/TM over a five-year period.

Recruitment efforts should be directed to middle school, high school and community college students, as well as existing university undergraduates. Once students are enrolled at the community college level, efforts should be focused on fostering the transition to the baccalaureate level and beyond. In Kentucky, although a transfer structure exists, the success rate for transfers to the universities is poor, ranging from 16 to 28 percent [6]. However, STEM disciplines are one of the highest areas of interest for transfer students [7]. There is ample opportunity for considerable improvement in the transfer rate if students are engaged early and successfully sustained through the pipeline.

The Approach: Institutions Operating as One

No single institution is simply a provider or a user. Rather, all participating institutions are intimately involved in the development, implementation and success of the program. This program allows the partnering institutions to function as one large educational institution (unprecedented in many educational environments) to provide the best possible career opportunities. The barriers in educational administration and control will become less critical as the needs of the students in Kentucky and the region are placed as a priority. The logistics and operations of this are challenging.

In addition to further developing the existing 2+2 programs, the approach requires the participating institutions to provide a seamless transition from the community college to the university. The faculty work closely with regional industry to develop "relevant and interactive" courses fully developed for online delivery to students and industry professionals. The following describes how each institution contributes to the goals and objectives.

University Level

Two institutions are represented at the university level. One institutional program focuses primarily on technology management while the other focuses on engineering technology. The technology management programs consist of advanced manufacturing, architectural science, construction management and industrial education. These programs maintain an enrollment of approximately 400 students and graduate 60-70 high-quality majors each year. The institution has had a 2+2 agreement with the community college system for the last five years. This program has grown from 33 students in 2007 to over 70 majors using online course delivery to students in Kentucky and across the U.S. Faculty and administration consistently support the online program and are particularly interested in further development as it relates to retention of transfer students, as this is an institutional strategic goal.

The engineering technology programs consist of architectural engineering technology, civil engineering technology, construction engineering technology, environmental engineering technology and electromechanical engineering technology. It also includes three industrial technology programs of engineering graphics and design, interior design, manufacturing technology, as well as a telecommunications systems management program. With over 500 students, this unit produces 80-90 highly technical and industry-focused graduates annually. The institution has had a 2+2 agreement with the community college system for over 12 years and also uses an online delivery method for courses.

Duplication of the 2+2 model allows students to transfer from the community and technical colleges into the universities without duplication of coursework. The current state of industry across Kentucky and the U.S. is the reconditioning of industry to cutting-edge, state-of-the-art high-tech production and integration. TM and ET programs are positioned to have a great deal of interaction and support for the direction of industry throughout this region as there is almost 100% placement in the manufacturing industries.

Using new and cutting-edge technology, students in years three and four of the programs have hands-on experience in lab-based courses using VMware and Internet capabilities to operate equipment remotely from wherever they live in the world. The live, hands-on labs set these programs apart from other on-line programs around the world. Faculty and administration have fully embraced the direction of the programs and anticipate future program development, especially through the exploration and delivery of an interactive remote online program.

Community and Technical College Level

In Kentucky, the community and technical college system consists of campuses strategically located to provide accessible education and workforce training that is relevant and responsive to the needs of students, business and industry leaders, and the communities they serve. They offer certificates (some as short as 6 weeks) and diplomas as well as two-year associate degrees in over 600 credit program offerings. The most popular area of study is the baccalaureate transfer program, which allows a student to earn an associate degree and then transfer to a four-year institution within the state.

While emphasizing its historical mission to provide general education, the community college system has expanded its focus on occupational/technical education. In the past 10 years, the Kentucky Community and Technical College System (KCTCS) has become the largest provider of post-secondary education and workforce training in the state. In 2007, KCTCS provided workforce services to 4,850 businesses and industries and approximately 48,000 employees [8]. More recently, KCTCS and the state of Kentucky invested millions of dollars in the development of state-of-the-art emerging technology centers at many of the community colleges. These institutions are perfectly positioned to articulate with four-year institutions with innovative, industry-relevant engineering technology and technology management programs.

All of the KCTCS institutions work very closely with the universities. Students throughout Kentucky (and on-line around the world) have the ability to either physically attend one of the participating community colleges or work completely *on-line* to progress through an Associate of Applied Science (AAS) degree and then move forward to a Bachelor of Science degree. What is different from most on-line programs is that these students would have the potential to work with hands-on lab equipment in one of the institutions or work on lab equipment from any remote location (e.g., home, work). Students would also have the choice of graduating from an AAS degree into a technology-management-based curriculum or articulate to an engineering technology program. This would provide the best alternative for a student wanting to go beyond the AAS degree.

Secondary Level

Kentucky has over 200 high schools in the state [9]. Transition-to-college programs for high-school students typically cater to those deemed either gifted or at-risk with very little attention paid to the middle majority. One of the more successful transition programs has been Tech-Prep, a vocational and technology education curriculum that promotes articulation agreements between secondary schools and community colleges. Cellini [10] found that Tech-Prep participants were more likely to complete high school and attend a two-year college. While encouraging, the results of the study also found that the same participants were less likely to attend a four-year university. This has led to some concern that programs like Tech-Prep may be diluting the college-prep track. Conversely, the findings may be an indicator that more articulation and cooperation is needed between community colleges and four-year institutions in the ET and TM areas.

A number of other states such as Oregon, Illinois, Maryland, Georgia, New York and Washington have implemented statewide programs that prepare students both vocationally and for college. The programs develop and measure both aptitudes and skills critical for work or post-secondary success. In some cases, the measures are used instead of placement exams [11]. Statewide articulation helps reduce confusion between different high schools and post-secondary institutions. Articulation should be more than local agreements between schools. Articulation should be comprehensive, involving all levels of education [12-14]. Kentucky could easily do some of the same coordination.

Middle School Level

At the middle school level, transition to secondary school programs is virtually non-existent, but some degree of coordination between educators at the middle and secondary level is desirable. Particularly, there should be common agreements about grading, promotion, educational objectives and guidance counseling. If articulation is to take place, it should be based upon what knowledge and skills are needed at the next level. From a vocational perspective, educators need to ask employers what skills are necessary to obtain and hold a job. This could then lead to courses or programs such as business writing or applied math that reinforce these skills and encourage interest [15]. National studies have indicated that it is in the middle grades where most students begin to formulate their career goals and where many students lose interest in math and science [16-17]. Exposing middle schools to some form of technology is a critical component for establishing a sustainable pipeline.

The Program Plan

Each educational institution brings unique and valuable experience and expertise to the program. The plan seeks to build on proven capabilities to produce a powerful mechanism for ET/TM degree production, workforce development and economic growth in Kentucky. The approach has four strong activities to support and expand efforts to recruit, prepare and retain highly qualified ET/TM majors. The activities are targeted recruitment, student engagement, articulation and capability development. Each of these attracts potential students and builds capacity for the knowledge/skills needed at the university level.

Targeted Recruitment

The establishment of a secondary education pipeline:

a) In an effort of this breadth and scope, it is critical that target markets, such as students, parents, counselors and faculty, be fully informed of the unique opportunities that it provides [18]. According to Lipton [19], "thoughtful consideration must be given to strategies for marketing the program on several levels." Therefore, a full-time professional advisor assigned to the 38-county service area of WKU and MSU as a service area circuit rider is critical to overall success. The circuit rider has direct and frequent interactions with the target middle and high schools. This person is responsible for promotion of ET/TM careers and pre-technology curricula, publicizing the various opportunities and features of the collaboration, scholarships, summer opportunities and workshops and conferences. Through direct interaction with students and teachers, the circuit rider enhances positive perceptions about technology careers and provides consistent information about the technology programs with the high schools, two-year community colleges and four-year universities. The circuit rider position will be funded and shared between MSU and WKU.

b) Scholarships, identified by all partner schools and administered by the community college system, are awarded to students who take math and science courses in high school and plan to enroll in any of the participating schools. The service region consists of 38 counties with a population of more than 900,000. In this region, 28 of the counties have low socioeconomic status compared to the U.S. average poverty rate of 13.2% [20-21]. The scholarships are reserved for students who successfully complete mathematics at the algebra II level, have a minimum of five science credits, an overall 2.5 grade point average, and meet the federal criteria for financial aid.

c) ET/TM career encounter programs and early career counseling for young students plays a critical role in providing students a chance to explore careers outside of their social norms. One day each summer, one of the participating post-secondary schools would host a "Super Saturday" for high school students to introduce them to applied engineering and industrial technologies using hands-on instruction in one of the campus laboratories. This could be done in conjunction with career-planning fairs held at the postsecondary schools for students, teachers, and guidance counselors to inform them about educational and career choices available for students interested in technology.

Student Engagement

Sustain students through the pipeline and across institutions:

a) The circuit rider would nurture student awareness, enthusiasm and capabilities that end with transfer and completion of programs at one of the university programs. The aim is to provide motivation and seamless continuity for a student even when this crosses institutional boundaries.

b) ET/TM distance students would be automatically enrolled in the on-campus national professional student chapter organizations such as the Association of Technology, Management, and Applied Engineering (ATMAE), The Society of Manufacturing Engineers (SME) or the International Society of Automation (ISA). This would promote communication, friendships and collaboration with traditional on-campus students for senior projects, design competitions and student chapter activities.

c) The community college technology students would be invited to participate in national competitions, design teams and chapter student activities at the four-year institutions and vice versa.

Integrated Articulation

Provide for a seamless transition between institutions:

a) Permanently establish 2+2 programs through Memoranda of Agreements (MOA) for ET/TM disciplines for a seamless transition with little or no lost credit hours between institutions. Make long-term agreements by providing or expanding block or program articulation through which the completion of coursework at one institution results in advanced placement at another. This strategy is much more effective than course-to-course articulation [2], [19]. Annual meetings among the principles at the participating institutions would facilitate this.

b) There should be transition, advising and support services for transfer students to establish connections with the university and their departments of interest. In particular, offer campus tours, create student cohorts and provide access to the well-established transition programs at the universities.

c) Offer programs at the community college that are focused on community needs and career opportunities for ET/TM-targeted enrollment, while using the pre-existing, degree-granting capability and teacher base of the universities using both distance and face-to-face formats.

d) A scholarship program for students who graduate from the community college with a GPA of 3.5 or higher would cover the difference in tuition costs between the university and the community college for their remaining two years of study.

e) Expand non-traditional student opportunities for ET and TM degrees via industrial cohorts in agreements with commercial partners that have industrial and technology employment needs.

f) Hold annual conferences for faculty that include facility and capability reviews of the participating institutions. The purpose of these reviews would be to reduce redundancy of equipment and services and identify gaps in curricula or resources.

Capability Development

Support teacher and counselor development:

a) In-service and pre-service workshops and conferences should be held for industrial technology secondary/post-secondary education teachers and school counselors. This would promote sharing of best classroom practices and recruitment strategies between a team of likeminded individuals “in the trenches”.

b) Critically lowly enrolled courses should be evaluated for funding streams so they can be offered with adequate frequency at the participating institutions. The growth plan of the program is to increase the total number of students in the program at all levels to a self-supporting level.

c) Provide initial front-end funding for needed laboratory classroom and equipment development in ET/TM-related classes and labs such as the ones that will be identified in the following paragraphs.

Facilities for ET/TM majors are critical to establishing a high-quality curriculum. While the universities have infrastructure for science labs and other crucial parts of the curricula, all partner schools would need to review and assess existing facilities for quality and equipment. In particular, the following areas have high potential.

- Multi-skilled technician programs. One such example is the Advanced Industrial Integrated Technology (AIIT) program at KCTCS-Madisonville campus. Students have three options within this program: multi-skilled technician, medical instrumentation and management, or power plant technician. The last option, established in 2010, meets the needs of coal-fired power plants to help replace their aging workforce. It is the only degree in the state that directly prepares graduates to work as skilled technicians in coal-fired power plants.

- Food automation programs. An example is the Automated Food Processing program in Advanced Manufacturing at Western Kentucky University (WKU). In partnership with KCTCS-Owensboro, Perdue Farms and the Owensboro Economic Development Authority, WKU is developing a scale-up laboratory with major unit operations in food manufacturing, biotechnology and agro-technology. Due to the geographic location and a readily available workforce, this region of Kentucky is fast becoming attractive to food processing facilities. However, industry is unable to recruit enough technically competent managers for the growth envisioned. The program provides students with the unique opportunity to do applied research with food processing companies such as Smuckers, Marzetti, Sara Lee, Unilever, Specialty Foods, Tyson, Barton Brands and Swedish Match.

- Early college-start programs. The OnTrack program at KCTCS-Bowling Green is a partnership between three of the region's largest county high schools. It provides opportunities for college success, affordability and a head start in college achievement while in high school. In its first cohort, 93% of high school participants matriculated into a college or university. Students graduate "college ready" with no requirement that they take developmental courses. The project raises funds to alleviate any financial hardships for high school students who cannot afford to pay for college tuition or books. Students enroll in the technical school while still in high school in order to gain a head start to finishing college. This allows students to graduate high school with workplace skills. Students have the potential to earn college credentials while enrolled in high school. The joint admissions agreement gives students access to more resources and creates a smooth and seamless transfer pathway to a four-year degree. It ensures a successful transfer process for students in engineering technology, nursing and related health occupations, and an associate degree in science.

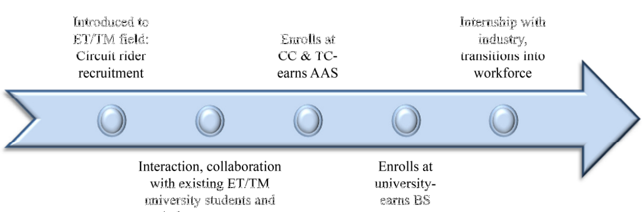

Figure 1. Transitioning Through the Pipeline – An Example of How a Student Might Transition Through the Program

Conclusion

Among the STEM disciplines, technology programs are often an afterthought for students interested in science and engineering. A well-designed program such as the one described here would help dispel the myths associated with the technologist and their applied skill sets and could redefine the value of the technologist as a viable career path for young men and women to advance in science and engineering for practical use.

Strategies include development of a secondary education pipeline, transition and transfer support for post-secondary institutions, instructional and course support at all levels, and capability development. Well-designed cooperative agreements between secondary and post-secondary technical education programs increase visibility, promote first-generation college success and dispel media-perpetuated myths [2]. The strength of collaborative relationships can transform the technology education pipeline and improve the economic prospects of the future workforce. Coupled with the innovative use of the multi-institutional partnerships and the circuit rider position, this plan could double the annual production of baccalaureate ET/TM degrees over a five-year period. However, institutional commitment is important for sustaining subsequent gains.

