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The TECHNOLOGY INTERFACE INTERNATIONAL JOURNAL (TIIJ) is an independent, not-for-profit publication, which aims to provide the engineering technology community with a resource and forum for scholarly expression and reflection.

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

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THE TECHNOLOGY INTERFACE INTERNATIONAL JOURNAL EDITORS

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EDITOR'S NOTE: REFLECTIONS ON IAJC AND THE 2011 JOINT INTERNATIONAL CONFERENCE WITH ASEE

Philip Weinsier, TIIJ Editor-in-Chief

As we in higher education and industry reflect back on the first decade in this new millennium, we realize that the sharing of ideas and resources is the best way for us to create a better future for the next generation of students, faculty, and researchers. In the competitive and tight global markets of the 21st century, leading companies across industry have embarked on massive reorganizations, mergers, partnerships, and all sorts of collaborative projects with their like-minded peers and rivals in order to not only survive but grow and thrive. But, as industry changes with time, so must academia. Conversely, as academic R&D efforts provide advancements in technology, so must industry provide a quick turnaround from concept to market. However, many academic organizations, journals, and conferences have been slow to adapt and provide the necessary platforms for the dissemination of knowledge.

Beginning in 2006, the editorial board of the International Association of Journals and Conferences (IAJC) embarked on groundbreaking and unprecedented efforts to establish strategic partnerships with other major rival journals and organizations to share resources and offer authors a unique opportunity to come to one conference and publish their papers in a broad selection of journals representing interests as diverse as those of the researchers and educators in fields related to engineering, engineering technology, industrial technology, mathematics, science and teaching. These efforts resulted in an innovative model of joint international conferences that includes a variety of organizations and journals.

IAJC joint and independent international conferences have been a great success with the main conferences being held in the United States and regional, simultaneous conferences, in other parts of the world. In additional to bringing people together at its conference venues, IAJC attracts myriad journals that wish to publish the best of what its attendees have to offer, thereby creating excitement in academic communities around the world. IAJC is a first-of-its-kind, pioneering organization. It is a prestigious global, multilayered umbrella consortium of academic journals, conferences, organizations and individuals committed to advancing excellence in all aspects of technology-related education.

Conference Statistics: A total of 285 abstracts from more than 100 educational institutions and companies were submitted from around the world. In the multi-level review process, papers are subjected to blind reviews by three or more highly qualified reviewers. For this conference, a total of 80 papers were accepted. Most of these were presented and are published in the conference proceedings. This reflects an acceptance rate of less than 30%, which is one of the lowest acceptance rates of any international conference.

This conference was sponsored by the International Association of Journals and Conferences (IAJC), which includes 13 member journals and a number of universities and organizations. Other sponsors were the American Society for Engineering Education (ASEE) and the Institute of Electrical and Electronics Engineers (IEEE). Selected papers from this conference will be published in one of the 13 IAJC member journals. Organizing such broad conferences is a monumental task and could not be accomplished without the help and support of the conference committee, the division/session chairs and the reviewers. Thus, we offer our sincerest thanks to all for their hard work and dedication in the development of the outstanding 2011 conference program. We personally hope you will seek them out to thank them for their fine work.

Editorial Review Board Members

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

As we continually strive to improve upon our conferences, we are seeking dedicated individuals to join us on the planning committee for the next conference—scheduled for fall, 2012. Please watch for updates on our web site (**www.IAJC.org**) and contact us anytime with comments, concerns or suggestions. On behalf of the 2011 IAJC-ASEE conference committee and IAJC Board of Directors, we thank all of you who participated in this great conference and hope you will consider submitting papers in one or more areas of engineering and related technologies for future IAJC conferences.

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

THE ASCE STUDENT CONCRETE BEAM COMPETITION: A HOLISTIC LEARNING EXPERIENCE

Nirmal K. Das, Georgia Southern University; David C. Griggs, Plant Vogle; Mackenzie T. Rowland, Georgia Southern University; Donald F. Singer, Georgia Southern University; Junan Shen, Georgia Southern University

Abstract

In spring 2010, a new event called Concrete Beam Competition was included in the American Society of Civil Engineers (ASCE) Southeast Regional Student Conference held at Auburn University, Alabama. About 18 schools participated in the event. The competition's purpose is to design a 5"wx6"hx20"l beam having a hollow center large enough for a ping-pong ball to pass through, with the highest flexural strength and the lowest weight. This interesting and challenging event provided a unique learning experience for the civil engineering and civil engineering technology majors, as it encompasses several important aspects of civil engineering—mechanics of materials, reinforced concrete design and sustainability—so that students can clearly see actual applications of the theories they learn in different courses.

Introduction

In the spring of 2010, a new event called Concrete Beam Competition was included in the American Society of Civil Engineers (ASCE) Southeast Regional Student Conference held at Auburn University, Alabama. About 18 schools participated in the event. As the name indicates, this competition is about testing concrete beams, but these are not typical beams. The most significant difference lies in the restriction imposed that no reinforcement can be used in the beam. In addition, the beam must be hollow. Also, other restrictions apply with respect to the aggregates that can be used. With all these stipulations to be adhered to, the challenging goal is to design a beam of given dimensions made of certain types of ingredients (with limits on quantities for some), and with no reinforcement, to resist the largest transverse load.

This interesting and challenging event provided a unique learning experience for the civil engineering and civil engineering technology majors, as it encompasses several important aspects of civil engineering – structural mechanics, properties and behavior of Portland cement concrete, and sustainability so that students can clearly see actual applications of the theories they learn in different courses.

The paper describes the following:

- Competition details
- Learning aspects, and
- Georgia Southern University team experience

Competition Details

This competition [1] incorporates principles of both concrete proportioning and structural engineering. It requires problem-solving and reasoning skills in order to optimize the design and construction of an unreinforced concrete beam with special dimensional and material constraints. Up to 30 points are awarded to each team based on (1) sustainability, (2) weight, and (3) flexural strength of its submitted beam. The weight and flexural strength reflect structural efficiency. The flexural strength is determined using a modified version of a standard flexural test. Sustainability, an increasingly common requirement in concrete mixture design, is evaluated based on the concrete's constituent materials and their proportions.

Required Dimensions and Features

The external dimensions for the beam shall be 5"wx6"hx20"l with a tolerance of ± ¼ inches on each of these dimensions. The outer 6" x 5" surfaces are referred to hereafter as the ends of the beam.

The beam shall have one hole along which a 40-mm-diameter ping pong ball can pass unobstructed from one beam end to the other. This hole shall have a centerline length of at least 19¾ inches and open only on the ends of the beam. All surfaces of the beam, including all hole surfaces, shall be free of any non-concrete debris at time of submittal. Failure to satisfy these dimensional requirements will result in disqualification from the competition.

Concrete Raw Material Requirements

Only materials listed below conforming to the corresponding ASTM specifications are allowed to be used in the concrete of the submitted beam:

Portland cement (ASTM C 150)
Fly ash (ASTM C 618)
Slag cement (ASTM C 989)
Chemical admixtures (ASTM C 494 or ASTM C 260)
Coarse aggregate - No. 67 or No. 57 gradation (ASTM C 33) [A minimum of 30% coarse aggregate by volume of concrete is permitted]
Fine aggregate (ASTM C 33)

Any source of potable water is allowed. No fibers, coatings, or any forms of reinforcement are permitted.

Sustainability

Teams are awarded points based on the overall sustainability of their concrete mixture. Up to 10 points are awarded for this category.

Fly Ash Use (percent by weight of total cementitious material):

$15\% \leq$ Fly ash content $< 30\% = 2$ points
$30\% \leq$ Fly ash content $< 50\% = 3$ points
Fly ash content $\geq 50\% = 4$ points

Slag Cement Use (percent by weight of total cementitious material):

$20\% \leq$ Slag cement content $< 40\% = 2$ points
$40\% \leq$ Slag cement content $< 60\% = 3$ points
Slag cement content $\geq 60\% = 4$ points

Portland Cement Use:

Portland cement content < 188 pcy $= 4$ points
188 pcy $\leq$ Portland cement content < 282 pcy $= 3$ points
282 pcy $\leq$ Portland cement content ≤ 376 pcy $= 2$ points

Recycled Aggregate Use (percent by volume of total aggregate content):
To qualify as recycled aggregate for the purpose of this competition, aggregate shall be produced from construction or demolition *waste* of a real-world facility. Recycled aggregate may not be manufactured by competitors by making concrete for the specific use of recycling it for this competition.