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USING AN OPEN-SOURCE LANGUAGE TO TEACH INTRODUCTORY PROGRAMMING AND GRAPHICS CONCEPTS IN FIRST-YEAR ENGINEERING AND TECHNOLOGY COURSES

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Abstract

In this paper, the authors propose the use of an open-source programming environment called Processing© in first-year undergraduate engineering and technology education courses. Currently, there is significant use of proprietary commercial software in technology education. The use of such tools for teaching introductory graphics principles to students has resulted in a heavy dependence on commercial software, which in turn has financial implications for the educational institution. On the other hand, open-source programming languages (PL) reduce the financial burden for both institutions and students. Processing© is an open-source PL that can be used to teach basic programming and graphics concepts to first-year engineering/technology students. The syntax of Processing© is relatively straightforward. Students can develop intermediate-level graphic applications in a relatively shorter time period with less complexity. Also, Processing© can serve as a bridge to facilitate the subsequent transition to more advanced Object-Oriented Programming (OOP) languages like Java and C-Sharp as Processing© itself is built on OO principles. In this paper, the authors explain how to use Processing© to design and implement freshman-level graphics courses in the disciplines of engineering and technology. The results presented show that students are receptive to the idea of learning the concepts of computer graphics using a programming medium. Overall, the results evince that the visual- and graphics-based lecture samples and lab exercises helped students learn complex concepts.

Introduction

The computer graphics technology program at Purdue University Calumet (PUC) does not include many programming courses at the freshman and sophomore levels. To better prepare the students to meet industry requirements and to enhance their employability by sharpening their programming skills, it is essential to teach introductory graphics programming course(s) during the first and second years. The undergraduate Computer Graphics Technology (CGT) program at PUC focuses on areas such as multimedia design, web design and development, computer animation, game development and graphic design. The plan of study of the CGT program consists of six courses in computer animation and game development, seven courses in multimedia and web design, five courses in graphic design, five foundational courses in sketch, raster and vector visualization, and one graphics programming course.

Formerly, CGT students would take programming courses (Java or C++) from other academic departments, but these often would be too discipline-specific to meet the needs of the CGT students. To resolve this issue, a CGT-specific PL course was developed. Since CGT students tend to be visually oriented, and are exposed to various graphic design and animation tools (e.g., Photoshop©, Illustrator©, 3D Max©, Maya©, etc.), it was anticipated that the development of a course of this type would be beneficial. It was also believed that the course would serve the dual purpose of enhancing general programming skills and inculcating computer graphics concepts. The programming course is required for all CGT undergraduate students and meets the general education requirement of all undergraduate students in STEM disciplines at PUC.

Several key components impacting student motivation must be considered when discussing programming instruction and learning. Driscoll [1] stated that instructional material must appeal to learners and must also motivate learners in their goal achievement. Keller and Litchfield [2] claimed that considering student motivation "is particularly important because it pertains to a person's basic decisions as to whether or not to accept responsibility for a task and to pursue a given goal". As applied to instruction, Talton and Fitzpatrick [3] noted: "A long-standing difficulty in the development of introductory courses in computer graphics is balancing the educational necessity of ensuring mastery of fundamental graphics concepts with the highly desirable goal of exciting and inspiring students to further study by enabling them to produce visually interesting programming projects."

Many researchers in education have shown that the use of instructional methods other than the traditional lecture format is much more effective in facilitating student learning. Methods such as active learning [4], problem solving [5], [6], and project-based learning [7], [8] are encouraged as ways of exciting students, providing real-world problem-solving experiences, and increasing transfer of critical skill-sets from the classroom to the workplace, especially in introductory programming instruction [9] and other technology-based learning [6], [10], [11]. To allow students to relate new learning to existing skills/knowledge without cognitive overload, teaching in technology environments should include as much contextual content as possible [1].

Teaching a foundational programming course to freshman is a challenging task. The difficulty of passing a programming course at the freshman level has resulted in high drop-out rates in computer science (CS) and information technology (IT) majors in higher education worldwide [12]. Computing educators stated that learning programming languages and acquiring problem-solving skills are time-consuming and difficult tasks [13], [14]. One important reason is that the current programming languages are mainly designed for industrial use and, hence, are way too complicated for teaching programming foundations. Jenkins [15] indicated that the programming language for freshman should be chosen for educational purposes rather than its popularity in industry. These points further corroborate the authors' rationale for choosing Processing© as a medium for teaching foundational programming and graphics skills to freshmen.

A freshman programming course is an important foundational course in computer science and graphics education. Educators in these disciplines have proposed various ways to enhance the learning of programming concepts in freshman courses. Recently, Hernandez et al. [16] taught fundamental programming principles to freshmen students through 2D Game Engine: GameMaker. Game Engine allows students to understand fundamental programming principles without having to learn the complex syntax of programming languages. Similarly, Kazimoglu [17] felt that digital game play could be an effective method for computational thinking programming instruction. Additionally, Papastergiou [18] showed that a digital gaming method of learning was both more motivational and more successful than traditional non-gaming methods in teaching computer memory basics to high school students. However, Holzinger et al. [19] cautioned that although dynamic media can be an effective learning tool, excessive use of such methods can lead to cognitive overload if not utilized judiciously. Another example along these lines would be the failure of PASCAL as a PL tool in CS and graphics education. PASCAL is a strongly typed procedural PL that was designed mainly for computer science education. Unfortunately, PASCAL has evolved into a complex industrial-level PL and, therefore, lost its merit in CS education. To overcome this complexity, several new programming languages were introduced [20]. Processing© is one such language which was introduced especially for visual artists, making it less programming-intensive [21]. From the above discussion, the choice of Processing© for the freshman course discussed in this study is evident.

Teaching Programming Fundamentals

Programming skills have become crucial for engineering and technology students irrespective of their major discipline. Programming tasks inculcate problem-solving and critical-thinking skills in students. Typically, upon graduation, students may enter industry or pursue graduate studies. Problem-solving and critical-thinking are essential skills for succeeding in both industry and academia. Furthermore, immediately after the freshman year, students continue to take several Engineering Technology (ET) courses that involve various assignments and projects. Students can accomplish several important components of these projects using programming tools or can even complete an entirely programming-based project that meets the course requirements.

In Processing©, a programming statement to print a sentence to the console would be just a single line such as: println('hi! Good day!'). On the other hand, printing a small phrase to the console would still require several lines of code. This will be explained further with examples in the Results and Discussion section. That which can be accomplished with Processing© in a single straight-forward statement takes several lines of code. This by no means implies that Java is not as efficient as Processing©. Of course, Processing© is built on Java and employs the basic notions on which Java is based. However, the argument here is that for students at the beginner level, learning programming via Processing© can be much easier than using a language like Java. Java keywords in the above program such as 'public', 'static', 'void', etc. are based on concepts such as variable scope, return-type, etc., which may be too complex for a student at the beginner level.

Besides enabling students to learn programming skills, Processing© teaches students a very important notion called object-oriented programming (OOP). Extremely successful PLs like Java and C++ are based on the notion of OOP. Processing© can be considered a stepping stone for Java.

Knowledge of Processing© helps students upgrade to learning Java at a later stage. The ultimate objective of using Processing© is to facilitate the learning of introductory programming and graphics concepts by first-year students. When teaching programming fundamentals to students, 'cognitive overload' is a key issue [1], [19]. This can be caused by several factors, including material complexity, failure to integrate new material with previous knowledge and disruptive elements that distract from learning the materials. Courses loaded with perplexing jargon or complex programming terminology can easily discourage students at the beginner level. Also, it gets tiring when students need to do a lot of coding before they can see the actual result, which is the case with languages like C++, OpenGL, Java, etc. Instead of directly learning programming using languages such as Java or C++, if a simpler language such as Processing© is used, the learning process becomes a smooth one. With Processing©, students can create simple shapes and programs using very little code, which reduces the gap between learning and executing.

Some programming notions are generic and span different languages. These include: data, variables, scope, functions (or methods/routines) loops, iteration, conditionals, recursion, etc. Illustrations can quickly communicate programming concepts, especially for students with visual learning style preferences [22-24]. For instance, one of the fundamental programming concepts is loops. Graphics examples may help students to transcend the abstract level and take the learning process to a more concrete level. This is because, when using Processing©, students can actually see the visual result of using loops via the graphic output window. In Processing©, this graphic output is called a "sketch". This iterative logic is used to illustrate the three main loops: for, while and do-while (see Figure 1). This shows a circle repeated diagonally, a face-like object, and a checkerboard representation created using loops. From left to right, Figures 1a-1c represent a sequential learning process, going from simple to complex graphics objects: iterative do…while loop for circle primitives; while loop to create faces from primitives; nested for loop to create an array or grid. Another important concept in programming is conditional expressions. Upon satisfying a condition, a particular set of commands are executed, else, another set of commands are executed. One exercise involves generating a random float value less than 200. The program's function was to draw a black/yellow checkerboard pattern if the value < 100 or a blue/red pattern if the value generated was > 100 (see Figure 2). The visual nature of graphics plays a dual role of aiding the learning process and reinforcing material learned.

Programming Elements

Despite the plethora of PLs available today, all programming languages are built upon some fundamental concepts such as data types, variables, constants, functions, iterations, and so on. 'Brevity' is a salient advantage when using Processing© for teaching the introductory programming terms. In other words, when using Processing© [25], the above terms and associated concepts can be explained using very few lines of code. Creating a simple program to store data and print it out can involve several lines of code in other

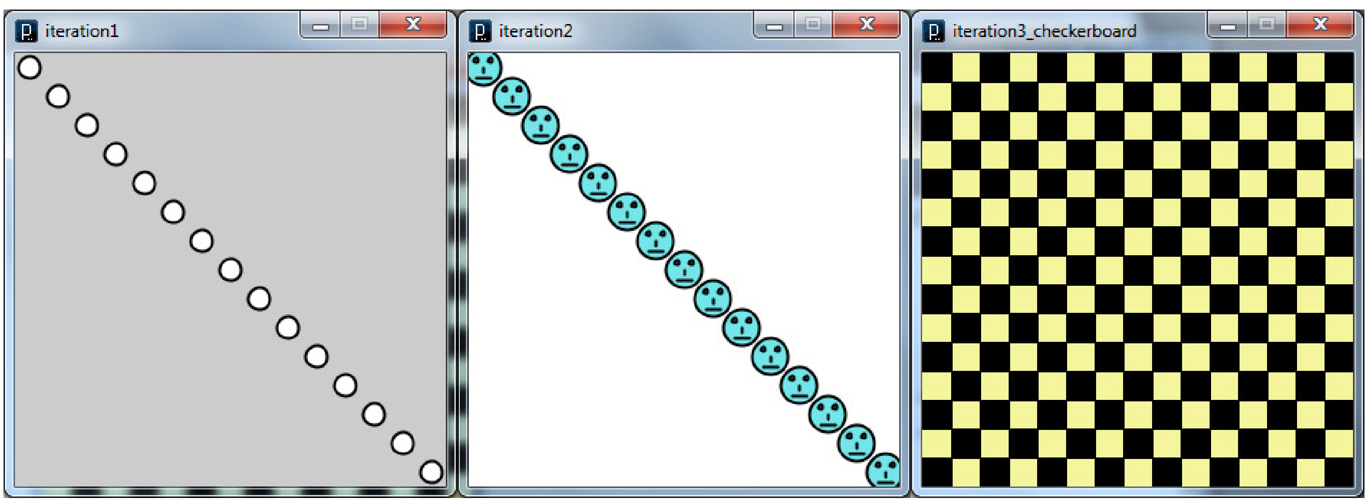

Figure 1. Illustration of Loops Using Simple Object Geometries
(a) Circular Objects ('do…while')
(b) Face-like objects ('while' loop)
(c) Checkerboard ('for' loop)

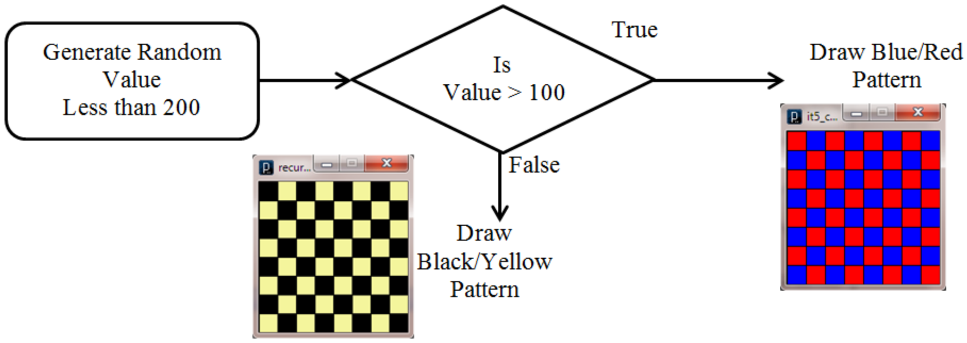

Figure 2. Conditional Expression 'if..else'

PLs. On the other hand, 2 or 3 lines of simple Processing© code can clearly explain basic programming concepts.

Data and Declaration

Simply stated, a variable is a data-holder or a container used to hold data. Just as in the real-world, different containers are used to hold different types of materials, and different variables are used to store different types of data. Let us consider the very simple code snippet, int x = 25; this line of code creates a variable, x, of type integer and assigns it a value of 25. Data is useless unless it can be applied. With Processing©, this can be done instantaneously. This value stored in x can be used by adding a line of code—line (0,0,x,x);—thereby generating a line from the origin (0,0) to (25,25). Concepts covered by these two brief lines of code include:

- Data-type (integer)
- Variable declaration (int x)
- Assignment (x = 25)
- Using variable (line(0,0,x,x))
- Parameters (enclosed between parentheses)

This brief example illustrates the simplicity as well as immense potential of Processing©. In several other programming languages, explaining and understanding the terms and concepts mentioned here could have involved numerous lines of code, which was accomplished in only two small programming statements.

Functions

Functions are also known as method/routines in different programming languages. Functions are used to facilitate code reusability and readability, while reducing redundancy. Typically, functions can be classified into two broad categories: built-in and user-defined. The former refers to pre-existing functions provided to the user by the programming language. Common examples include print(), println(), etc. The second type of function, known as user-defined function (UDF), is the primary means by which a programmer writes a customized program for a specific application. Here, the process involves two steps: teaching the principle and using the function in graphics. The first step is to teach the fundamental concept of the function. A simple example of calculating the sum of two numbers is used. This function computes the sum of integers x and y and returns the value. This example shows input parameters and return type in a function.

```
int sum(int x, int y)
{ return x+y; }
```

The next step is extending the previous example to illustrate the use of a function in spatial transformation (translation) in computer graphics. The translate function takes the input of the original 2D point and then translates it by the value of T. (return value = translated coordinate)

```
Point2D translate(Point2D x, Point2D T)
{ return x+T; }
```

Graphics Fundamentals

Similarly, on the graphics side, various concepts are common across all graphics programming languages such as points, lines, polygons, primitives, compound shapes, transformations, etc. The use of a high-level programming language necessitates that students learn and complete many basic language-specific coding exercises before creating their first program or graphics object. However, the straightforward commands in Processing© such as point() and line() enable students to create simple shapes instantaneously.

Students can create simple shapes and programs using very little code. This reduces the gap between learning and executing. To create a circle, a single line of command is sufficient; ellipse(50,50,50,50) will create a circle with a radius of 50 pixels in the center of the default Processing© window. A simple 'face' can be created by putting together primitive shapes, as shown in Figure 3.