$25\% \leq$ Recycled aggregate content $< 50\% = 2$ points
Recycled aggregate content $\geq 50\% = 4$ points

Beam Weight

Teams are awarded points based on the overall weight of their beam. Up to 10 points are awarded for this category. Each beam's weight is determined using a scale with accuracy to 0.1 lb. The team with the lowest beam weight is awarded 10 points. The team with the highest beam weight is awarded 1 point. All other points are determined using Equation (1) and rounded to the nearest tenth of a point.

$$Team's\ points = 10 - 9\frac{(W - L)}{(H - L)} \quad (1)$$

where W = team's beam weight, L = lowest weight and H = highest weight.

Beam Flexural Strength

The beam flexural strength is determined in accordance with ASTM C78 [2] specification. The test setup is shown in Figure 1. Load is applied perpendicularly to the length of the beam at a rate between 1,500 and 2,100 pounds per minute until failure occurs. The load that causes flexural failure of the beam is recorded to the nearest pound.

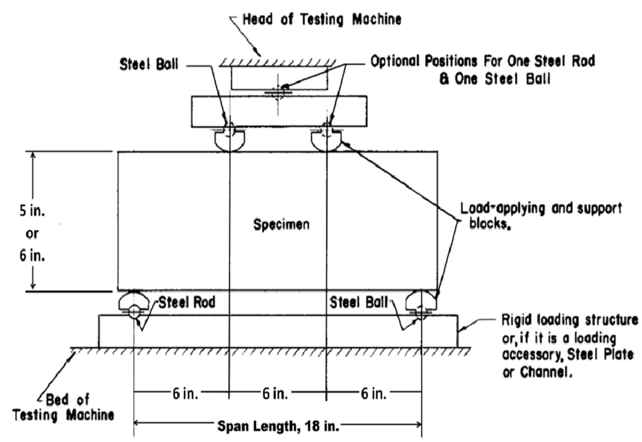

Figure 1. Flexural Strength Test Setup (adapted from ASTM C 78 2008)

In this category, a team can achieve a maximum of 10 points. The team with the highest beam failure load is awarded 10 points. The team with the lowest beam failure load (of all beams tested) is awarded 1 point. All other strength points are determined using Equations (2) and (3) and are rounded to the nearest tenth of a point.

$$x = \frac{P - P_{min}}{P_{max} - P_{min}} \quad (2)$$

where P = team's beam failure load, P_{min} = lowest load, and P_{max} = highest load

$$Team's\ points = 6.9x^2 + 2.1x + 1.0 \quad (3)$$

Sustainability, strength, and weight of each beam are considered. Points are awarded in these categories as specified in previous sections. The points awarded in these categories are summed to obtain each team's total points for this competition. The team with the most total points wins this competition.

Learning Aspects

The important lessons to be learned from this competition event are related to (a) behavior of unreinforced concrete beams under transverse load and the effects of mix proportions on the beam's behavior, and (b) the mechanics of materials concept related to flexure, e.g., effects of neutral axis location and moment of inertia on flexural stresses. As the concrete beam is unreinforced, it will fail in a brittle manner, as soon as the maximum moment reaches the beam's cracking moment (M_{cr}) obtained from Equation (4), which is Equation (9-9) of ACI 318 [3]
where

$$M_{cr} = \frac{f_r I_g}{y_t} \quad (4)$$

- f_r = modulus of rupture of concrete (i.e. tensile strength of concrete in flexure)
- I_g = gross moment of inertia of the beam cross-section, and
- y_t = distance from the neutral axis to the extreme tension fiber of the beam cross-section

The modulus of rupture (f_r) of normal-weight concrete is given by Equation (5) which is Equation (9-10) of ACI 318 Building Code [3]

$$f_r = 7.5\sqrt{f_c'} \quad (5)$$

where f_c' = 28-day compressive strength of concrete.

For light-weight concrete, the modulus of rupture value needs to be modified using a multiplier. Several different concrete mix-proportions need to be tried to obtain an optimum value of concrete compressive strength, hence an optimum value of the modulus of rupture.

It is common knowledge that concrete is very strong in compression, but quite weak in tension. An unreinforced concrete beam will behave elastically under applied transverse load, and will fail in a brittle manner once the load becomes large enough to cause the maximum tensile stress to reach the modulus of rupture value. So, the maximum tensile stress due to flexure must be kept low, which means the y_t value must be minimized, while maximizing the gross moment of inertia, I_g. In order to minimize the y_t value, the centroid (through which the neutral axis passes) of the beam cross-section needs to be positioned as low as possible – this necessitates that the hole in the beam has to be placed not at the center of the cross-section but instead somewhat higher. Also, the use of recycled aggregates and fly ash in making concrete instills an awareness of the importance of sustainability and environmentally friendly design and construction.

Georgia Southern University Team Experience

The Georgia Southern University team understood that the two main ways to reduce weight of the beam included increasing the size of the cross-sectional void and creating the lightest concrete mix.

The team experimented with several different mix designs to find the lightest one with the highest strength. Different gradations of aggregates as well as the w/c (water/cement) ratio were tried to find the best mix to meet the requirements. In order to do this correctly, they started with finding the gradation of the coarse and fine aggregates. Using this information, they then analyzed the different coarse aggregates to determine which should be used in the mix. They also experimented on the percent of additives to increase workability and strength. They made many samples per mix and tested each one at 7-day and 28-day strengths. They used two different shapes to test the strength—the beam for flexural strength and cylinders for compressive strength (see Figures 2 and 3).

Figure 2. Beam and Cylinder Specimens Being Cured at GSU

Figure 3. One of Several Hollow Beams Cast at GSU

In their final design, they implemented the use of recycled aggregates to address the sustainability part of the competition. The percentage of recycled aggregates used was 60% of the total aggregates distributed between fine and coarse aggregates. The final mix design was 1 part cement with 16.5% Fly Ash and 60% Slag, 1.41 parts coarse aggregate, 2.53 parts fine aggregate and .28 parts water. The team used 10.5 mL of Super Plasticizer and 118.25 mL accelerant.

The Georgia Southern team was one of 18 participants at this competition event (see Figure 4), and performed quite well in the competition. The load at which their beam failed was 9120 pounds, the second highest load in the competition (see Figure 5). The team won second place with a total score of 24.1 out of a maximum 30 points. The first-place winner scored 24.8 out of 30.

Summary

The Concrete Beam Competition at the 2010 ASCE Southeast Regional Student Conference is discussed in this paper. The competition's purpose is to design a 5"wx6"hx20"l beam having a hollow center large enough for a ping pong ball to pass through, with the highest flexural strength and the lowest weight. This interesting and challenging event provided a unique learning experience for the civil engineering and civil engineering technology majors, as it encompasses several important aspects of civil engineering—mechanics of materials, reinforced concrete design and sustainability—so that students can clearly see actual applications of the theories they learn in different courses.

Figure 4. GSU Beam Dimensions Being Checked at the Competition

Figure 5. Display of Failure Load (9,120 lb.) for GSU Team's Beam at the Competition

Acknowledgements

We gratefully acknowledge our students Dejari Banks, Carys Fincher, Derrell Johnson, Matthew Sands, and Nicholas Tovar, all Civil Engineering Technology majors at Georgia Southern University, for their contributions in fabrication and testing of beams, as well as participation at the competition.

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[3] ACI Committee 318, "Building Code Requirements for Structural Concrete (ACI 318-05) and Commentary (ACI 318 R-05)," American Concrete Institute, Farmington Hills, Michigan, 2005

Biographies

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MEASURING CLOCK SIGNAL JITTER

Chao Li, Florida A&M University; Antonio Soares, Florida A&M University

Abstract

In digital transmission systems, jitter is a very important but less well-known phenomenon. With the clock frequency in digital systems becoming higher and higher, the jitter impact is more and more severe. It is urgent to measure jitter accurately. This paper introduces the concept of jitter and the effect it has on digital systems. The corresponding international standard, from the International Telecommunication Union (ITU), on jitter is also introduced. A scheme will then be proposed to measure the jitter of a fixed-frequency (2.048 MHz) PLL clock signal. This scheme uses digital methods with DSP as the core. It also employs CPLD in its implementation. This method has the advantage of being simple, cost effective and, at the same time, easy to implement.