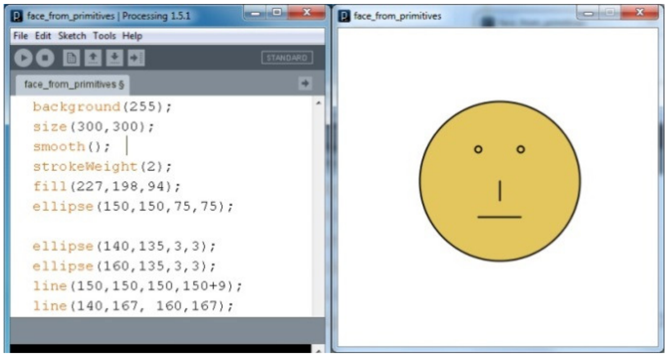

Figure 3. Simple Object using Primitives

The basic graphics primitives such as points, lines and polygons can be explained to students using straightforward single line code:

1. Point(50, 50) creates a point at 2D coordinate (50,50)
2. Line(0, 0, 50, 50) creates a line from 2D coordinate (0,0) to (50,50)
3. Rect(50, 50, 50, 50) creates a rectangular polygon at the corner (50,50) with height/width=50

Transformations constitute an important element of any graphic modeling environment. Instead of using complex 3D objects to explain the notion of transformations, simple primitives can be used to efficiently communicate the concept of transformation. Considering the flowing diagram, all shapes used are essentially circles. The scene consists of circles that have been transformed (scaled and translated). Similar to the prior scene, which used only circles, just by using primitives and applying rotation/translation, a simple Clock can be created. (see Figure 4).

In the following sections, these graphics fundamentals are explained, in particular two extremely important programming paradigms: Object Oriented Programming and Event Driven Programming.

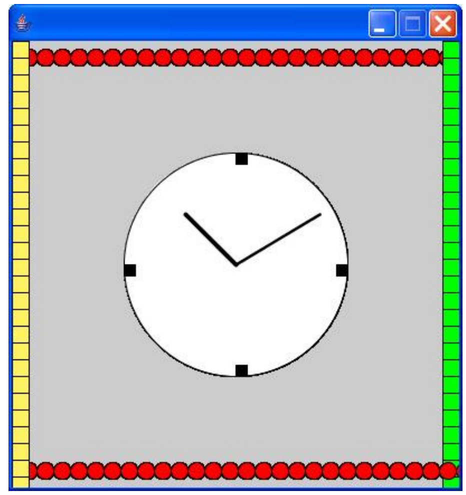

Figure 4. Clock Object from Classes (OOP)

Objects and Object Oriented Programming

The concept of Object Oriented Programming (OOP) is relatively difficult for freshman college students to understand. Therefore, in this course, only the following essential topics of OOP were covered: Class/Object, Data/Method, Private/Public keyword and inheritance. To describe the concept of Class and Object, illustrations of various cars such as SUV, Convertible, Coupe, Hatchback, Sedan, etc. were used. Each individual car is an object, and all cars share some common characteristics. All of the cars can be described using a common 'car' class. Extending this further to explain inheritance, geometric shapes were used. A Shape class is a parent class for Circle and Rectangle classes, and the Rectangle class is a parent class for a Square class. Also, as an object is made of several other objects, the different objects can be grouped into one coordinate system or into different coordinate systems in order to achieve desired movements. Additional OOP topics covered in the class were used to create an object using default and non-default constructors. In the following example, a Clock object is created using objects belonging to the Circle class. Loops were used to create the border designs. Continuing to the next paradigm mentioned earlier, the same clock was animated based on the event-driven programming notion, as explained below.

Events and Event-Driven Programming

An 'event' is the critical feature in the event-based or event-driven programming paradigm. An event acts as the trigger that initiates an action. A wide range of possible occurrences can serve as triggers or events and a wide range of responses can occur. A computer, washing machine, electric oven or television can be made to respond to events appropriately. This is because they all contain something (data) and, upon being initiated (or put to use), they perform specific tasks. In other words, they have their own properties and they can 'act' or behave. An object may be acted upon and it reacts in accordance with the action. The mouse and keyboard event and interaction topics are introduced using graphical drawing applications. For the mouse interaction, the mouse button pressed, released and mouse move events were covered.

The mouse and keyboard events are ubiquitous in most modern programming languages. However, the lack of visual elements may make the teaching of mouse interaction concepts a very tedious process because students may have difficulty in relating to such new logic. Nevertheless, the use of visual media significantly reduces the cognitive load. Most students in the CGT program have used Photoshop and Illustrator to create 2D graphic images. In these graphics programs, the mouse and keyboard are commonly used to draw custom shapes and move the created shapes. To illustrate mouse click, mouse move and mouse release events, Bezier curve and object movement applications were generated (see Figure 5). The Bezier curve drawing application mimics the Pen tool in Photoshop and Illustrator. The left mouse click will create a curve vertex on the 2D screen. The user can drag the mouse in any direction in order to define the tangent vector of the curve. If the user releases the mouse button immediately after mouse click, a corner vertex will be created. The mouse pressed, mouse released and mouse move events were combined to implement curve drawing application. The object movement application requires the user to click on one of the pre-drawn shapes and move it to a new location. When the mouse button is pressed, the program will check if the mouse cursor is inside an object. If it is inside, the object will be selected, and the user can move the object to a new location with the mouse move event.

The clock created in the earlier lab exercise (Figure 4) is animated so that the hands of the clock show the actual (current) time. Using loops, the hands of the Clock object are animated. In Processing©, there is a function called draw () that draws objects to the graphic output window at a specific rate. Typically, this is 60fps (frames per second). Using this repetitive drawing of objects to the screen and by using a counter variable to track the number of iterations, the new positions of the hands (hour hand, minute hand, and second hand) are incremented and drawn continually to the screen. This produces the final outcome of an animated clock. This builds upon the notion of integrating objects generated from classes with the concept of event-driven programming to produce an animated version of the clock object shown earlier.

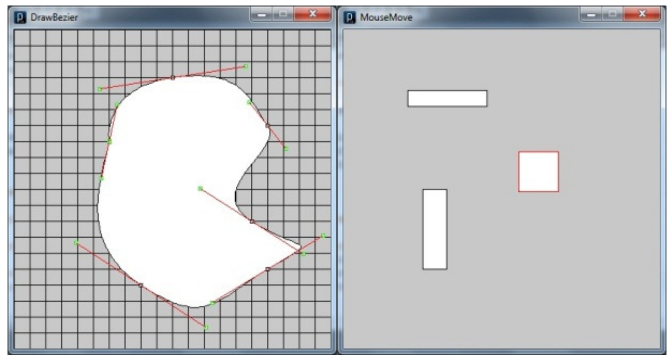

Figure 5. Curve Drawing and Object Manipulation using Mouse Event and Interaction

The lack of such visual elements may make understanding programming concepts very tedious. Hence, a visual medium was employed to reduce the cognitive load and facilitate understanding.

Results and Discussion

This course was designed to cover essential programming and graphics concepts in an easy-to-understand manner. The exams/quizzes and labs/projects were also designed based on the aforementioned points. Table 1 shows the grading criteria.

Table 1. Grading Criteria

Activity	%	Scale	Grade
Exercises	20%	90-100	A
Project	20%	80-89	B
Participation	10%	70-79	C
Midterm Exam	25%	60-69	D
Final Exam	25%	<60	F
Total	100%		

Table 2 shows some of the sample exam/quiz questions. The exams and quizzes included different types of questions that reinforce theory, actual programming code and graphics elements administered in the form of MCQ (Multiple Choice Questions), fill in the blank, and True or False questions administered via the Purdue Blackboard system. Being an introductory course, the level of difficulty of the exam questions and lab/project requirements was maintained between simple and intermediate. Students were also provided with the Processing© software. This course covered two kinds of materials:

1. Introductory material for freshmen in the Computer Graphics Technology program that introduces them to general university life [26].
2. An introduction to Computer Graphics using Processing© (a Java Variant).

The exercises included materials from the introductory freshman material and the Processing-based CG component. Students also completed a Processing-based project. These projects included generating scenes with simple and compound graphic objects. A compound object is made from multiple Processing© objects. Students created a wide range of scenes on a 900-by-900 Processing© canvas (sketch) using graphic tools such as color, background, fill, stroke weight, etc. that resulted in creative graphic designs.

The midterm and final exams consisted of 100 questions that tested students' understanding of graphics programming concepts. Table 3 illustrates the number of questions in each sub-category, and the students' performance in the corresponding sub-category. The exam results indicate that students performed extremely well in understanding 2D graphics transformation concepts. The results also showed that approximately 80% of the students correctly answered basic programming questions. These questions covered concepts such as variable, conditional statement, loop, array, OOP and event-driven programming. Overall, the results evinced that the visual- and graphics-based lecture samples and lab exercises helped the students learn complex concepts. The function part had the lowest rate (72%). An analysis of the questions in that category showed that the low rate was due to the recursive concept. While this approach worked well in teaching basic programming concepts, limitations exist in teaching 'recursion'.

In summary, a comprehensive table showing all of the advantages of using this Open Source language is given in Table 4. The table encapsulates the advantages of using Processing© for a freshman-year course. Processing© also proved to be beneficial from the perspective of software procurement. This is a significant advantage when compared to commercial software packages that impose significant financial hardship on the university and the students. Relying heavily on expensive software packages for teaching computer graphics courses can contribute to increasing tuition costs. As Processing© is based on Java language, students will find transitioning to higher-level programming including Java / C++ and other Object Oriented courses

Table 2. Sample Exam Questions Based On Processing©

	Question Type	Question	Answer Choices***

Sample Qn. 1.	MCQ* (Programming/ Graphics)	What will be output displayed in the console?
		int x = 125;
		float y ;
		y = float(x);
		println(y);
			1. 125
			2. 12.5
			3. 1.25
			4. 125.0
			5. None of the above

Sample Qn. 2.	MCQ / Theory	For Bezier curve, the middle parameters are *Control Points* which define the shape of the curve.	*True* False
Sample Qn. 3.	TF** (Theory/Prog)	A Processing© program can have any number of draw() functions	True *False*

Sample Qn. 4.	MCQ* (Programming/ Graphics)	This program generates how many circles?
		size(500,500);
		int x = 1;
		while(x > 100)
		{ellipse(150+x,250+x,150,150); };
			1. 5
			2. 20
			3. 9
			4. 14
			5. None of the above

*MCQ - Multiple Choice Question **TF – True or False *** For the reader's convenience, the correct answer is underlined here.			

Table 3. Question Distribution and Student Success Rates in Midterm/Final Exam

	Midterm (50 Questions) and Final (50 Questions)	
	Number of Question	Success Rate
Variable	10	79.6%
Conditional Statement	12	86.6%
Loop	6	89.2%
Array	9	78.9%
Functions	14	72.2%
Graphics Transformation	9	95.1%
Object Oriented Programming	14	84.5%
User Interaction(Keyboard/Mouse)	12	89.8%
Images/Text	5	76.7%
Processing© Specific Functions	9	89.5 %
Total	100	83.9%

smoother and easier. Two types of end-of-semester course evaluations were conducted: Course Learning Outcomes and Instructor Evaluation. The Course Learning Outcomes are presented in Table 5. In order to further confirm the positive results demonstrated in this section, the following question was included in the final instructor evaluation: 'I am glad that I took a Graphics Programming course in my freshman year'. Fifty percent of the students replied 'Strongly Agree' and 50% selected 'Agree'. This confirms that students are receptive to the idea of learning CG concepts using a programming medium.

Conclusion

In this paper, the authors propose using an Open Source programming environment called Processing© in first-year undergraduate engineering and technology education courses. The study explored the reduction of the gap between learning and executing by using Processing©, which is a Java-based language that is easily understood by first-year students in engineering and technology. With Processing©, students can create simple shapes and programs using a small amount of code, which reduces the gap between learning and executing. The study also addressed the issue of reducing cognitive overload by minimizing perplexing jargon or complex programming terminology. Even though Processing© was used as a medium for teaching introductory graphics concepts, the use of a graphic software package also had another notable advantage. Using graphics illustrations served as an effective means to communicate programming notions.

When using Processing©, the students could actually see the visual results of using loops via the graphic output window. This facilitated understanding important programming concepts including loops/iteration, recursion, functions/methods, etc. In addition, Processing© serves as a link facilitating the subsequent transition to more advanced programming and Object-Oriented Programming (OOP) languages like Java and C-Sharp as Processing© itself is built on OOP principles. In summary, then, the authors explain the use of Processing© to design and implement freshman-level graphics courses in the disciplines of engineering and technology. This can be extended and modified further in the forthcoming years to lay a foundation for junior- and senior-year coursework involving EXL (Experiential Learning) projects.

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Table 4. Advantages of Processing© for Teaching Graphics/Programming to Beginners

	Processing©	Other Popular OO languages like Java/C++
Syntax	Common tasks like printing and drawing simple graphic primitives can be performed using simple, brief programming statements	Getting familiarized with the syntax involves time and practice. Even simple tasks like printing to the console or creating a sample graphic object involves writing several lines of code
API (Application Programming Interface)	Very simple, easy-to-understand graphics programming interface, especially for beginners	Understanding the Java API is a time-consuming process and involves considerable time input
Graphics Programming	Users can create graphic objects straightaway using simple one-line statements	Typically, a good understanding of the basic programming concepts of Java/C++ is required before starting graphic programming
Object-Oriented Programming	OO notions such as Class, Methods, Inheritance can be demonstrated using few lines of code and simple graphic examples	Employing OO using Java/C++ entails understanding class and instance variables, class and instance methods, inheritance etc. , which may be challenging for a beginner-level programmer
Event-Driven Programming	Mouse and Keyboard events can be handled by calling mousePressed() and keyPressed() functions. The mouse location can be directly acquired from pre-defined variables.	To enable the mouse interaction in the Java, a programmer needs to import MouseEvent and MouseListener package, inherit MouseListener class to the frame window, and overwrite mouse event handling methods. Mouse position is acquired by calling a MouseEvent object's getX() / getY().
Installation	Straightforward (The software can be downloaded in a single zip file. Software can immediately be used after unzipping it.)	Installation procedure might involve multiple steps and often times, post-installation procedures may be involved (e.g. setting environment variables in Java, etc.)
Importing Libraries	User only needs to copy library files to a predetermined processing folder. Then the library can be easily imported from Processing© menu.	In C++, user needs to specify header file, library file and DLL files using complicated user interface. In source code the corresponding header file should be included by the user. In Java, the precompiled Jar file should be added to the project and the user needs to the import correct package into the Java source file.
Execution	No such explicit conversion needs to be performed by the user	In C++/Java, program first needs to be compiled into byte code files before execution.