Introduction

In the past decade, jitter has become a very important parameter to describe the quality of clock-pulse signals. In digital systems, clock frequencies have become higher and higher. With this increase in clock frequency, tiny changes in rising or falling edges will have a bigger impact on system performance, such as the integrity of the data, setup and hold time of the data. The concept of jitter is described in the JEDEC Standard No.65 (EIA/JESD 65). It is described as “the shift of the controlled or affected edge in respect to its normal position”. IEEE and ITU have similar definitions for jitter: “The short-term variations of the significant instances of a digital signal from their ideal positions in time (where short-term implies these variations are of frequency greater than or equal to 10Hz)” [1]. This means that jitter is an unwanted phase modulation to the original digital signal. The frequency of the change of the phase is defined as “jitter frequency”, as shown in Figures 1 and 2.

When talking about jitter, one must consider a closely related concept, “wander”. The definition of wander is: “The long-term variations of the significant instances of a digital signal from their ideal position in time”, where long-term implies that these variations are of frequencies less than 10Hz [1]. In other words, wander is a very slow drift of the clock from its original value. Figure 3 shows the difference between jitter and wander in terms of frequency.

Jitter can be classified as “systematic jitter” or “random jitter”. Systematic jitter results from misaligned timing recovery circuits in signal regenerating devices or from intersymbol interference and amplitude-to-phase conversion caused by imperfect cable equalization. Systematic jitter depends on the system itself. Random jitter originates from internal or external interfering signals such as repeater noise, crosstalk or reflections. Random jitter is independent of the transmitted pattern [2].

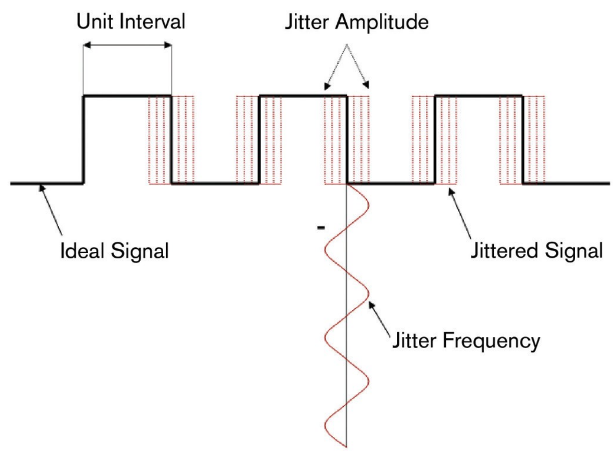

Figure 1. Illustration of Jitter and Jitter Frequency [3]

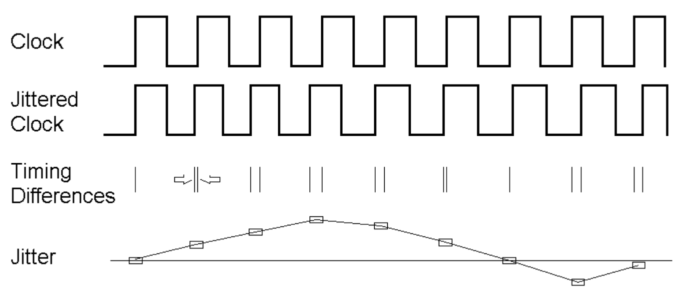

Figure 2. Another Illustration of Jitter

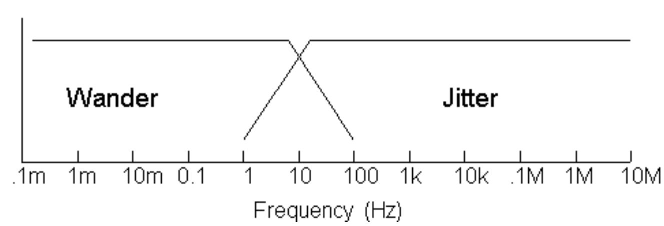

Figure 3. Jitter vs. Wander [3]

Jitter may deteriorate the transmission performance of a digital circuit. As a result of signal displacement from its ideal position in time, errors may be introduced into the digital bit stream at points of signal regenerations. Slips may be introduced into digital signals resulting from either data overflow or depletion in digital equipment incorporating buffer stores and phase comparators. In addition, phase modulation of the reconstructed samples in digital-to-analogue conversion devices may result in degradation of the decoded analogue signals. This is more likely to be a problem when transmitting encoded wide-band signal.

Measuring Jitter

To measure jitter, it is necessary to use jitter measuring devices. Jitter measuring devices are specialized telecommunication measuring devices. Examples of general measuring devices include voltmeters, power meters, spectrum analyzers and noise meters. The requirements for general measuring devices are frequency range, signal waveform, dynamic range, ease of use, etc. For jitter measuring devices, besides the above requirements, there are some special requirements. Because in telecommunication systems, different communication equipment supporting devices are inter-connected. Therefore, measuring devices have to meet a uniform standard. The International Telecommunication Union (ITU) has set a series of standards for communication measuring equipment manufacturers. As one of these telecommunication devices, jitter measuring devices have to comply with the international standards.

The international standards related to measuring jitter are ITU-T.O171 and ITU-T.O172. The former is used to measure the jitter in Plesiochronous Digital Hierarchy (PDH) digital systems. The latter is used to measure the jitter in Synchronized Digital Hierarchy (SDH) digital systems. Other related standards are ITU-T G.823, ITU-T G.824, which regulate the corresponding parameters and values in jitter measuring devices in 2048 kbit/s and 144 kbit/s PDH systems, respectively.

There are many different ways to measure jitter. An eye diagram provides the most fundamental, intuitive view of jitter. It is a composite view of all the bit periods of a captured waveform superimposed upon each other. In other words, the waveform trajectory from the start of period 2 to the start of period 3 is overlaid on the trajectory from the start of period 1 to the start of period 2, and so on, for all bit periods [4]. Shown in Figure 4 is an idealized eye diagram with very smooth and symmetrical transitions at the left and right crossing points. The eye shape will include systematic as well as random jitters. It also can display the time during which the signal can be considered effective. From this eye diagram, it is possible to judge how large the jitter is but not the quantitative parameters of jitter, such as jitter frequency and amplitude.

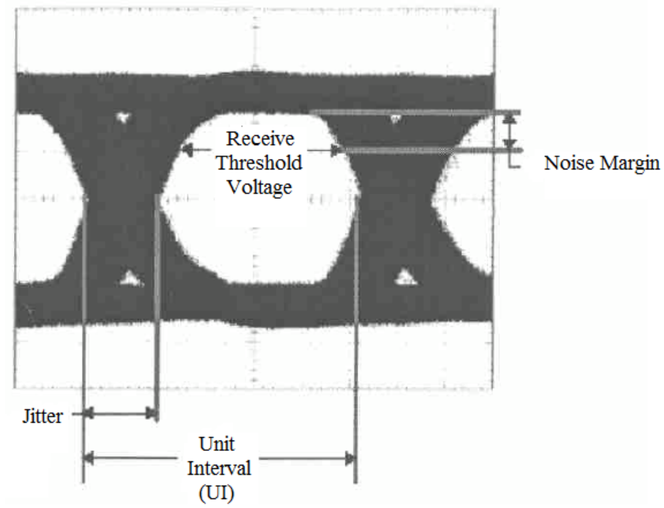

Figure 4. Eye Diagram

In industry, because of the rarity of jitter measuring devices, innovative measurement solutions using general measuring equipment, such as digitizing oscilloscopes, logic analyzers, real-time spectrum analyzers, time-domain reflectometers, signal generators, high-fidelity probes and analysis software, have emerged to help deal with jitter measurement. High-speed, real-time digital storage oscilloscopes (DSOs) are the most versatile, flexible and commonly used instruments for jitter analysis [5]. On the Tektronix website, the following Q&A shows how to use Tektronix waveform monitors to measure jitter: [6]

Q. How do Tektronix waveform monitors measure jitter and why does it disagree with an oscilloscope?

A. The WFM700, WFM7000 and WVR7000 series instruments measure jitter using a phase demodulation method whereby the clock is extracted from the SDI deserializer and is compared against an internally generated stable clock signal. A peak detector is then used to measure the actual jitter value.