Table 5. Question Distribution and Student Success Rates in Midterm/Final Exam

Survey Question (1-Lowest, 5-Highest)	Score
1.I learned basic programming concepts such as variables, data types, selection and repetition control structures, arrays, files, and methods and functions from this course.	4.375
2. After taking this course, I can create simple object-oriented applications.	4.19
3. After this course, I can understand the similarities between Processing© and Java.	3.875
4. After this course, I can apply knowledge to different computer graphics software applications.	4.3125

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TEACHING CONSTRUCTION SCHEDULING USING A SIMULATION GAME

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Abstract

Repetitive construction projects are typically scheduled by the Linear Scheduling Method (LSM) due to repetitive construction processes in multiple units or locations. Workflow between subcontractors in repetitive construction projects affects project performance. Thus, selection of appropriate size workflow has been of interest to contractors. However, LSM is based on an assumption of single unit flow of work between subcontractors. Therefore, combining LSM scheduling with a consideration of impacts of workflow amount is important, and a simulation game was developed in this study for teaching the subject. The game simulates actual construction processes by using building blocks. The effectiveness of the game for teaching was evaluated through a hypothesis test which was conducted via a quiz on student learning. A questionnaire was also conducted to determine the effectiveness of the game. The evaluation results are presented here.

Introduction

In repetitive construction projects, such as multi-unit residential building construction projects, subcontractors need to repeat a construction process—or, at least, a similar one—in multiple units or locations by moving from one unit to the next. Then, the next subcontractor follows after which a series of subcontractors work on the job simultaneously. Since subcontractors require that the work be completed by a preceding contractor, the amount of work available to start with is an important issue to subcontractors. The amount of work available is affected by size of workflow between subcontractors, which affects the project's overall performance as well as each subcontractor's duration and cost [1], [2]

The Linear Scheduling Method (LSM) is a scheduling method used for repetitive construction projects, and its key features include the easy-to-understand relationship between quantity of units delivered and the rate of unit production [3]. However, LSM is based on a single-piece workflow and the impact of its size of workflow on project performance was not incorporated in LSM scheduling.

Therefore, a simulation game was developed to help Construction Management (CM) students learn LSM combined with consideration for the impact of workflow size. The game simulates actual construction processes of a repetitive construction project by building multiple houses with building blocks. Students are expected to learn LSM and the impact of the size of workflow on project performance. The effectiveness of the game for teaching was evaluated through a hypothesis test: the hypothesis is that teaching with the simulation game is more effective than typical lecturing methods. The hypothesis test was performed by comparing students' knowledge gained under two different teaching methods: one group was taught using traditional lecture and the other group was taught using the simulation game. Also, a questionnaire was conducted to gather students' perceptions about their learning and the helpfulness of the game.

Repetitive Construction Projects

Repetitive construction projects such as multi-unit apartment projects or highway projects need to execute (or install) similar construction processes in multiple units or locations, typically performed by subcontractors [4]. Each subcontractor is responsible for a construction activity to build or install one unit and then move to the next unit. Thus, multiple subcontractors are typically required to perform their jobs on different units or locations simultaneously.

Subcontractors in repetitive construction projects need work to be completed by preceding subcontractors before beginning their own work. If a subcontractor has to wait on other contractors to complete their work, then they will have to wait and possibly incur additional expenses. It is of interest to subcontractors to keep work continuity of each subcontractor's labor over the course of constructing the unit [5]. Therefore, workflow between subcontractors who work simultaneously affects the production rate of following subcontractors, and overall project performance in terms of duration and cost is affected accordingly. As Tommelein et al. [6] described the 'Parade' of subcontractors, it is important to balance or coordinate the pace of subcontractors in repetitive construction projects.

Scheduling Method for Repetitive Construction Projects

Due to repetitive construction processes required in multiple units or locations, repetitive construction projects are not scheduled by using the critical path method (CPM) [3]. Instead, LSM is used for repetitive construction projects. LSM is one method of construction project scheduling and is also called the Line of Balance (LOB) or Repetitive Scheduling method [3]. Since LSM can visually plot repetitive operations, it helps contractors schedule continuous workflow. The main benefits of LSM include simple graphical presentation and easy understanding of the progress of each activity and when, where and what activities are being performed at any given time [7]. Due to these features, LSM is reported to have advantages of maximized resource utilization and minimized interruptions [3].

The unit or location is a critical component of LSM and represents a numerical sequence of repetitive operations. For example, in the case of multi-unit residential building construction projects, each residential unit (or apartment) can be the base for scheduling and measuring progress. This means that contractors can schedule and monitor construction operations based on each residential unit. However, another size can be used for multi-unit residential building construction projects: each floor. If multiple units are to be constructed in a building, each floor can be the base for scheduling. Unit size can affect the amount of workflow between subcontractors, thus affecting production rates of subcontractors. Therefore, it is critical to select an appropriate workflow size in LSM [3].

Batching Production in Repetitive Construction Projects

Batching production means making products in lots, not by pieces [1]. Batching production related management is of interest in the manufacturing industry because the setup costs of work stations can be reduced by decreasing the number of setups and batching production. Some construction processes are considered as batching production. For example, a subcontractor (a work station in the manufacturing industry) repeats a construction operation in multiple units in a multi-unit residential building construction project. If there are four residential units on each floor in which subcontractors are to occupy a floor exclusively and release the space to the next subcontractor after completion of all the work on the floor, then the subcontractors construct four units in a batch. Thus, the size of workflow in this example is the batch size of four units.

Since batch size affects construction project performance, selection of an appropriate batch size in construction project scheduling has been of interest to researchers [1], [2], [8-10]. For example, Ward and McElwee [2] examined a hotel construction project in England and proposed using a small batch size of 4 rooms instead of a big batch size of 20 rooms, which was used in the real construction processes. Also, Sacks and Goldin [9] analyzed multiple apartment building construction projects and recommended using a small batch size to reduce overall project duration and to maximize the value to the project owner.

It has been reported by several researchers and practitioners that using a small batch size has advantages over bigger batch sizes: 1) faster project delivery, 2) cost reduction and 3) reduction in rework and defects [2]. While small batch size can lead to early completion of the project and reduced costs, as mentioned above, at the project level, a batch size preferred by one subcontractor may be different from a batch size preferred by another subcontractor, depending on their production rates and other job conditions.

In addition to batch size, buffer is another important factor to be considered in repetitive construction projects. Buffer is defined as "the additional absorbable allowance provided to absorb any disturbance between two activities or tasks as a component of the logical connection between two activities" [11]. Using a small batch size leads to small amounts of up-front work-in-process inventory; and, a small amount of work-in-process inventory may cause lost production or idle workers due to an insufficient amount of work-in-process inventory. Therefore, it is recommended to allocate a buffer along with a small batch size [2], [8].

Scheduling with the Consideration of Batching Production

While LSM is a practical and easy tool for scheduling repetitive construction projects, it is based on a selected unit of workflow (i.e., each unit in a multi-unit residential project) [3]. On the other hand, understanding the impact of batch size on project performance and incorporating it into scheduling can improve project performance. Therefore, it is recommended that repetitive construction projects are scheduled along with consideration of batch size.

Game and Simulation for Enhanced Teaching

Game and simulation is an instructional method that can enhance student learning through active participation [12].

While the benefits and disadvantages of game and simulation in the academic learning environment in general are discussed by Ncube [13], simulation games are excellent tools for practical decision-making and management experience [14]. Especially in the construction industry and construction education, simulation is a very useful tool due to the complex interaction among various participants or processes [15].

Due to the benefits of game and simulation and features in the construction industry, educators in construction have developed or used several games and simulations such as Super-Bid [16], Equipment Replacement game [14], *CONSTRUCTO* [17], Negotiation Game [18], Parade of Trade game [6] and LEAPCON game [19]. The LEAPCON game is to simulate interior finishing processes of a high-rise apartment building with customized design in each unit and is used to help students understand the benefits of LEAN construction management principles: 1) pull flow—to construct what the immediate downstream activity needs, not to build a product from what is available; 2) small batch size; and, 3) multi-skilled workforce.

However, there is no a simple game available which can be used for teaching LSM while also considering batch size. While the LEAPCON game can provide insight into the impacts of batch size on project performance, it is based on a specific case in which each apartment's design is customized and change orders are expected due to information available late. Therefore, a simulation game for teaching LSM combined with impacts of batch size was developed. This simulation game is based on a more typical and generalized repetitive construction project and, thus, students can understand the subject more easily.

The Simulation Game

The objective for the development of this simulation game is to help Construction Management (CM) students understand 1) features of construction processes in repetitive construction projects; 2) impacts of batch size (size of workflow) on project performance; and, 3) how to develop an LSM-based schedule with the consideration of different batch sizes.

The game is to build four houses by using building blocks, as shown in Figure 1. The four houses in the game are different from one another in terms of color and location. Four houses are to be built by six players each of whom plays the role of subcontractor. Table 1 shows the roles and jobs of six players required for this game. Each player is given a container with all blocks and information needed for four houses, as shown in Figure 2. The information included in the containers includes size, color, number of blocks needed and location of houses.

Figure 1. A House Built of Building Blocks in the Game

Table 1. The Roles and Jobs of Six Players in the Game

No.	Role	Assigned job
1	Building layout surveyor	To locate four corners of a building
2	Subcontractor for Foundation	To build the first layer
3	Subcontractor for wall	To build next five layers
4	Subcontractor for doors and windows	To install a door & frame, two windows & frames
5	Subcontractor for roof framing	To build next two layers
6	Subcontractor for roofing	To build the last layer

Four houses should be constructed in the order of the first player (surveyor) to the last player (roof subcontractor), sequentially. All subcontractors except a surveyor can start the building process only after a preceding subcontractor finishes his (or her) job: If a preceding subcontractor's job is not finished, a subcontractor has to wait. Only one subcontractor is allowed to perform building processes at each site. All players are given the information about preceding work as well as their own work. Therefore, game players are required to inspect the work completed by a preceding subcontractor. If erroneous work is detected, the defective work should be corrected by the preceding subcontractor. The game is finished when four houses are built.

Figure 2. The Game Being Played in a CM Course

The game players' performance is measured by time spent on the building process and wait time. Each player is given a sheet for recording time, and players are required to keep a record of start time and finish time for each house. At the end of the game, the amounts of time spent by the six players are totaled, and the total amount of time represents overall project duration. Also, the amount of wait time experienced by each player is calculated to present additional costs incurred due to waiting.

The game is designed to be played in two rounds with different batch sizes (or size of workflow between subcontractors). In the first round, it is assumed that the batch size for all subcontractors is one house. In other words, each subcontractor can occupy only one site and the work completed at one site should be released to the next subcontractor without a delay. After the first round, all finished houses should be disassembled for the next round. In the second round, players need to assume that the batch size for all subcontractors is four houses. Each player occupies four sites and the work completed on four houses should be released to the next subcontractor all at once. In the second round, some players may need to wait because preceding subcontractors' production rates may be slow. By comparing resulting time performances from two rounds of the game, students participating in the game can understand the impacts of different batch sizes on project performance along with LSM scheduling.

The game simulates actual construction processes and has the following features:

- Reflection of different production rates: subcontractors' production rates may vary depending on the amount of resources allocated, difficulty level of the jobs, etc., as in real construction projects. Also, production rates of subcontractors in a sequence may not be balanced or comparable to each other. The game is designed to reflect different production rates among subcontractors by different work amounts among subcontractors. For example, installation of one door and two windows can be done relatively quickly. However, building five layers of bricks for wall construction needs more time than installation of doors and windows. Therefore, students are expected to understand the importance of balancing production rates between subcontractors and recognize the need to buffer the time between subcontractors.
- Easy measurement of project performance: players need to keep records of times they start and finish each house. After each round of the game, all times for each player and the overall project are calculated. Thus, overall project performance and each subcontractor's performance are measured in terms of time and cost. Assuming that subcontractors do not do anything productive during their wait time, wait time would represent an additional cost caused by an insufficient amount of work.
- Reflection of uncertainty in quality: contractors (or their workers) may make mistakes. Erroneous work may be detected by an inspector or downstream subcontractor and should be corrected. The game reflects the uncertainty in quality of workmanship by defective work which may be produced by players.

Implementation of the Game

The game was played in a Construction Management course in December, 2011, as shown in Figure 2, after having been tested in a pilot study in April, 2011, at one educational institution. The students played the game over two rounds and discussed the results and what they learned. After playing the game, the time records were collected and simple plots of performance were prepared by one of the authors. The plots are shown in Figures 3 and 4. (The plots in Figures 3 and 4 are the results from one team's play). The plots in Figure 3 show the progress of six subcontractors: the plot on the left is from the first round with a batch size of one house; the plot on the right is with a batch size of four houses. These plots show overall project duration, production rates, wait time, the amount of buffer time and the differences between the two rounds.

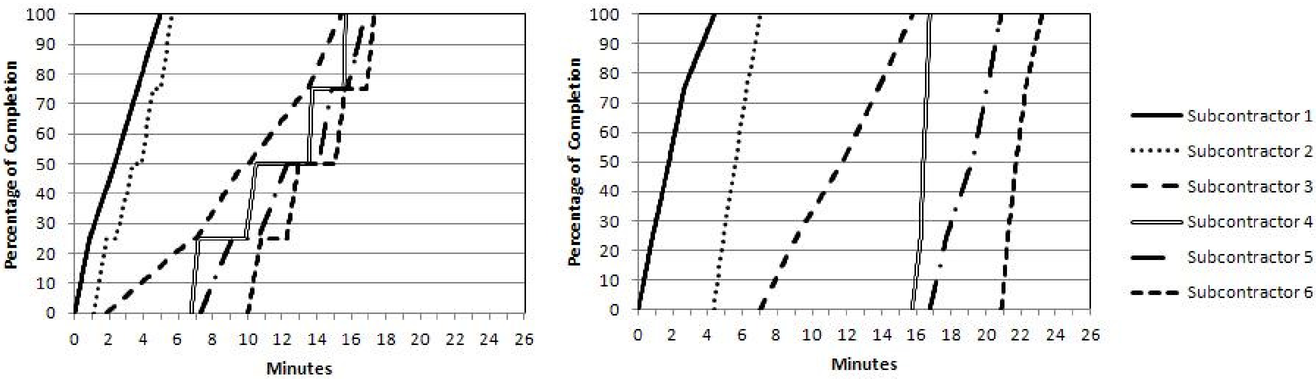

Figure 3. Examples of Progress Plots Resulting from the Game

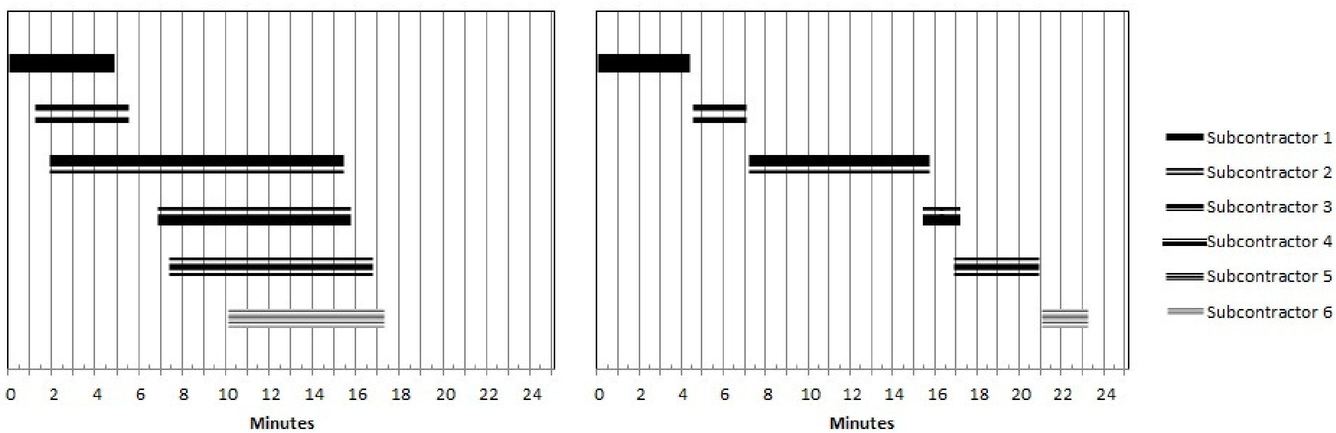

Figure 4. Examples of Duration Plots

The plots in Figure 4 show the amount of time spent by each player, which represents costs (or amount of resources) incurred by each subcontractor. The plot on the left is for a batch size of one house; the plot on the right is with a batch size of four houses. While the overall project duration is reduced when a smaller batch size (one house) is used, the small batch size caused more costs (wait time) for several subcontractors (subcontractors #2, #4, #5 and #6). In the discussion session after playing the game, it was discussed that subcontractors may have resistance to small batch size due to increased costs caused by no (or insufficient) buffers. Accordingly, it was also discussed that subcontractors may need buffer time in order to reduce wait time (or cost) under LSM.

Evaluation of the Effectiveness of the Game

Hypothesis Test

In order to evaluate the effectiveness of the game in teaching construction scheduling, a hypothesis test was conducted with the following hypothesis:

H_0: there is no difference between teaching using the simulation game and teaching using typical lecturing.
H_a: teaching using the simulation game is more effective than teaching using typical lecturing.

This hypothesis test was performed by comparing quiz results between two groups of students. The control group (16 students) received a lecture on the subject and then took a quiz. The experimental group (11 students) played the game and then took the same quiz.

The quiz included seven questions: the first five questions pertained to knowledge gained, while the other two questions pertained to perceived knowledge gained. The questions on the quiz were multiple-choice questions on the following topics:

- Question #1: definition of batching production
- Question #2: characteristics of repetitive construction
- Question #3: advantage of small batch size
- Question #4: disadvantage of small batch size
- Question #5: usage of both small batch size and buffer

Table 2 shows the mean and standard deviations of the percentage of correct answers to the questions pertaining to the knowledge gained (questions #1 through #5) by each group. While there was a slight difference between the two groups, it was concluded that the difference was not statistically significant from a student's t-test: the computed *t* value (0.358) is smaller than the critical value for the rejection of the null hypothesis at the 95% confidence level and the null hypothesis should not be rejected.

Table 2. Descriptive Statistics of the Quiz Results (Questions about the Knowledge Gained)

	% of correct answer	
	Experimental group	Control group
Question #1	54.5%	93.8%
Question #2	63.6%	56.3%
Question #3	100.0%	93.8%
Question #4	36.4%	56.3%
Question #5	72.7%	43.8%
Mean	65.5%	68.8%
Standard deviation	0.24	0.23

Questionnaire

In addition to the hypothesis test through a quiz, a supplementary evaluation of the efficacy of the game was conducted in two ways. The first approach to the supplementary evaluation was to ask questions (included on the quiz) of the two groups about their perception of knowledge gained, as follows.

- Question #6: confidence level in knowledge gained
- Question #7: degree of enhancement in knowledge by a teaching method

The students in both groups were asked to determine their confidence level on their knowledge gained on a scale of 1 to 5 (1 is for no confidence and 5 is for high confidence). The mean values and standard deviations of the students' confidence levels for both questions are summarized in Table 3. Based on a student's t-test, it was concluded that the students who played the game (the experimental group) had higher confidence in their knowledge than the students who received a lecture (the control group) for both questions.

Table 3. Descriptive Statistics of the Quiz Results (Questions about the Perceived Knowledge Gained)

Question		Experimental group	Control group
#6	Mean	4.09	3.50
	Standard deviation	0.70	0.82
#7	Mean	4.64	3.38
	Standard deviation	0.50	0.72

The second approach to the supplementary evaluation was a questionnaire on the helpfulness of the simulation game. The students in the control group were asked to play the game after taking the quiz. Also, the students in the experimental group received a lecture after taking the quiz. Then, the students in both groups were asked to take a questionnaire. Four questions were asked of the students, as shown in Figure 5.

The first question on the questionnaire was if the game was helpful in understanding batching production and impacts of batch size. All of the students (100%) answered that the game was helpful in their learning ('Strongly Agree' and 'Moderately Agree').

The second question was if the game was helpful in understanding the need for cooperation among subcontractors. The students compared the results of the two rounds: while overall project duration was reduced by using a small batch size in the first round, some of the subcontractors' durations were increased due to wait time. However, in the second round, each subcontractor's duration was minimized, while overall project duration was increased. Based on the results

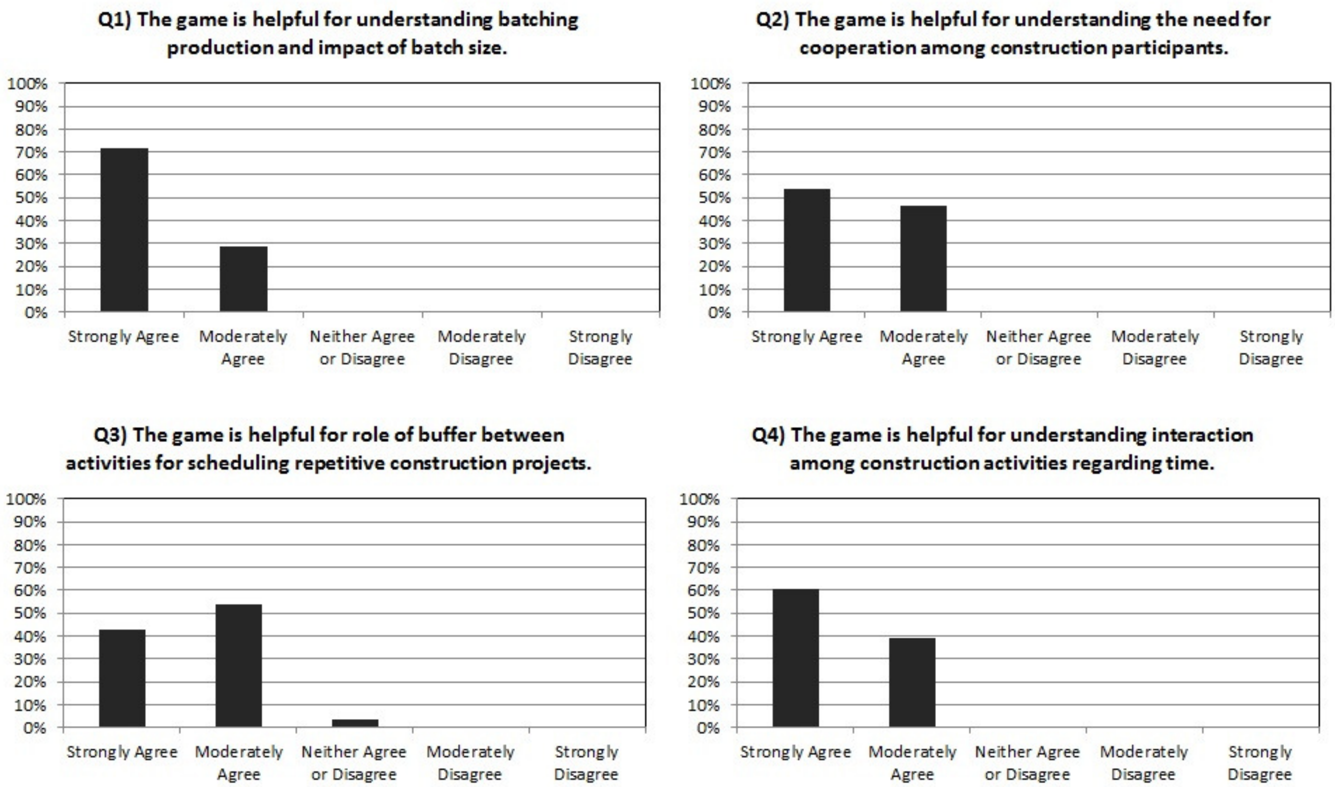

Figure 5. Results of the Questionnaire

shown in Figures 3 and 4, students recognized that construction project participants needed cooperation in regards to selection of batch size. The results of the questionnaire confirmed student learning. The third question was about the helpfulness of the game in understanding the role of buffers between activities. Almost all students (except one student) responded that the game was helpful.

The last question was about the helpfulness of the game in understanding the importance of interaction between construction activities. During the game, some students had to wait due to an insufficient amount of work available (or late progress in the preceding subcontractor's work). In the discussion session, some possible methods for improving the interaction were suggested and examined by the students. The overall results of the questionnaire show that the game was helpful for understanding the importance of interaction between activities.

Discussion and Conclusions

Repetitive construction projects are typically scheduled by LSM due to repetitive construction processes in multiple units (or locations). Also, the amount of workflow (or batch size) between subcontractors in a repetitive construction project is important and affects project performance. Therefore, teaching LSM along with the consideration of the impact of batch size can help construction management students prepare a better schedule for construction projects.

A simulation game was developed to help construction management students understand the impacts of batch size as well as LSM. The game simulates building processes by using building blocks. From comparisons between the results of two rounds of game play with different batch sizes, students can understand the impacts of batch size on project performance in addition to LSM.

The efficacy of the game in teaching was evaluated by a hypothesis test: teaching with the simulation game is more effective than typical lecturing. Student learning in both groups was measured by a quiz and the results of the quiz for the two groups were compared. The results of the student t-test showed that the hypothesis should be rejected. Therefore, it was concluded that teaching with the simulation game was not more effective than typical lecturing.

On the other hand, student perception about their knowledge gained in both groups was also analyzed. The results showed that the students who played the game had more confidence in their knowledge gained. Also, the helpfulness of the game based on the students' perception was determined by a questionnaire. The results showed that all of the students perceived the game as helpful in understanding the subject.

Combining the results from the hypothesis test and the questionnaire, it was concluded that the simulation game developed by the authors is not more effective than traditional lecture methods. However, considering the students' perceptions on their knowledge gained and helpfulness of the game, the game is still a good method of teaching.

The authors believe that students can learn more effectively through 'learning by doing' than 'learning by watching and listening'. Thus, the simulation game developed from this study can be utilized as a supplementary method for teaching construction scheduling with the consideration of the impacts of batch size.

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PREPARING ENGINEERING STUDENTS FOR JOBS THROUGH MOCK INTERVIEWS

Sofia M. Vidalis, Penn State Harrisburg

Abstract

A standard university curriculum often incorporates lessons on how to conduct a job search, prepare a professional resume, and interviewing skills. In addition to classroom lectures and discussions, students must also have the opportunity to practice their skills in a mock interview activity. A mock interview is one way to prepare students for an actual employment interview. It allows them to gain experience and practice answering questions similar to ones asked during an actual interview. It also helps them become more comfortable in the interview setting. Despite the importance of mock interviews, most college students do not have that experience until their first job interview during a career fair, internship, or even after graduation. However, in today's society, communication is everything and interview preparation may be the determining factor in landing that job. One way of breaking the ice of interviewing jitters is to prepare the students in advance.

The Civil Engineering/Structural Design and Construction Engineering Technology program at Penn State Harrisburg holds realistic Mock Interview and Panel Discussion events every spring to help students better prepare for an interview. This was accomplished by inviting professionals from the construction management and engineering design fields to interview the students. Each student had a chance to interview with two professionals and was then critiqued on their performance. This paper presents the process of a different approach to mock interviews, feedback from industry and students, and what lessons were learned. Overall, this paper shows how a mock interview event can be a win-win relationship for both students and industry.

Introduction and Literature Review

Instructors seeking to prepare their students for success in employment interviews use various methods including, for example, mock interviews. A mock interview provides a professional one-on-one opportunity for all students to practice their interviewing and resume writing skills with an actual interviewer, who is an engineer from the community. Studies have shown the importance of teaching students how to prepare for an interview [1]. Interviews are one area where active learning techniques are especially helpful. For example, a study that was done by Perry and Goldberg [2] suggests that interview preparation is important because when recruiters were asked about college students they interviewed, interviewing skills surpassed the student background or experience in recruiter assessments of the likelihood that their companies would consider hiring a given student.

A study by Smith and Glover [3] showed that mock interviews are designed to teach job application and personnel selection skills. In addition, Teague [4] found out that preparation and practice in interviewing is known to boost the confidence and performance of students. Despite the importance of mock interviews, most college students do not have that experience until their first job interview, which can be from a career fair, internship, or even after graduation. Despite possessing excellent resumes, students may fail to secure placement if they perform poorly during their first interview [5]. The employment interview continues to be one of the most popular selection and recruiting devices in organizations and is intended to predict the future job success of applicants [6].

Mock interview experience includes both the role of the interviewer and the interviewee, who practice together and help each other refine skills which include perceived self-efficacy and peer tutoring [7]. There are many different types of mock interview strategies that facilitate active learning. One method used by Harchar [8] was to use graduate and undergraduate students to play the role of interviewer and interviewee. This method used the Reciprocal Peer Tutoring (RPT) technique, where students alternated roles of tutor and tutee.

Marks and O'Connor [9] developed a round-robin mock interview activity that provided learning opportunities in one 75-minute class period by dividing the class into teams that would travel to different stations. In this case, each student had the opportunity to be interviewed once, observe interviews from the other teammates, and to participate in multiple feedback sessions.

Another mock interview method by Powell et al. [10] used participants to play the role of the interviewer and interviewee along with observers to observe their performance and behavior. This was done in a couple of studies over several hours during which the individual stability of each interviewer's performance was analyzed and measured by questions.

All of these techniques allowed students to perceive interview self-efficacy, maximize learning and boost self-confidence. However, it did not portray the real type of interview experience from an actual interviewer from the industry. The mock interview event, described in this paper, prepares students for the job search because real firms were conducting the interviews. It was not told to the students which firms were hiring, but that made it seem even more close to a real interview. The mock interview event was unique because it used active learning techniques in which students were able to practice knowledge learned, while receiving immediate feedback on their interviewing skills and resume from the interviewers to maximize their learning. Compared to previous methods, the students would receive immediate feedback from the interviewers based on their behavior, performance, communication and writing skills.

Types of Interviews

Traditional methods of employment interviewing typically use one-on-one interview formats and questions concerning the applicant's education, work history, career goals and types of training. Employment interviews can be either structured or unstructured. The main issues for either type of interview, which has to be considered when discussing them, are reliability and validity. Structured interviews ensure that candidates have equal opportunities to provide information and are assessed accurately and consistently. A structured interview asks all candidates the same questions and in the same order, allows the same amount of time for each question, and is evaluated using a common rating scale. However, in unstructured interviews, the opposite is true. In an unstructured interview, candidates may be asked questions that are not specifically limited and set. In this case, the conversation can flow freely. The questions asked in an unstructured interview can change depending on how each individual responds and questions are usually open-ended. This allows for several topics to be discussed during this type of interview. In these cases, the interviewer usually engages in lengthy explanations of the job and asks questions which are not necessarily predetermined by the interviewer. In addition, a standard rating scale is not required for an unstructured interview.