Most oscilloscopes use a method where the serial signal is sampled and measurements of jitter are made directly from that samples eye pattern. These two approaches can sometimes result in slightly different jitter measurements however the SMPTE standards for measuring jitter in SDI signals specify the use of the phase demodulation method described above and implemented in our waveform monitors. (See Figure 5)

Although these aforementioned methods can measure jitter, the problem with these methods is their high cost.

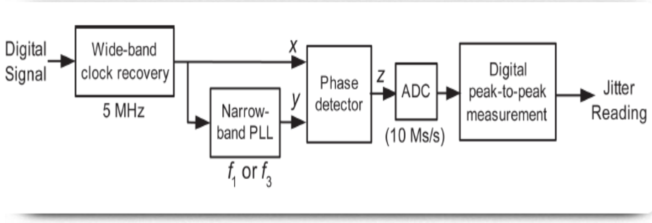

Figure 5. Block Diagram for Measuring Jitter [7]

Most of them use expensive, general-purpose high-resolution measurement devices. In this paper, the authors propose a simple and cost-effective method to measure jitter. The main goal of this digital method is to get the exact time for each period of the clock signal. Then, digital-processing methods can be used to extract information such as jitter amplitude and jitter frequency from these data.

DSP-based Jitter Measuring Scheme

The rest of this paper will deal with a digital jitter measuring method using a Digital Signal Processor (DSP). The measured PLL clock signal was 2.048 MHz. Figure 6 is the block diagram of the design. The main design concept was to get an accurate time in each period and then, using digital signal processing methods, process the data. In order to get the exact time, a 100 MHz clock was used as a counter clock signal in each period. But using a 100 MHz clock signal, it was only possible to get a time resolution of 10 ns. In order to improve the time resolution and, thus, to improve the measurement of jitter, the error pulses generated by the 100 MHz clock signal and the 2 MHz signal were expanded to K times wider, then the 100 MHz clock was used again to count the expanded error pulse. Thus, if K is 10, the time resolution can be improved to 1 ns. It can be seen that the design has the following blocks: Counter module, pulsewave expansion module, data storage module and data processing module. Except for the pulsewave expansion module, which was an analog circuit, the rest were digital circuits.

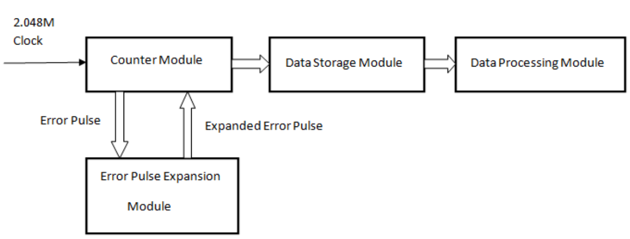

Figure 6. Block Diagram

In the following sections, each module is described in detail.

Counter Module

The functions of the counter module are as follows:

- This module is used to count the number for the 2 MHz in each period.
- It is also used to generate error signals. The error signal is generated when the 100 MHz signal is used to count the 2 MHz signal.
- It is used to count the expanded error signal.
- Generate the interfacing signals such WR, Clk_En for the data storage module.
- The counter values are outputted using an 8-bit data bus to the data storage module.
- This module is implemented using XC95108 by Xilinx. XC9108 is a CPLD, which is good for the design of digital circuits.

Figure 7 shows the corresponding waveforms in the counter module.

A. The 2.048 MHz PLL clock signal, which needs to be measured.
B. The 1 MHz pulsewave after frequency division by 2
C. The inverting waveform of (B)
D. 100 MHz clock signal for the counter
E. The error pulse generated at the rising edge when (B) waveform is counted using 100 Mhz
F. The error pulse generated at the falling edge when (C) waveform is counted using 100MHz
G. The expanded waveform of (E)
H. The expanded waveform of (F)

In the counter module, the 100 MHz clock signal counts the four signal channels, B, C, G, and H. Thus, there are four 8-bit counters in this module. The counter will start counting the B waveform when it is a logical high such as during T1 and T5. Similarly, the counter will start counting the G waveform during T2 and T6, C waveform during T3 and T7, H waveform during T4 and T8. Basically, when the signal is a logical high, the counter starts, while the signal is a logical low, the counter holds the value. Since it is possible to control how wide the error pulse is to be expanded, it is also possible to control the time during which G and H are a logical high and when B and C are a logical high. The module will output the counting values in the order of T1, T2, T3, T4, T5, T6, T7, T8…….They use one 8-bit data bus by time division to output to the data storage module.

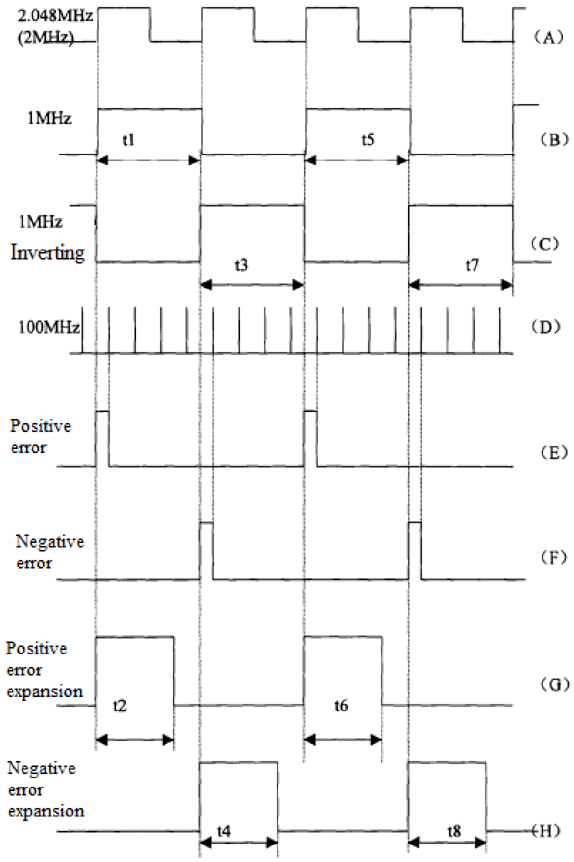

Figure 7. Waveforms of Counter Module

Error-pulse Expansion Module

The error-pulse expansion module is used to increase the accuracy of the measurement. The principle of error-pulse expansion is using two LM234, which can act as current sources. One is used to charge a capacitor and the other is used to discharge the same capacitor, which will generate a charging and discharging waveform. The charging time is controlled by the error pulse. The generated waveform then is converted to a pulse waveform. The time of pulse will be K times that of the error pulse. Figure 8 shows the diagram of the pulse-expansion circuit. The MAX913 is a comparator. The 2SC3357 is high-frequency transistor with a working range of 1 GHz.

The following is how the circuit works:

- When there's no error pulse
  - The current source will charge capacitor C1 with current I2 (I2=0.1mA). Because of the parallel Zener diode, the maximum charge voltage will be 4V.
  - The transistor, Q2, is in the on state, so it provides a route to the current source. Because if there is no such route, then it takes several ns for the current source to reach the steady state, then it makes it impossible to be able to expand the error pulse, which is only several ns long.
- When the error pulse comes
  - Now the transistor is in on state and capacitor C1 will discharge through current source I1. But since I2 is still charging capacitor C1, the real discharging current is I1-I2.

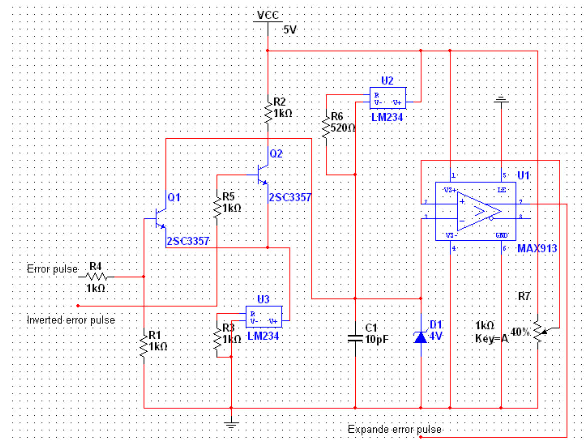

Figure 8. Diagram of Error-pulse Expansion

The following figure shows the waveforms at different points.