At first glance, the unstructured interview may appear more attractive due to its loose framework, but research shows that it has little value in predicting job performance. Unstructured interviews typically demonstrate the following:

- Low levels of reliability due to inconsistent ratings
- Low to moderate levels of validity due to not having a method to assess the interview
- Lack of standardization in interview procedure and questions makes it susceptible to legal challenges [2]

However, an unstructured interview does have some advantages such that it can help gain information which was not planned and can be helpful in areas which need more explanation. A structured interview is not necessarily more valid than an unstructured one. It may, however, be deemed so because it allows employers to ask preset questions of all candidates and, thereby, compare answers uniformly across the board [11].

Structured also means that every candidate's responses are evaluated and scored, typically using behaviorally anchored rating scales that were developed for each question asked. After all structured questions have been asked and evaluated, any follow-up questions can be asked based on answers given by the candidates. Structured questions are also documented for future reference, provide the employer with more detailed information, reduce the possibility of unfair discrimination, tend to be more reliable and objective, and applicants seem to be more accepting of them. Some elements of structure in employment interviewing, as defined by Huffcutt and Arthur [12] include:

1. Basing questions on an analysis of the target job (i.e., tying questions to competencies required by the job)
2. Asking the same questions of each candidate
3. Asking specific types of questions (e.g., past job behaviors or what one would do in hypothetical job-related situations)
4. Using detailed, behaviorally anchored rating scales (i.e., rating scales with behavioral examples to illustrate points along the scale)
5. Limiting the use of follow-up questions by the interviewer
6. Systematically combining ratings of questions in order to derive an overall score
7. Providing comprehensive training for interviewers

Although there are more advantages in conducting structured interviews, a lot of interviewers today mix the two. This is commonly known as competency-based interviews, where the areas the employers want to ask questions are categorized and set; however, they then adapt questions under these headings to each candidate based on their responses. This also gives candidates the opportunity to sell themselves much better than with structured interviews.

After all, human beings communicate mostly in an unstructured way. Therefore, the mock interviews that were conducted by the professionals at Penn State Harrisburg used a combination of structured and unstructured interviewing approaches [13].

Mock Interview Event Planning

The mock interview event started in the spring of 2011. It became such a huge success that the Civil Engineering and Structural Design and Construction Engineering Technology (CE/SDCET) department now has it offered to students once every spring semester. There were a lot of learning curves and changes from the first time this event took place compared to the second. Some of those changes included:

- Invite more people from industry.
- Make it mandatory for students taking the Internship course (SSET 295).
- Prepare students for the job market in advance through lectures and assignments (resume building, cover letters, company research and interviewing skills).

The mock interview event was mandatory for students taking the SSET 295 course, but was also opened up to all students in the CE/SDCET major. An e-mail was sent out to many industry professionals in varying fields of civil engineering (e.g., environmental, construction management, transportation, structural design and water management) around the area to inform them of the event and ask for their participation as an interviewer. Having a varying discipline of professionals in the event allowed the students to choose their interviewer in their discipline of interest. The first time that the mock interview event took place, the event had eight industry professionals participate and a total of seven students that signed up for the event. Because of the overwhelming positive feedback from the students and making it mandatory for the SSET 295 course, the second time around was even more of a success.

The second mock interview event in the spring of 2012, had a total of 12 people from industry (interviewers) and a total of 24 students (interviewees) that attended the event. The students that signed up for the mock interview event had to upload a one-page resume, in PDF format, on the ANGEL learning website a couple weeks before the event. The one-page resumes from all of the students were then compiled and sent out to all of the professionals, who agreed to conduct the interviews, a couple weeks prior the event. This was done so that all of the interviewers had time to look over the resumes and provide suggestions and/or comments on them during the event. A flyer with details about the event (e.g., location, time, breakout sessions and quick reminders), as seen in Figure 1, was e-mailed to everyone. In addition, the students received a list of all the interviewers, their companies, contact information, and areas of expertise before the event. This allowed the students to research each interviewer and the company they were representing before the event in order to become more familiar with the company.

The Mock Interview Event Group Break-Out

The students came prepared by dressing up in the appropriate business attire, bringing a notepad and a writing utensil to jot down notes from the interview process, and having copies of their resumes in hand. In addition, extra copies of all student resumes were made and, along with an interview rating sheet that one professional put together for the event, handed out to all of the professionals during the day of the event. The rating sheet, that was used to rate the students and make comments during the interviewing process, is shown in Table 1. There were five criteria listed on the rating sheet on which the interviewers rated each student. The rating scale ranged from below basic to advanced, with advanced being the highest rating that meant that the interviewee excelled on that specific criterion. The event started off with a dinner social. It was initially suggested to start with a social so that the students and industry professionals had time to meet each other and talk informally before the interviewing process began. This turned out to be a great ice-breaker for the students who felt a little nervous before the interviews.

During the mock interviewing process, each professional was given his/her own table from which to conduct the interviewing process. Since there was twice as many students as professionals in the event, the students were separated into two groups, group one and group two, which consisted of 12 students each (see Figure 1). The first 12 students, or group one, interviewed first, while the remaining 12 students, or group two, gathered together at a roundtable to discuss interviewing. Some of the roundtable discussion questions that were asked and talked about in group two, before their interview, were:

1. How did you prepare for today's interview?
2. What type of questions would you like to ask the interviewer?
3. What are your strengths and weaknesses?
4. What do you plan on doing after you graduate? In the next five years from now?

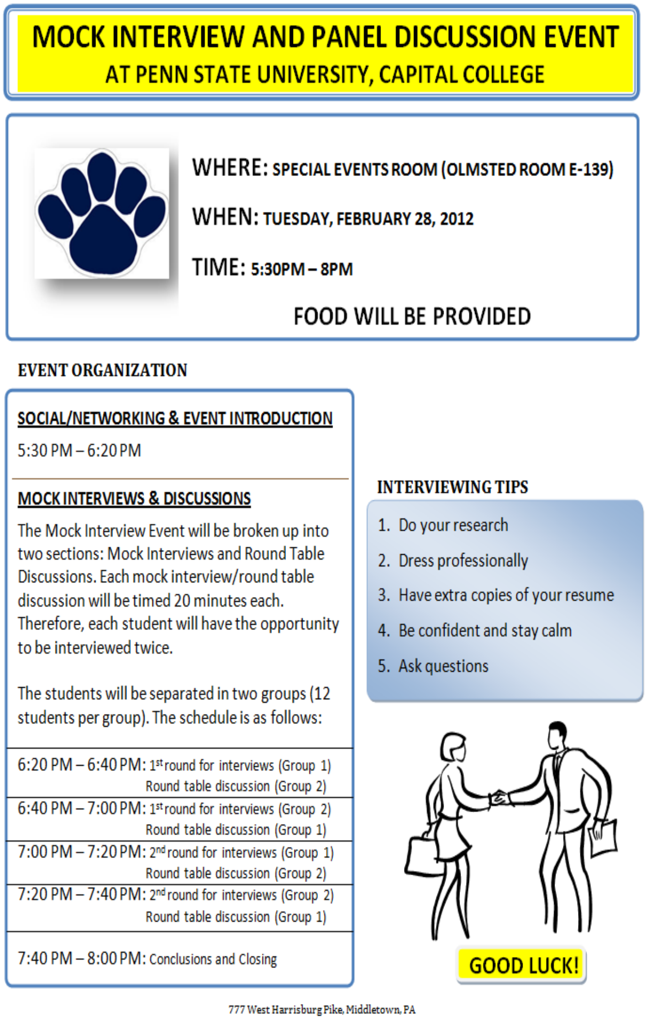

Figure 1. Mock Interview and Panel Discussion Event Flyer

The groups would switch every 20 minutes. When it was group one's turn to meet at the roundtable for discussion, the questions were different because they had already gone through round one of the interviews. Some of the roundtable discussion questions that were asked and talked about with group one, after their first interview, were:

1. Did you feel that you were prepared for the interview? Why or why not?
2. What questions did the interviewer ask?
3. What questions did you ask the interviewer?
4. What kind of feedback did you receive from the reviewer?

There was a total of four sessions. Each session lasted 20 minutes; therefore, each student got to be interviewed twice.

Table 1. Mock Interview Rating Sheet

Name: ____________ Interviewer: ____________		Below Basic	Basic	Proficient	Advanced	Comments
Preparation	Turn off cell phone/ pager. Resume					
Poise/Self Confidence	Introduces self with firm handshake & friendly greeting. Avoids nervous actions and mannerisms during interview. Reacts appropriately. Sits correctly with good posture. Maintains eye contact. Refers to interviewer by name.					
Communication Skills	Uses correct grammar and avoids slang. Speaks slowly and clearly. Avoids mumbling. Answers questions thoroughly but keeps answers pertinent. Phrases responses in short, simple sentences. Ask appropriate questions.					
Experience & Skills	Does not criticize former employer. Does not discuss personal problems, finances, religion, or politics. Listens closely to any questions and comments. Makes positive statements. Clearly describes value from experiences/skills/ related coursework.					
Closing	Thanks employer for interview with firm handshake. Ask preferred communication type for future correspondence.					

A timer was used during the event so that each person had a fair amount of time given and knew when to start and end on time.

Interview Process

Students came prepared with extra copies of their resumes and questions they wanted to ask. As seen in Table 1, the interviewers rated each student on five factors:

1. Preparation:
   a. Did they wear the proper attire?
   b. Were there any cell-phone distractions?
   c. Did the students hand their resumes to the interviewer after introducing themselves?
2. Poise and Self-Confidence (body language):
   a. Did they have a firm handshake and friendly greeting?
   b. Were they nervous?
   c. Did they have good posture?
   d. Did they maintain eye contact?
   e. Did they refer to the interviewer by name?
3. Communication Skills:
   a. Did they use correct grammar and avoid slang?
   b. Did they speak clearly and answers questions thoroughly?
   c. Did they ask appropriate questions?
4. Experience and Skills:
   a. Did they criticize, discuss personal problems, or have a negative attitude?
   b. Did they listen closely to questions and comments?
   c. Did they clearly describe value from experience, skills, and related coursework?
5. Closing:
   a. Did they thank the employer for the interview with a firm handshake?
   b. Did they seem interested during the interview?

In addition to the five factors on which the interviewers rated each student, they also reviewed and commented on their resume. Finally, the event closed with some interviewing pointers and comments made by the interviewers and then were opened up for questions and discussion. Even though this event was intended to prepare students for an actual interview, a couple of students received an internship and full-time job opportunities from interviewers that were looking to hire.

A set of questionnaires, for both the interviewers and interviewees, was handed out in order to evaluate the event and also give some feedback on the interviewing process. A day after the event took place, thank-you cards were sent out to all industry professionals that participated, thanking them for their help and for the successful event.

Questionnaire and Feedback

The event showed a promising turn for all of the participants and it was suggested that this event be hosted once a semester. A questionnaire was sent out to all students and industry professionals that participated in order to receive comments and suggestions. This questionnaire would aid in making future Mock Interview Events more successful and also attract more participants.

There were two separate short questionnaires that were given at the end of the event: one for the interviewers and the other for the interviewees. The questionnaire for the industry professionals that participated consisted of three questions, as follows:

1. What was your overall experience with the students and the Mock Interview Event?
2. What type of comments, recommendations, and/or suggestions would you like to share with the students that you think may help them have a successful interviewing process?
3. Do you have any suggestions and/or recommendations for future Mock Interview events?

The questionnaire for the students that participated consisted of five short questions, as follows:

1. How did you prepare for the Mock Interview Event? Did you research the list of companies that came to the event beforehand?
2. What were some questions that the interviewers asked you?
3. Did you receive any feedback from the interviewers after your interview? If so, what were some tips, comments, recommendations and/or suggestions that were given in order to help you prepare for future interviews?
4. How was your overall experience with the Mock Interview and Panel Discussion Event? Do you have any comments and/or suggestions?

These questionnaires were handed out to all participants. Only 83% of the industry professionals and 96% of the students that participated responded, which was a good percentage. The feedback that was received from the participants can be seen in the Appendix. The common questions asked of the interviewees were as follows:

- Describe yourself.
- What is your strength and weakness?
- Where do you see yourself in two, five, or 10 years from now?
- What brings you to construction or engineering?
- What is your favorite part in your major?
- What are some of your relevant classes?
- Will you be able to travel or move around?
- What do you like better, working in groups or alone?
- How do you feel managing multiple operations?
- Why should I hire you over the other interviewees?
- What skills can you bring?
- What are you doing for your senior project?
- What type of responsibilities do you have in your summer internship?

The students also received a lot of good feedback and criticism on their resumes and overall interview. All of the industry professionals at the event mentioned that their experience with the students was very positive. The following are some comments and advice that the students were given during their mock interviewing process:

- Have a positive way to respond for low GPA or questions that are negative.
- Do not be afraid to emphasize strong points and have confidence.
- Know every detail of your past experiences and further compliment the resume.
- Research the company that you plan on interviewing with.
- Dress professional.
- Have firm handshake, turn of cell phone, and have good eye contact.
- Resume should have proper spelling and grammar (one-page for first job career)
- Stay focused on questions being asked during the interview.
- Have questions for interviewer.
- Develop computer skills during education.
- Speak clearly during the interview.
- Describe own aspirations for the future.
- Expect unusual questions as well as the "popular" interview questions.

The majority of the students did mention that they felt more confident after the first interview round and also expressed that they learned a lot from this event. They also mentioned that they did prepare in advance and also looked over some of the most common questions asked. They were surprised to hear that they should expect uncommon questions. Overall, the feedback showed a very positive overview of the event and that some students also were given a job after graduation or an internship. All of the participants would want to see this event take place twice a year and have more students attend.

Conclusions and Recommendations

Conducting mock interviews so that each student's learning is maximized is often a time-consuming process and sometimes difficult to schedule. This event enabled each student to complete two mock interviews and two roundtable question-and-answer sessions. The mock interview event was different than the other techniques mentioned in this paper because it involved industry as the interviewers and the students did not know which industries were hiring until the interview took place. The interview also used active learning techniques in which students were able to practice knowledge learned while receiving immediate feedback on their interviewing skills and resumes from the interviewers. This was even more of an advantage to the interviewees because they were critiqued by a possible employer, which is always more heavily weighted. Although students practiced popular interviewing questions, as mentioned in the feedback, it was also a good experience for them to see that they should also expect some unusual questions.

Overall, the feedback from both the interviewers and interviewees turned out to be very positive. The responses from the questionnaire showed that the students maximized their learning and also became more confident after the first interview round. A couple of students also received a job or an internship because of the event. The results of the participants' feedback clearly identified positive trends in students' perceptions in regards the benefits of having a mock interview event on campus.

Even though the event was a success, there were some things that could have made the event even better. Based on the feedback received, the following are some extra recommendations from the participants in order to have a more successive future mock interview event:

- Allow more time to have more sessions of interviews.
- Allow more time for interviewers to fill out interviewee evaluation form.
- Distribute a hand-out to all participants before the event that goes over a brief introduction about the event with an organization of the event by time.
- Hold a social before and after the mock interview event in order to break the ice in the beginning and also to conclude the session with remarks at the end.