(a) The voltage across C1
(b) The input error pulse to the base of transistor Q1
(c) The expanded error pulse.

In the (B) waveform in Figure 9, 10ns is added to the front of the error pulse. The reason for adding 10 ns is because in the charging and discharging circuit, the beginning stage is not exactly linear. This area should be avoided by adding 10 ns to the error pulse. The selection of Vref also depends on the added 10 ns pulse. In the debugging state, one can generate a pulse equal to 10 ns. The reference voltage, Vref, should be the minimum voltage in waveform (A). There will be no output voltage at this moment. The output of the comparator will be the expanded error pulse.

The expansion factor is:

The selection of the capacitor will satisfy that the 20ns error pulse will make the voltage change about 2V. The currents of I1 and I2 can be controlled by R3 and R6, respectively.

$$K = \frac{\text{The slope of charing curve}}{\text{The slope of discharging curve}} + 1 = \frac{I1 - I2}{I2} + 1 = \frac{I1}{I2}$$

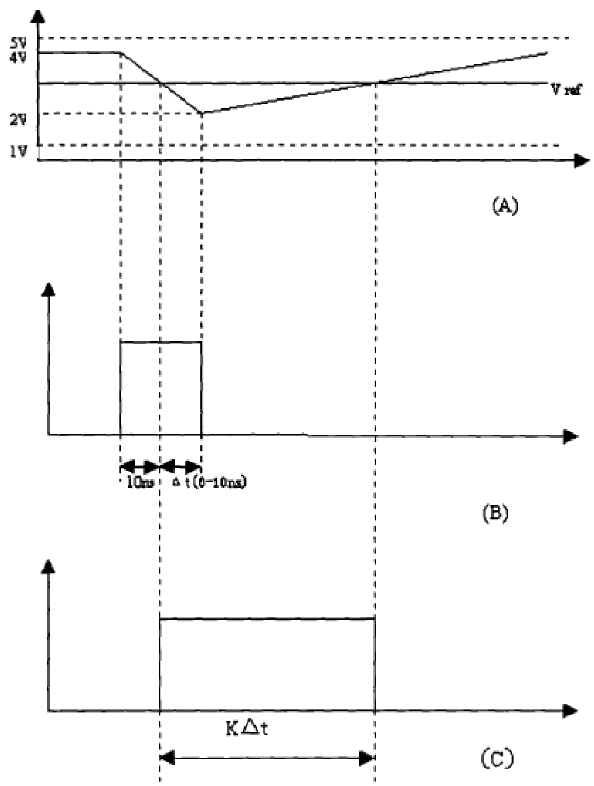

Figure 9. Waveforms for Pulse Expansion

Data Storage Module

The data storage module is used as a buffer to store the data from this counter module. A FIFO IDT 72230 is used to do this. IDT72230 has 2K×8 storage space. When it is full, the FF (Full Flag) will send an interrupt request signal to the data processing module.

Data Processing Module

The core of the data processing module is a DSP TMS320F206 [8]. This module is used to process the data from counters and output the measurement of the jitter. The interrupt from the FIFO is used to trigger an interrupt service routine to read out 2K data from the FIFO. The other external communication DSP is through an RS 232 cable.

The following explains the algorithm in the data processing module. The method to measure jitter is to get the exact value in each period of the clock signal. In order to get the exact value, three data from the counter module are needed. From Figure 6, t1, t2, t3, t4… represent the time for each period (ns), T1, T2, T3, T4….T8 represent the counter value using a 100 MHz clock signal. From Figure 6, it can be seen:

$$t1 = (T1 - 1) * 10 + Front\_error + End\_error$$

Since

$$End\ error\ of\ T1 = 10ns - Front\ error\ of T3$$

$$Front\ error\ of\ T1 = T2 * \frac{10}{Expansion\ rate\ K}$$

$$t1 = T1 * 10 + (T2 - T4) * \frac{10}{Expansion\ rate\ K}$$

$$t_n = T_n + (T_{n+1} - T_{n+3}) * 10/K$$

This can be extrapolated to the following equation. Next, the accuracy of the scheme will be analyzed.

First we have the following three assumptions:

(1) The accuracy of the 100MHz clock signal is high enough. In other words, error will not be introduced by the 100 MHz crystal. In fact, the 100 MHz crystal clock can reach the 4th digit after the decimal point.

(2) After frequency division of the 1MHz signal and its inverting signal, the edges are in line with each other. There's no time delay. This can also be met by putting time-delay buffers in the CPLD design.

(3) The linearity of the error-pulse expansion circuit is good enough. This is being satisfied by choosing the right working region for the charging and discharging circuit.

Next, use error-pulse expansion K=20, for example, to analyze the error of the jitter measuring circuit. When the error pulse is 0.5ns, the expanded pulse will be 10ns. Suppose when the error pulse is between 10ns and 20ns, the counter value will be 1.

when

$$10Nns < T < 10(N+1)ns$$

The counter value is N; thus, the maximum error generated by this jitter measuring scheme is 0.5 ns. If the error pulse expansion circuit is not used, the maximum error will be 10 ns. From the above discussion, it can be seen that error-pulse expansion is a crucial part of the design.

Results

The following is the result of sinusoidal modulated jitter on the 2.048MHz clock signal. The values represent the time of each period in ns.

467463 **460.5** 461 464.5 469 …….499.5 503 507 511.5 514 **518** 515.5 510 507…….468.5 462.5 **459**……463.5 467 471……

From the data above, it can be seen that the period of the 2 MHz clock signal has local peak values, shown in bold fonts. The jitter is sinusoidaly modulated. The frequency of the jitter can be obtained from the data. Jitter in each period is the absolute difference of the actual time with 488 (1 UI). In a practical case, the jitter is random. Then, one needs to get the spectrum and the amplitude of the jitter for different frequencies.

The following table shows when the frequency of the clock signal changes, the measured maximum and minimum times for each period will also change. The signal used is not modulated with sinusoidal signals. It is just the output from the function generator (Model: SFG-2120, 20 MHz DDS).

Table 1. Results

Input clock frequency/period	Maximum period	Minimum period	Average period
2MHz/500ns	505ns	496ns	500.6ns
2.028MHz/493ns	498ns	488ns	493.5ns
2.048MHz/488ns	493ns	483ns	488.8ns
2.070MHz/483ns	488ns	478ns	484.1ns
2.222MHz/450ns	456ns	445ns	450.3ns

From the results above, it can be seen that the DSP-based jitter measurement scheme works for 2.048 MHz pulse clock signals. With an error-pulse expansion module, the accuracy of the measurement is greatly improved.

Conclusion and Future Work

In summary, this paper presents a feasible jitter measuring scheme based on DSP. Using an error-pulse expansion circuit is an innovative way to improving jitter accuracy. Compared with jitter measuring using expensive digital oscilloscopes or waveform monitors, the proposed method is easy to implement and cost effective. It can be developed into a specialized jitter measuring device in the future.

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THE EFFECTS OF GENDER ON VISUALIZATION AND TECHNICAL PROBLEM SOLVING IN TECHNOLOGY STUDENTS

Doug S. Koch, Southeast Missouri State University; Sophia Scott, Southeast Missouri State University

Abstract

This initial study was conducted in order to investigate the effects of gender on visualization and problem solving. The participants were 47 students enrolled in two different solid modeling classes at Southeast Missouri State University. There were 13 females and 34 males that participated in the study. The control group was comprised of 23 students of which six were female and the experimental group consisted of 24 students of which seven were female.

The study was a posttest only design that used the Purdue Spatial-Visualization Test-Visualization of Rotations (PSVT-R) to measure the students' spatial-visualization skills. Logistic regression was used to determine if there were gender differences and if utilizing solid modeling software offset any hypothesized differences. Both groups were given a problem which required them to design and construct a prototype of their solution. The control group used sketching as their design method and the experimental group used solid modeling software to design their solutions. The prototype was evaluated to determine if it met the design requirements and scored as either successful or unsuccessful.