- Make the mock interview event mandatory so that more students can participate.
- The event should be once a semester.

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Biography

SOFIA M. VIDALIS is an Assistant Professor of Civil Engineering at Penn State Harrisburg. She earned her B.S. degree, MS degree, and Ph.D. in Civil Engineering from the University of Florida, Gainesville, FL. Dr. Vidalis is currently teaching at Penn State University, Capital College. Her interests are in construction management, quality control/quality assurance in pavement, and transportation operation. Dr. Vidalis may be reached at svidalis@psu.edu

Appendix

INTERVIEWEE'S FEEDBACK

Question 1. How did you prepare for the Mock Interview Event? Did you research the list of companies beforehand?

1. Researched companies and looked up potential questions asked in interview.
2. Resume, cover letter, dressed up. Yes, a little.
3. I made a list of companies and the name of who is here and what they do.
4. Yes, I researched the ones that interested me most.
5. Yes, I did research the companies to see if any of them had an office close to where I live.
6. Revised my resume a little. I did look up some of the companies.
7. Great and informative. Yes.
8. Yes, I saw they designed a bridge at an area I know well and went on that.
9. Looked over resume, reviewed company, researched interview etiquette.
10. I didn't do anything special for this event. I made sure I had up to date resumes with me and was ready to discuss whatever they presented to me. No, but only a view on the list interested me and I know about them already.

11. I brought my resume, researched the companies dressed appropriate, came prepared
12. Copies of resumes, dressed up, researched, told myself, "I am the man."
13. I researched a hand full of companies in their past projects and location of work.
14. Prepared resume and reference lists.
15. I researched the various companies and made some mental questions and points to bring up. I just Googled the company and read their homepages.
16. Bring resumes, dress appropriately. No.
17. Dressed up, printed out resume. Some, I looked up the ones that interested me.
18. Looked over my resume, prepared for questions I may be asked, printed out a portfolio. I did research a few companies.
19. Online research of a few companies. Mentally thought of some questions that could be asked to any company. Yes, some.
20. Looked up questions and determined my responses. Yes, webpages…current and future projects, locations, and careers page.
21. Looked up each company online and reviewed them in what they did. Yes.
22. Dressed professionally and printed resumes.
23. Worked on resume. Researched a few companies on the list.

Question 2. What were some questions that the interviewers asked you?

1. What is your biggest weakness?
2. Strengths, weakness, opportunities
3. Where am I headed? When will I graduate? What do I like the most about engineering?
4. Asked me why I want to be a structural engineer and what kind of duties I want to do.
5. What are your favorite courses? How would your current/present supervisor describe you?
6. What are my goals in 3-5 years? What do I want to be doing? What made you interested in engineering?
7. Where do I think I will be in 2-years? Which branch of engineering am I searching for? What experience do I have?
8. Where do I see myself in the future? What are you more interested in bridge or buildings?
9. What makes you, you? What are your goals? How do you deal with deadlines/stress?
10. Why building construction? Would you be willing to move around?
11. What are your strengths? What are your goals? Where do you see yourself in 5 years?
12. Asked me about my resume, my leadership experience, time management.
13. What are my major and favorite classes? Do I have any experience? What my plans were down the road (summer and future)? If I was willing to travel.
14. Do you have any questions?
15. Have I ever gone above and beyond in a job? Have I ever dealt with a highly emotional person? He asked me to describe my Eagle Scout project.
16. Why should I hire you over the other interviewees? What skills can you bring to my company?
17. Do you mind to travel? What is a problem you overcame?
18. Where I want to be in five years? Favorite classes in school.
19. Where I see myself in 5 years? What area of construction I wanted to work in? Asked about educations. What made me pick this field?
20. Goals in career? Describe group projects in class-How/What did I do to contribute? What knowledge do you have about the company? Experience-talk about previous experiences.
21. Do you like what you do? What is your favorite class? What is your least favorite class?
22. What filed I wanted to get into.
23. What field do you want to work in? What experience do you have?

Question 3. Did you receive any feedback from the interviewers after your interview?

5. Some feedback, not enough time for a lot. Put more of my activities on resume.
6. Yes, good resume. Work on strength and weaknesses.
7. Yes, edit resume, add objective, and broaden my horizons.
8. No, but he did recommend getting involved and taking advantage of ASCE here.
9. No, but he did say he would keep me in mind for an internship.
10. No, not many. Time went quick.
11. No, not enough time. However, throughout the interview, he told me about how my experience will elevate my salary through experience.
12. No, but I recommend researching the company so if there are speaking gaps you have something to mention.
13. Yes, positive. Objective, elaborate more on past goals and achievements.
14. I received feedback through the whole interview starting from my resume to my thoughts on living locally. Be flexible and look for a career, not just a job.
15. Some minor adjustments to resume
16. Yes, told me to try really hard to get engineering experience, otherwise, I was told I did a good job.

17. He said to always ask for business cards and to build as many relationships as possible.
18. Ask more questions.
19. He didn't give me any feedback but I could have had a better posture and spike louder and more clearly.
20. How to better answer their questions.
21. Gain some construction experience. N/A
22. I was told my presentation was great but to add some things to my resume such as I plan to take my F.E.
23. Gave me some things to research.
24. Not for the first one. We ran out of time. Research he companies beforehand.
25. Yes. Put GPA on resume no matter what it is.
26. To keep resume updated.
27. Got a few tips on what to do better. Research companies, dress appropriately, turn off cell phone.

Question 4. How was your overall experience with the event? Comments/Suggestions?

1. Great experience.
2. Very good. Will help in the future.
3. Interesting
4. Very informative
5. It was a very worthwhile experience.
6. Good connection. Our conversations went smoothly. Maybe give time count downs.
7. I had a great experience. No.
8. I think it is very helpful in knowing what to expect for and interview.
9. Positive and worthwhile
10. Ok, I would have the interviews separated by type of business, so if you're looking to go make the management route you can talk to construction managers.
11. Very insightful
12. Was good. Really nice change to network.
13. Eye opening
14. Good, got lucky to pick a bridge engineer.
15. I liked it. I feel that it will greatly aid me during an actual interview and give me some good pointers and questions to expect.
16. Feedback on how to improve is very helpful. Bring more construction/contractor interviewers instead of mostly design.
17. It was really well. I was told I would be a contractor in the future. It went well; pinpoint the areas the company's do work in.
18. To maybe ask students who they would like to interview with ahead of time.
19. OK. Had interview with a company that does 90% bridges, but I want to work in the building construction industry/commercial. Let people say who they would like to interview with or you pick based on field they want to enter.
20. (A-) More time interviewing would be nice but I understand that is challenging to plan
21. Had fun the guys I interviewed with were very nice and helpful.
22. Good.
23. It was a great event. Good way to network and learn how to better yourself in the interviewing process.

INTERVIEWER'S FEEDBACK

Question 1. What was your overall experience with the students and the Mock Interview Event?

1. Excellent. Most of the students I met understood who they were meeting and they wanted to pursue a career in our market place.
2. Good experience-students not nervous.
3. Good.
4. It was excellent. I really enjoyed meeting all of the students and helping them in their interviewing skills.
5. Very professional in manners and appearance. Very well prepared for event.
6. Very good, some of the lower student will get better as they progress through the years.
7. Mock interview is a great idea. Resumes were generally well prepared.
8. Interesting. Enjoyed talking with them.
9. Good. Students seemed well prepared and comfortable.
10. Excellent Interacting with students.

Question 2. What type of comments, recommendations, and/or suggestions would you like to share to the students that you may think will help them have a successful interviewing process?

1. Be confident. Some display of nervousness which is natural. Demonstrate and communicate experiences
2. Make sure students have a positive way to respond for low GPA or questions that are negative.
3. Make sure to ask questions at the end.
4. Be prepared to give detailed answers and don't be reluctant to reveal your true personality. Do some research on the company and discuss your interest.
5. Maintain their current confidence and good attitude. Be prepared! Research Company beforehand.
6. How to present self to the interviewer. Know something about the company that you are interviewing with. Research.
7. Their answers were forth-right and honest. Some were too honest. Don't be afraid to ask some questions.
8. Relax, have questions ready to ask interviewer.

9. Be comfortable and confident. Selling yourself and having an interviewer like you, both professionally and personally, is key to being hired.
10. Expect unusual questions, as well as the "popular" interview questions. Calmly think of an answer and deliver it without getting distracted/lack confidence.

Question 3. Do you have any suggestions and/or recommendations for future Mock Interview events?

1. If possible, quieter room and perhaps a slightly longer duration than 20 minutes.
2. Maybe seek input/volunteers sooner. My company not really looking so it changed the dynamic.
3. Would like to know who specifically we will be interviewing so that we can more consistently prepare questions for four students rather than read over 20+/- resumes.
4. Allow time to complete the evaluation form after each interview, five minutes would suffice.
5. Give interviewers a break between interviews to fill out the review forms and develop feedback. Have an open discussion at end for interviewers to provide general feedback and observations to whole group of students.
6. N/A
7. Pre-social was a bit of a challenge. Most interviews are "COLD," Could run through more students. 20 minutes was good. I was not aware I needed to give the stunts their review paper.
8. Give two or three minutes after each interview to fill out the interview form.
9. N/A
10. N/A

DEVELOPMENT OF AN IPHONE APPLICATION AND A STUDY OF ITS DESIGN ISSUES

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Abstract

Mobile applications is a fast-growing research area and provides new research opportunities for students in areas of computer science, networking technology and information technology. This paper discusses the development of an Apple iPhone application, which provides an interactive campus map for new students or visitors trying to navigate the campus; or, for existing students, faculty and staff to help them find a building in an obscure corner of the campus which they may never have visited. This work is a faculty-student research project funded by the university. The project successfully promoted student engagement in hands-on research, a High-Impact Practice identified by the American Association of Colleges and Universities. In addition, the project explored some characteristics of Apple-based application design issues. The success of the project also provided a framework for faculty and students to develop similar projects, with components usually available on campus.

Introduction

The mobile phone industry has exploded over the last five years. One estimate is that there are more mobile phones in the U.S. than people [1]. A research project involving faculty and students will help faculty explore new research ideas, and students gain real-world experience and cutting-edge technologies. This project required project formulation, platform and development tools selection, application design, application development and debugging, documentation and presentation. Additionally, various design and development issues were studied. In the future, similar projects could include all of the above or a subset if the same platform and development tools are used.

There are currently only a few mobile phone applications specifically targeted at faculty, staff and student functions and capabilities on each individual campus due to limited user pools, which leaves a large number of hands-on research opportunities for students, as they are familiar with their own daily life and needs. The ability of students to access much of the content and capability of a university website—such as the interactive campus map, faculty and staff directory, online instruction and many other functions from mobile devices—is a significant strategic direction that must be pursued.

The intent of the application developed in this project was to provide a mobile analog to the interactive campus map that utilizes built-in mobile device capabilities for mapping and self-location to guide people to buildings on campus. This application will simplify navigation of the campus and assist people in finding obscure buildings, which they may not have visited previously. The existing physical signage will not help students or visitors locate and navigate to a building that is on the opposite side of the campus from their current location, nor does it provide any indication as to how close the person is to their destination. This application provides both of those capabilities.

Platform

This project targeted the Apple iPhone. While Android-based phones have surpassed iPhones in terms of total market share [2], Android devices are notorious for manufacturer-specific implementations of the Android OS along with differences in application development. The Android phone marketplace is divided among several major manufacturers including HTC, Samsung and even Google with their acquisition of Motorola. The iPhone market is monolithic, meaning that all iPhones are essentially the same. Almost all iPhones run the same version of the iPhone OS (iOS). All iPhone apps are distributed through a tightly controlled Apple App Store. There are currently more than 425,000 applications in the iPhone App Store with over 15 billion downloads [3].

The development tools for Apple iPhone are:

- Apple Xcode - an Object-Oriented superset of C++ which includes methods for invoking iPhone and iOS internal functionality
- HTML/CSS/JavaScript - standard web application development tools that do not have the capability to easily integrate with iPhone/iOS capabilities
- Independent third-party development environments such as MonoTouch [4]. These environments generally contain the same capabilities as Apple Xcode.

This project utilized Apple Xcode for development of the proposed application. This decision was motivated primarily by the cost of third-party tools at the time the application was written. Xcode includes a mature Integrated Developer Environment (IDE) and, when combined with the iPhone Software Development Kit (SDK), provides native access to iPhone capabilities including mapping, data management, screen management and application management. Third-party applications are fairly expensive. MonoTouch retails for $399 and has no advertised educational or student discount.

Design

The project utilized iPhone/iOS MapKit services to determine the user's current location. MapKit services display a satellite or birds-eye view map of the campus, centered on the user's location. A selector, not yet determined, will be used to select the building to be located. A database of buildings and their spatial locations will be used to place a marker on the map to indicate the location of the chosen building. The marker will be interactive, enabling display of basic information about the building.

The interactive nature of MapKit services enables the map to be updated in real-time as the user navigates the campus in order to ensure that he/she is proceeding in the correct direction. Opening another application on the phone will terminate the mapping application and reduce battery drain caused by the use of the internal GPS required for MapKit services.

iPhone applications constructed using the Xcode IDE and the iPhone SDK utilize Objective C, a proprietary extension of C++, and a Model-View-Controller (MVC) software pattern. The basic design of the application is represented in the diagram of Figure 1.

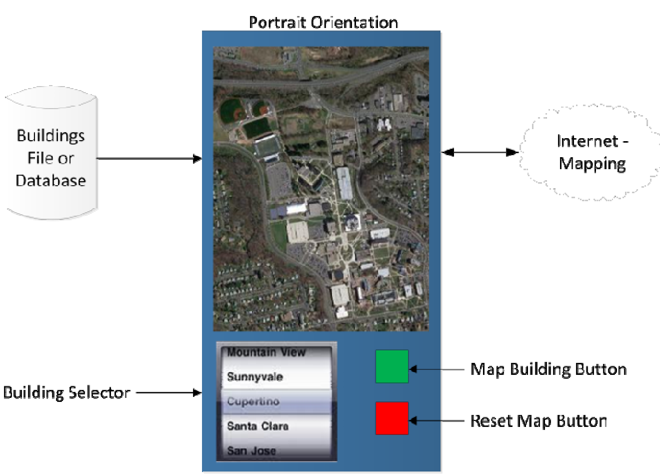

Figure 1. Design Diagram

The application was designed to suppress the selector and buttons when the phone is rotated to Landscape mode in order to increase the size of the map providing more detail, as shown in Figure 2. The application was developed on a Mac and tested via a direct download of the application to the iPhone via a USB connection.