The findings revealed that there was no significant difference between the males and females in this study (p=.069). Because there was no significant difference between their visualization scores, there were also no differences in how visualization affected their problem-solving ability (p=.98). Thus, for this study, it was found that the spatial visualization of the males and females did not differ and that the use of solid-modeling software for this design problem did not offset any hypothesized differences.

Introduction

Problem solving and spatial visualization are both areas of critical importance to technology and engineering educators. Spatial visualization has been identified as one of the most important skills related to engineering and technical graphics [1]. Devon et al. [2] state that "Spatial visualization skills are an important component of engineering because of their direct relationship to the graphical communication associated with design" (p.4). Strong spatial-visualization skills have been shown to correlate to success, achievement, and retention in engineering programs and success in mathematics [3]. In problem solving, a mental model must first be created and, regardless of the representation, that mental construction is the "most important for problem solving…problem solving requires some activity-based manipulation of the problem space" according to Jonassen [4]. Previous research points out that there are often differences in visualization skills of males and females. Males, as a whole, tend to have higher visualization scores [5].

Technology education has placed great emphasis on problem solving, yet little is known about how individuals approach solving problems and what skills or tools are needed to better solve problems. There are no standardized instruments for measuring problem-solving ability. As more females enter into technology fields, more information is needed to determine if differences in visualization and problem solving exist and how to overcome those differences and what tools and techniques are needed to do so. The potential exists for students to be able to better visualize problems when designing with 3D representation. Research dealing with assembling objects shows that students tend to do better when they can view a physical or 3D object as opposed to 2D drawings [6]. Few dispute the importance of being able to solve problems, but more information and research is needed on how individuals solve problems and what methods, instruction, and experiences can improve this ability. The potential of gender differences needs to be investigated with the significant emphasis on problem solving and the crucial role that visualization plays in problem solving.

The purpose of this study was to determine if there are differences in the visualization and problem-solving abilities of male and female technology students and, if differences exist, does the use of solid modeling offset those differences.

Research Questions:

RQ1. Do the spatial-visualization abilities of male and female technology students differ?

RQ2. Are there differences between how males' and females' visualization skills affect their problem solving ability?
RQ3. Does the use of 3D modeling software offsets potential gender differences in spatial-visualization ability?

The knowledge gained from this study can benefit both educators and students who focus on problem solving and visualization. Determining if gender differences exist can influence how educators teach problem solving and the importance of developing strong visualization skills. Information gained in this research can also provide insight on the role solid modeling plays on visualization and the problem-solving process.

Review of Literature

Spatial Visualization

The term visualization is often used in many different ways, so it is often difficult to understand or interpret the true intent of its use. Visualization research from the late 1800's to the 1970's identified two major factors that appeared from several factorial analyses: spatial visualization and spatial orientation [3], [7]. McGee [3] defined spatial visualization as "an ability to mentally manipulate, rotate, twist, or invert pictorially presented visual stimuli" (p.3) and that spatial visualization involves recognition, retention, and recall. Guilford and Lacey, as cited by Mack [8], define spatial visualization as the ability to imagine the rotation of depicted objects, the folding or unfolding of flat patterns, the relative changes in position of an object in space, or the motion of machinery. Stated somewhat differently by Smith and Strong [7], "spatial visualization is the ability to manipulate an object in an imaginary 3-D space and create a new representation of the object from a new viewpoint" (p.2). McGee [3] states that spatial orientation "involves the comprehension of the arrangement of elements within a visual stimulus pattern, the aptitude for remaining unconfused by the changing orientations in which a configuration may be presented…" (p.4).

Visualization was not thought of as a reflection or measurement of intelligence and until recently had not received the same emphasis as verbal skills. Spatial visualization and spatial orientation are shown to be more highly correlated with technical, vocational, mathematical, and occupational domains than verbal ability [1], [4], [5]. Research supports the idea that visualization can be learned and improved through practice. Gillespie [1] studied the effects of tutorials for teaching solid modeling on visualization. His quasi-experiment examined students enrolled in an engineering graphics course at the University of Idaho. Sixty seven participants, 41 of whom completed the study, were divided into three groups. Each group was pretested using three tests: a mental rotations test; a paper folding test; and a rotated-block test. The rotated-block instrument was developed by Gillespie and is similar to the Purdue Spatial-Visualization Test-Visualization of Rotations (PSVT-R) [20] used for this study. One group was treated with ten weeks of seventeen modules on solid modeling. The two control groups received traditional 2D graphics instruction. All groups improved their scores from pretest to posttest, and the treatment group improved significantly over the two control groups. Since Gillespie's study in 1995, solid-modeling technology and software has changed a great deal. The software at that time typically involved the use of wire-frames, Boolean operations and, oftentimes confusing movement of a user coordinate systems (UCS) icon. Kurland [8] contends that modern solid-modeling software is simpler and more efficient to use. The images are more realistic with rendered representations. This makes visualization easier and accelerates or improves the advantages of using solid modeling [2].

Gender Differences of Spatial Visualization

The use of solid-modeling curriculum is an effective way to close the gender gap in spatial-visualization skills [2]. Several studies found that differences exist in the spatial -visualization abilities of males and females [1-3], [9]. Studies of younger children showed little or no spatial-visualization differences between males and females prior to puberty. After puberty, significantly different levels were evident, with males having a higher ability. In studies where differences were evident, males typically had stronger visualization skills [2], [3] and there were no significant gender differences reported when the Fall and Spring semesters were examined separately. The sections that received extensive solid modeling showed clear gender differences. Possible reasons given for this by the researchers, besides the effects of solid modeling, include: 1) there were more females in those groups, and 2) the lower pretest scores of the females made for larger gains than many of the males. In Gillespie's study [1], gender differences were found to be significant at the .10 level, but this finding was not consistent with many previous studies. He found that the females had higher spatial-visualization scores. Possible reasons for this were that the small number of females (5), may not have been a representative sample, and one female had exceptional gains, which skewed the results.

Whether or not current 3D software can affect or offset these differences remains to be determined. The software has evolved to the point that making and testing 3D models is much easier than it had been in the past few years. The ability to capture and create a model three dimensionally, while working toward a specific problem goal, may affect or lesson the cognitive load on an individual. This reduction on cognitive load could possibly offset gender differences that are related to problem solving and may help with visualization as well.

Problem Solving and Design

Problem solving is important to technology educators because they are trying to get students to problem solve as a means of doing. McCormick [10] states that research "shows that action affects thinking, and thinking affects action." (p. 23). Students need to be able to think and act on the problems they face and react to the changes they encounter. He also contends that problem solving is the most important procedural knowledge that occurs in technological activity. Jonassen [11] states that "problem solving is at the heart of practice in the everyday and professional contexts.…every secondary and tertiary education course should require students to solve problems" (p.362). An important question is whether or not there are differences between males and females related to problem solving.

Little research related to gender differences and technical problem solving has been conducted. Several studies related to mathematical problem solving report that there are gender differences. Males typically outperform females in many of the studies. Zhu [5] points out that there are many hypothesized reasons for this such as cognitive abilities, spatial abilities, verbal abilities, biological factors, and environmental factors. From a technology standpoint, we often utilize design as one form of problem solving.

Problem solving and design are often used interchangeably. McCade [12] argues that this is too limiting because problem solving often involves much more than just design; designing is a type of proactive problem solving. The majority of the design in most classrooms is new product design. New product design is only a small portion of the design that is conducted in real-world situations. Most designs require some form of troubleshooting in their development, but troubleshooting can also be a separate component of dealing with existing artifacts and systems.

Components of a Problem. Problem solving is the process of seeking feasible solutions to a problem [13]. There are only two critical parts of a problem: 1) an unknown entity in some state; and 2) finding the solution must have some benefit socially, culturally, or intellectually [4]. The basic unit in problem solving is an action and, if more than one solution is available for a certain problem state, a decision has to be made [14]. That decision can be based on learned knowledge, biases, "lookahead", or a combination of these factors.

Technical Problem Solving. Childress [15] defines technical problem solving as:

> The problem solving process… combined with the processes of technology in engineering, architecture, industrial workshops, research and development laboratories, the home, the office, and field, etc., and certainly the technology education laboratory. The processes of technology employed to solve problems of human need or want characterize this method. (p.94)

McCade [12] defines technical problem solving similarly but further divides it into three categories: design, troubleshooting, and technology assessment.