Figure 2. Landscape Mode of the Design

After completing this design, some choices were made based on the results of prototyping and lessons learned about the intricacies of the iPhone SDK:

- The application was designed using the Storyboard visual design interface of Xcode. This limits the application to iOS Version 5 or greater. This decision was supported by statistics showing that as of November, 2011, 60% of all iPhones were using Version 5 or greater. This will only increase over the short-term since all new iPhones are sold with the latest version of iOS (5.0.1 or greater).
- The User Interface utilizes two screens rather than one with a "fly-over" modal pop-up. This change was required due to the limitations of the iOS SDK for iPhone in which all Views display by default in full-screen mode.
- A Property List (Plist) was chosen as the data store for the building data. This choice was made over other data storage options. The text/CSV file option requires significantly more coding to load the data and instantiate the data source for the selector (Picker). SQLLite supported by iOS has no capability for batch loading of data and would have required the creation of an application just to provide a data entry function to build the SQLLite database. iOS also supports a built-in framework called Core Data. This

framework is essentially a wrapper around SQLLite that exposes the back-end database as a set of classes with appropriate methods and properties. Core Data handles persistence, transactions and advanced error handling. Core Data also has no methods for importing data to initialize the database so a secondary data management application would have had to be designed and written.

- The map was designed to support selection of only one building at a time and zooms to include a minimum amount of geography in order to display the user's position and the selected building. If the user is not located on the campus, a notification is displayed and the auto-zoom feature is disabled. The minimum geography displayed in these conditions is the entire campus. The map can be manually zoomed via gestures on the iPhone screen.

Architecture

Application Lifecycle

iPhone applications are governed by the Model-View-Controller architecture, as noted above. These applications are also event-based applications. The application lifecycle is shown in Figure 3 [5].

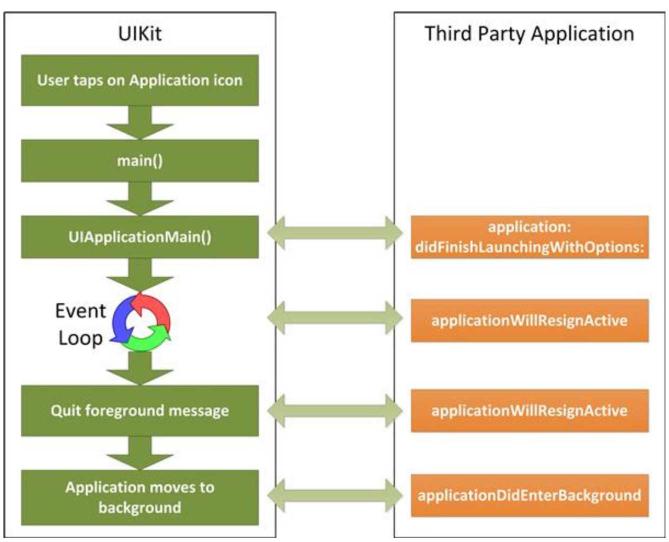

Figure 3. Typical Application Life Circle

iOS detects the user tapping the application icon. The application is loaded ("main()") and initialized. This fires the "didFinishLaunchingWithOptions" method in the Application Delegate where the developer can implement application-specific initialization code. The Interactive Map application uses this method to instantiate and initialize application-scope variables such as the Building List. Once fully initialized, including the user code in the "didFinishLaunchingWithOptions" method, the application waits for event messages ("HandleEvent").

The application is responsible for establishing the appropriate functions to handle event messages, not limited to application events, but also external events such as device rotation, pressing the "Home" button or other events. Event handling is the primary responsibility of the current View and the controls within that View. Views are managed via a Stack. An event that causes a new View to assume control of the Window pushes the current View down on the Stack and places the new View at the top of the Stack. An event replacing the new View with another new View repeats this process. An event returning to a previous View pops the current View off the Stack making the previous View current again. All of the View management methods are invoked for each of these operations, i.e. "viewDidBecomeActive" for a new View and "viewWillDisappear" for a View being replaced.

The user pressing the Home button or any other action, whether user-initiated or system-initiated (e.g., an incoming phone call), that causes the application to give up its ownership of foreground processing fires the "applicationWillResignActive" and "applicationDidEnterBackground" methods in the Application Delegate. These methods enable the programmer to take actions that would be appropriate to support or deny background processing for the application. Theoretically, the "applicationWillResignActive" method could be used to terminate the application if background multi-tasking processing is not desired. This is not necessary in version 5 of iOS or later. A configuration option in the "info.plist" file for the application, "UIApplicationExitsOnSuspend", can be specified that tells iOS the application is to be terminated completely if it is removed from foreground processing. The Interactive Map application was configured to terminate if it resigns control of foreground execution. This results in significant power savings since Location Services updates are no longer in effect and the GPS is turned off.

First Responder and Delegation

The basic structure of the iOS application utilizes two concepts known as "First Responder" and "delegation" to provide the functions to process event messages as well as to extend the iOS object model. The First Responder is the module that loaded the currently active view. The First Responder is the default handler for all event messages that occur while the view is instantiated.

The Delegate is a construct that is used in place of subclassing and inheritance in order to enable extending the methods available to an object. A Delegate implements a Protocol which defines the requirements to communicate with the Delegate. This includes any methods supported to handle event messages. The basic Delegate implemented in all applications is the Application Delegate or App Delegate. The App Delegate handles all events at the application level and can also be used to instantiate and initialize application-level data elements and structures. Delegates are also implemented in iOS for View Controllers and Navigation Controllers, two constructs used in this application. The full protocol for each Delegate is documented in the iOS Developer Center at Apple.com. [6]

Persisting Data

The arguments over methods for persisting data within the application for use by multiple Views and Delegates within the application resemble the religious war between Microsoft and Apple fanatics. There are three basic techniques for persisting data:

- Global Variables
- App Delegate Variables and Objects
- Singleton Classes

Simple applications might use a Global Variable defined in the project.pch file. This practice is generally frowned upon for more than single-view prototype or demonstration applications, since it is not thread-safe nor does it ascribe to the ARC memory management model. Many Developers recommend the use of objects and variables defined in the App Delegate. There is only one App Delegate, its scope is application-wide and it invokes the Singleton pattern making it thread-safe. Some argue that the App Delegate should be left to the responsibilities defined for that delegate protocol, handling initialization, termination, memory errors, etc. It is important to note also that since the App Delegate is the first user code executed, placing a large amount of variable initialization in the App Delegate slows down application startup and affects user experience.

The use of a Singleton class specifically designed to define and manage variables as objects within the Singleton with appropriate getters and setters is widely discussed and has its own support base. The Singleton model can be made thread-safe but is not so by default. Care must be taken to ensure thread-safety in the coding of the Singleton class definition. Also, the use of a Singleton class requires more coding for simple variables than just the definition of the variable. Since these variables are properties of the Singleton class, it is necessary to create the appropriate getters and setters. The Xcode @synthesize command can be used when the Singleton is instantiated in a module to automatically generate primitive getters and setters for basic variables, but more complex objects such as arrays, dictionaries and other classes must be fully coded in the Singleton class definition.

This application used the App Delegate model for global data. There were only a couple of variables to be initialized to default values, and the array of building dictionaries which was loaded directly from the Buildings.plist file. This did not materially affect application initialization performance. The majority of the application initialization is involved in determining the user's location and initializing the map, activities which take place in the first View loaded, not the App Delegate.

Structure and Function

The application was developed using Xcode 4.3 and the current iOS SDK. The Storyboard shown in Figure 4 depicts the basic structure of the application.

Figure 4. Storyboard

This Storyboard shows two View Controllers embedded in a Navigation View Controller. The Navigation View Controller automatically provides the forward (Buildings) and back (Map) buttons and the transition between the two Views. The connection between the two View Controllers is called a "segue" and enables properties and methods that can be used to control the transition. Much of the definition of the View Controllers, the Navigation View Controller and the segue are defined in properties in the Xcode IDE, eliminating dozens of lines of code required in previous versions of the SDK and down-level applications that support iOS versions prior to Version 5.

The primary View Controller is the Mapview. This is the first View displayed when opening the application. A screen-capture JPG file is displayed until the application is fully initialized. Once the application is initialized, a real-time map of the campus is displayed. If the user's location is within the bounds of the campus map, the location is displayed on the map. If the user is not located on the campus, an alert message is displayed and the auto-zoom functionality of the application is disabled.

Once the map is displayed, the user can then select a building by pressing the Buildings button. This transitions to the Dataview View Controller using the segue displayed on the Storyboard, the arrow connecting the Mapview and the Dataview. This segue is defined as a modal push segue, which means the new View is in control of the screen and cannot be dismissed by other than the appropriate button (modal); at this point, the new View is pushed onto a stack of views maintained by the OS. Returning to the original View is accomplished by popping the current View off the view stack and displaying the new "current" View.

Once on the Select Building screen, the user spins the selection control, a UIPickerView in iOS terminology, to select the desired building. The selected building is displayed in a text field below the Picker. Once the desired building is selected, the user returns to the map via the Map button on the Select Building screen. This pops the View from the stack and causes the original Mapview to be displayed.

Upon return to the Mapview, the application checks to see if a building was selected. An alert is displayed if no building was selected. If a building is found, the appropriate positional data is retrieved from the array of buildings and a pin is dropped onto the map. If the user's current location is on the campus, the auto-zoom code in the application determines a new set of bounds based on a rectangle constructed using the user's location and the building's location, then zooms the map to that rectangle. This provides greater detail for user navigation from their position to the building. The map is fully capable for panning and zooming and, while in motion, the user's location is updated every 45 seconds. This enables the user to track their progress towards the intended building in real-time, limited by the accuracy of the current user location.

A screenshot of the implemented application is shown in Figure 5, where the user's position is represented by the blue dot and the selected building is represented by the red pin. The blue circle surrounding the dot shows the relative accuracy estimate. For more information on the accuracy of iPhone locations, see the study by Zandbergen [7].

Data Gathering

The application requires the following properties for each Building: Building Name, Latitude and Longitude. The data are gathered using a HyperText Application (HTA), essentially an HTML page that runs locally on the user's desktop. This HTA displays a Google map of the campus and a drop-down of the buildings. The process is to select a building from the drop-down, locate the building on the map and click on it with the mouse. This would generate an entry in a textbox containing the three building properties. The latitude and longitude are retrieved from Google via map interaction implemented in Javascript. The building data is copied from the textbox, saved as a text file, imported into an Excel spreadsheet and used to generate the XML for the Buildings.Plist file.

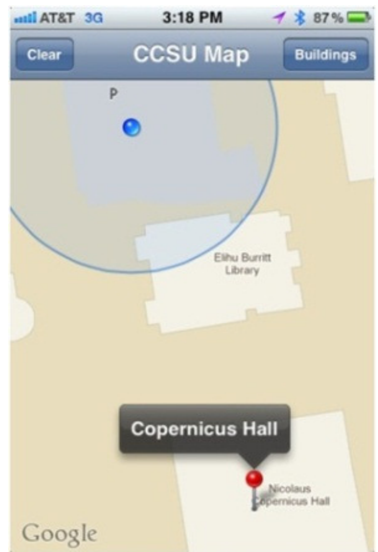

Figure 5. Screenshot of the Application

More Design Issues

Application design patterns that apply to most application platforms do not necessarily apply to Apple-based platforms. Any attempt to defend a design choice by Apple-only developers—based on previous experience or academic knowledge of what are considered standard design patterns—results in an avalanche of negative comments and little help from the Apple community. Their mantra is to "forget your tired old techniques and embrace the platform as Apple wrote it".

One example of this was a request to the developer community for assistance in locating the event which would trap the Back (Map) button in the Navigation Controller Delegate to enable enforcement of a business rule that a building must be selected before returning to the map. The concept that the Back button would be intercepted and not allowed to perform its designed function was met with a number of criticisms of the overall design.

Ultimately, one experienced developer did intervene in the piling on of abuse and pointed out that Delegate and Protocol appeared to meet our needs. However, a small caveat at the bottom of the Delegate definition negated the entire ability of the Delegate to trap the Back-button event. There is a way to programmatically replace the Back button with an application-generated button and trap that button's click event, but this was discovered much too late in the development process and would have required a complete redesign of the application. One of the more experienced developers submitted a feature request to Apple to enable the Navigation Delegate protocol to support an event for the Back button in order to enable enforcement of business rules prior to honoring the request to navigate back to the previous screen.

Other issues arise in using the Apple-specific development tools (i.e., Xcode) for iPhone/iPad development. Each new release of iOS requires a new version of Xcode. One cannot upgrade iOS on the target device without installing the latest version of Xcode and vice-versa. New or changed APIs in each release of iOS are then immediately applicable to the application. One example of the impact of how this affects application development is the use of iPhone Maps in the application. The original application was written based on the iPhone Maps provided by Google Maps. The release of iOS 6 replaces the underlying Google Maps with an Apple-internal map function. This could result in changes to the Map Service APIs, and empirical evidence demonstrates significant degradation of map quality with the initial release of iOS 6 Apple Maps. This could directly affect the application developed in this project. No other specific methods used in this current project have changed in iOS 6 in any way that would affect the functionality of the program.

Many companies are taking an approach that uses hybrid technologies such as Mono, described earlier in this paper, to attempt to mitigate the impact of iOS changes by replacing native Apple applications with hybrid HTML5/Javascript/Web Service applications using Javascript libraries that can access the device's internal functions (e.g., dialing, GPS, etc.) but selectively choose alternative technologies (e.g., Google Maps) where appropriate. This breaks down Apple's "walled garden" to a certain extent, offering the developer more flexibility in application development, and the end-user more stability with respect to iOS changes. Were these technologies more mature, and available at reasonable or no cost for educational purposes, at the time this project was undertaken this approach probably would have been chosen rather than Apple's native development environment. This would have enabled the use of iOS Location Services to determine the user's location, rather than web-service-based calls to Google Maps to provide the mapping services independent of iOS. This would have insulated the application from the iOS Map changes.

Conclusions

This project provided an opportunity for faculty and two graduate students to develop a mobile application and investigate the possibility of creating a framework for more similar projects. The application developed provides a useful tool for students and visitors to find buildings on campus, regardless of the user's location or the building's location. It also provides a handy reference to the campus when the user is not on the premises as it will still allow selection and location of buildings and the map may be manually zoomed using standard iPhone gestures to show additional map detail. The project, if published via the Apple App Store and updated regularly with new building data, could be a valuable tool for students and visitors to the campus.

In addition to the interactive map application developed here, more achievements have been obtained from this project:

- This project successfully solicited a faculty-student research fund from the university, which provided a Mac computer to partially support the application development.
- Two graduate students got involved in this project and fulfilled their capstone project requirements.
- In addition to successfully developing a mobile application, the more valuable achievement was several design and development issues were discovered and studied during the course of the project. Students would not be able to get such experience and knowledge without this project.

The success of this project demonstrates the feasibility of a framework of student hands-on research projects on mobile application development. 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 – An Apple Mac computer (Mac Pro, MacBook Pro, Mac mini, etc.) is required for programming and an iPhone for testing.
- Development tools - Apple Xcode is 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.

- Curriculum – Before starting the research work, students should be knowledgeable on areas including collaborative project development, information systems in business, research skills, Internet technology, foundations in computer science for arrays and dictionary used to store the building data and stacks used in view management, and software engineering for the design and development processes.
- Collaboration - To target a real-life application, it is critical for the team to work with users in various departments or student groups on campus or local business. One advantage is that the students know themselves very well. Another one is that mobile applications is a new and fast-growing market. Therefore, such applications are in great need. Students can easily find users and develop a mobile app for free or at very low cost.

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