External Representations and Problem Solving. Problem solving is a basic component of many technological design tasks. Problem solving and technical design are both being used in many technology and engineering technology classes to promote technological literacy and prepare students for future design challenges that they may face. An important aspect of being able to solve technical design problems is being able to visualize objects in different orientations and possible solutions to problems. External representations are a crucial part of many problem-solving activities, particularly technical design. Jonassen [16] states that all forms of external representation are important because "external problem representations, especially those in the form of dynamic models, enable learners to manipulate and test their models" (p.377).

A modern tool used for design and external representation is computer aided design (CAD). CAD has evolved from the simple replacement of traditional drafting equipment to a very sophisticated, highly visual design tool. The earlier CAD programs used the computer to generate lines for 2D drawings. As the software and hardware advanced, these 2D drawings could be converted into 3D objects that the computer recognized as having height, width, and depth. The software used to create these earlier 3D objects was still 2D based; they originated from and were primarily used to draw in two dimensions. Modern software used for solid modeling often functions in the reverse order; the three-dimensional object is drawn and then two-dimensional, orthographic drawings are generated from that model. Advantages are perceived in using this latter order because we live in and interact with a three-dimensional world.

Murray [17] identified the following advantages of modern parametric solid modeling software over earlier modeling software:

- Easier to use
- Easier for visualization
- Provides the ability to see the model grow and develop
- Often allows resolving design issues quicker
- Has the ability to determine material properties
- Models are easily converted to other graphic forms for marketing, advertising, etc.
- Finite element analysis (FEA) can be performed on solids.
- Can be linked directly to manufacturing operations such as rapid prototyping and CNC

With all of these advances, computer models cannot always replace physical objects; limitations in hardware and software still exist [18], [19]. The possible benefits and drawbacks of design instruction are still in question. How solid modeling software affects students' ability to design and solve problems needs to be better understood. Previous studies show that students with high visualization skills are often better at design and assembly operations. A primary question addressed by this study is: If females have lower visualization skills, does modern solid-modeling software provide students an equal or improved opportunity to solve design problems?

Methodology

Selection of Participants

The participants consisted of two classes from the Industrial and Engineering Technology Program at Southeast Missouri State University. One class was an introductory course and one the next course in series or a slightly more advanced course. Both courses were exposed to the same instruction related to the use of the ProDesktop software. The participants were all randomly assigned to either the experimental (ProDesktop) or the control group (sketching). There was a total of 24 participants in the experimental group and 23 in the control group. There were 13 females and 34 males in this study. Six of the females were in the control group and 7 were in the experimental group. The majority of the participants were technology education, engineering technology, and graphics technology majors in different stages of their academic programs.

Design

The design for this study was an experimental posttest only design. The randomly assigned participants first completed the PSVT-R. The control group designed a solution to the problem using sketching and then physically constructed their prototype with the provided materials. The experimental group participants each used *ProDesktop* solid modeling software and sketching to design their solutions and then constructed a prototype with the provided materials. The physical models or prototypes were then scored as either successful or unsuccessful.

Independent Variables. The independent variables in this study were: 1) The gender of the participants; 2) The method the participants used to design their prototype; and 3) The participants' spatial-visualization ability. Participants in the control group used sketching in the design of their prototype, while the experimental group used *ProDesktop* solid-modeling software for the design of their prototype. Spatial visualization was measured with the PSVT-R.

The PSVT-R test was designed to measure the participants' ability to visualize the rotation of three-dimensional objects. The format for the PSVT-R was 30 questions. Raw scores were used for this study so 30 would indicate that all 30 problems were answered correctly. A sample PSVT-R question is shown in Figure 1.

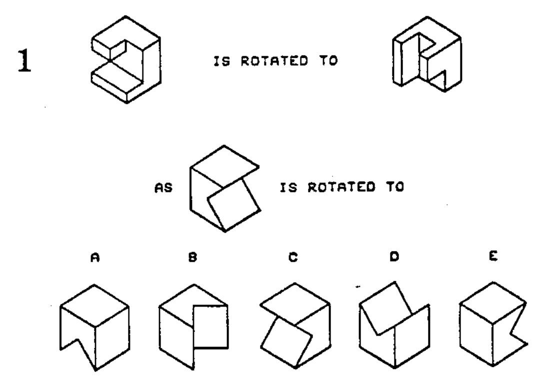

Figure 1. Sample PSVT/TR Problem

Dependent Variable. The participants were instructed to design a mechanism that would convert rotary motion to reciprocal motion and move a block forward a fixed amount within specified tolerances. Upon completion of the design, the participants were instructed to construct a working model or prototype using supplied materials.

The materials included:

1. Fixture made of ½" polystyrene foam (see figure 2)
2. Hot glue gun
3. Glue sticks
4. Double sided tape
5. Wood glue
6. Masking tape
7. Duct tape
8. ¼" dowel rods
9. 3/8" dowel rods
10. ½" dowel rods
11. Foam core board
12. ½" rigid foam
13. Corrugated cardboard
14. ¼" hardboard
15. ½" plywood
16. Assorted nails, screws, bolts, and nuts

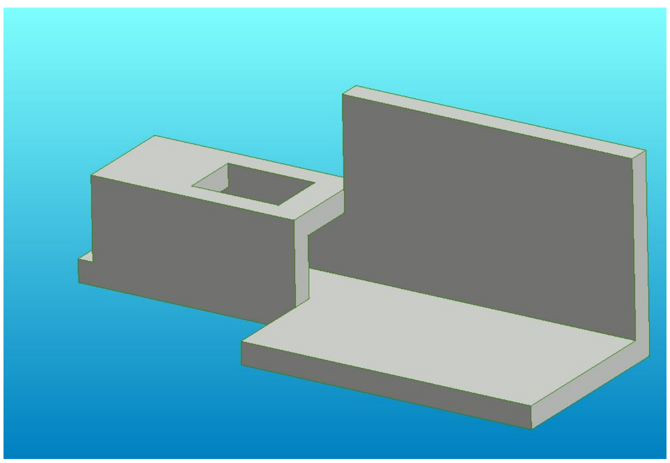

Figure 2. Polystyrene Fixture

The prototype had to successfully advance three 1.5" X 1.5" X 3" blocks a distance of 3.5" with a tolerance of plus or minus $^{1}/_{8}$". The prototypes were scored as either successful or not successful. If all three blocks successfully advanced the required 3" within the $^{1}/_{8}$" tolerances in one of two possible attempts, the prototype was scored as a successful solution to the design problem.

This either successful or unsuccessful value was the dependent variable. The evaluation was limited to only successful or unsuccessful because this and many ill-defined problem-solving activities may have multiple, correct solutions. For this problem, the participants were only evaluated on the stated objective and were not scored relative to other aspects such as creativity, durability, or manufacturability.

Results

Descriptive Statistics

The mean score for the PSVT-R for the 47 participants was 22.26 with a standard deviation of 4.55. The mean score for the 23 participants in the control group was 21.49 with a standard deviation of 4.39. The mean score for the experimental group's 24 participants was 23.00 with a standard deviation of 4.66. See Table 1.

Table 1. PSVT Scores

Group	*N*	*M*	*SD*
Control	23.00	21.49	4.39
Exp.	24.00	23.00	4.66

Five participants of the control or sketching-only group constructed successful prototypes of which 1 was female. Six of the experimental or ProDesktop group constructed successful prototypes of which 1 was female (see Table 2).

Table 2. Number of Successful and Unsuccessful Participants

Group	Successful	Unsuccessful	Total	% Successful
Control	5	18	23	21.7
Male	4	13	17	23.5
Female	1	5	6	16.7
Exp.	6	18	24	25
Male	5	12	17	29.4
Female	1	6	7	14.3

RQ1. Do the spatial-visualization abilities of male and female technology students differ?

Males have been found in many studies to have higher spatial-visualization abilities. The analysis of this study was similar to a minority of others in that it was found that the males did not have significantly higher spatial-visualization ability. There were 13 females and 34 males in this study. The males did not show a significant difference in visualization $F(1,45)=3.475$, $p=.069$, from the females' visualization scores (see Table 3). Although, the males did report a slightly higher mean score ($M=23.00$) with a slightly smaller standard deviation ($SD=4.55$) as opposed to the females ($M=20.31$, $SD=5.33$). See Table 3.

Table 3. Gender Differences in Visualization Scores

Source	***df***	***F***	***r^2***	***p***	***d***
Gender	1	3.475	0.072	0.069	0.608
Group	***N***	***M***	***SD***		
Males	34	23.00	4.55		
Females	13	20.31	5.33		

RQ2. Are there differences between how males' and females' visualization skills affect their problem-solving ability?

Because the dependent variable, successful or unsuccessful completion of the model, is dichotomous, logistic regression was used to determine if there were any significant differences between visualization, gender, and method of design used. For all of the participants it was found that spatial-visualization skills, as measured by the PSVT-R, was a significant predictor of successfully solving the design problem. The coefficient on the visualization variable has a Wald statistic equal to 5.313, which is significant at the .05 level (p=.021). The overall model was significant at the .05 level according to the model chi-square statistic. Analysis revealed that there were no significant differences (p=.98) between the males and females as would be expected since there was no significant difference between their visualization scores and such a low number of females.

RQ3. Does the use of 3D modeling software in the design and production of a prototype for a technical design problem offset potential gender differences in spatial-visualization ability?

It was hypothesized that if using solid modeling reduced a participant's cognitive load, it could possibly make visualization easier for the participants and, thus, offset any differences in their measured spatial-visualization ability. Because there were no gender differences found in visualization scores, the analysis showed that the method used for this particular problem was not significant (p=.753) and did not offset any gender differences. Without significant differences in the visualization scores of males and females, it is not possible to have a significant difference regarding the use or lack of use of modeling software.

Summary and Conclusions

Caution must be used when generalizing the results of this study to others because it consisted of only two classes of randomly assigned engineering technology students from Southeast Missouri State University. These classes were chosen because of their similar exposures to drafting, design, and solid modeling. There were only 13 females that participated in the study, which make significance and generalization difficult.

The purposes of this study were to determine if the spatial-visualization abilities of male and female technology students differs; if there are differences between how males' and females' visualization skills affect their problem solving ability; and, if the use of 3D modeling software in the design and production of a prototype for a technical design problem offsets potential gender differences in spatial-visualization ability. Previous research shows that males typically have higher visualization scores than females. The results of this study were similar to those of the study conducted by Devon et al. [2] in which the male participants did not show a significant difference. This may be due to the female participants' past experiences and interests related to engineering and technology. The populations for this study and the Devon et. al. [2] study were limited to engineering technology students and not representative of all females. Other studies that examined more diverse populations often found that males had significantly higher visualization scores [1-3], [9].

The female students' visualization scores were not different from the males. One could conclude that additional instruction or varied instruction for the females is not needed. This may be the case but, with the limited number of participants, it is difficult to generalize these findings to all female technology and engineering students. Providing opportunities to increase visualization abilities would benefit both male and female students that are struggling with the needed visualization skills. Doing so could help with student success and retention as well. Many of the tasks undertaken in the classroom and the profession relate to or require visualization skills and strengthening them would benefit the students greatly.

Because there was no difference between the male and female visualization scores, there was no possibility of the modeling software offsetting any differences related to spatial visualization. For these groups, it was found that using the modeling software had no significant impact. Visualization was a significant and better predictor of being able to solve the design problem.

There were several things related to problem solving that became apparent as the participants began working on the problem. Examination of the prototypes produced by the participants reinforces several basic strategies regarding design problem solving and ill-structured problem-solving activities. Many of the participants seemed to feel that they had successfully completed the problem but overlooked the specific requirements. This pointed out the importance that the problem and the requirements for the problem be understood and reviewed. Some participants may have been hindered by their lack of ability to properly build their design with the given materials. The females may not have been as familiar with devices that utilize similar simple machines and may not have had the background experiences to transfer previous knowledge to this problem.

This study reiterates the importance of good problem-solving techniques and strategies and the importance of strong visualization skills. Whether it is a technical design problem, mathematical problem, a short answer for a test, what automobile to purchase, etc., when faced with a problem to be solved, one must understand the problem, what criteria need to be met to consider the solution a success or acceptable, and the available resources. Jonassen [16] states that problem solving is one of the most important tasks that we do throughout our daily lives and that teaching problem solving should be a top priority of education.

Continued research related to gender differences in spatial visualization and technical problem solving is both warranted and needed. This study and related literature suggest that relatively little is known about how individuals solve technical design problems and how visualization and the use of technology affect males and females. Additional problems and types of problems need to be studied. Research that further examines gender differences in spatial visualization and cognitive load when using or viewing objects with solid-modeling software is needed to determine if the technology might improve problem solving or visualization.

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ENHANCING LEARNING AND ENGAGEMENT IN ENGINEERING CLASSES

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Abstract

Teaching engineering and technology subjects involves explicating abstract multidimensional information structures and processes that can be difficult to grasp. A methodology using Tablet PCs and interactive software was developed to enable students in telecommunications and computer science classrooms to grasp these complex concepts more quickly and easily. The presentation of theory by the instructor was immediately followed by real-time interaction between students and instructor during which students employed the theory while it was still in the students' short-term memories.

Two hypotheses were investigated:

#1 Complex data-structure concepts are learned faster and more completely when Tablet PCs are used appropriately in the classroom.
#2 The use of Tablet PCs in the classroom enables students to remain engaged in learning during the longer classes that are typical of accelerated learning environments.

Data captured from both students and instructors are analyzed in support of these hypotheses. Examples of specific exercises given in class, along with students' answers, are discussed. In addition, quantitative data showing improvements in scores on exams are presented. Finally, an analysis of questionnaires completed by students is presented. The results of the study confirmed both of the hypotheses. The study showed that the methodology employed not only improved student exam scores but also promoted their critical and innovative thinking skills. The results of students' surveys confirmed that students felt that using Tablet PCs enabled them to learn complex engineering material faster and in greater depth and be better engaged in classes.

Introduction

In his famous essay, Eugene Wigner commented, "the miracle of appropriateness of the language of mathematics for the formulation of the laws of physics is a wonderful gift which we neither understand nor deserve." [1] But it is not always easy for engineering students to grasp this appropriateness. In fact, understanding the relationship between mathematics and the physical world is only the start. Engineering students must learn to grasp many complex and sometimes abstract logical structures and processes. A few examples include Queues, Trees and, more generally, data structures in computer science; various kinds of database designs in information systems; layered architectures and complex telecommunication protocols in data networks; digital signal-processing algorithms that are necessary to generate, transmit and receive multiplexed radio signals; complex mathematical equations and graphs; and a myriad of details of physical structures in civil engineering. Conveying complex concepts for easy understanding at a fast pace is one of the many challenges instructors face while teaching engineering and technology subjects. Using equipment received under a two-year 2007 HP Technology for Teaching – Higher Education Grant, the School of Engineering and Technology at National University has introduced the use of Tablet PCs into the hands of every student in selected courses to enable his/her understanding of complex concepts more quickly and easily.

Related Research

Denning, Griswold and Simon [2], Koile and Singer [3] as well as a number of others, have reported that using Tablet PCs in the higher-education classroom not only positively impacts student learning but also expands the modes available for communication between instructors and students. Researchers at the University of Washington have reported on the use of Tablet PCs in the higher-education classroom using Classroom Presenter software. An in-depth discussion of Classroom Presenter and its impacts may be found in Wolfman's University of Washington doctoral dissertation [4]. Simon et al. reported on experiences in using a Tablet PC-based system with Classroom Presenter in computer science courses [5]. Researchers at the University of California at San Diego (UCSD) have made enhancements to the Classroom Presenter software. The use of this enhanced version, named Ubiquitous Presenter [6], in higher-education classrooms is discussed in a number of excellent papers [7], [8].

Anderson et al. [9] have reported that the use of learning devices in the on-site higher-education classroom enhances student engagement in the learning process, while Thomas and Carswell [10] have observed that collaborative learning is a powerful tool for distributed environments. A number of papers [11-13]have reported on the power of digital ink in teaching. The relation between active learning and use of digital ink, reported by Kowalski, Kowalski and Hoover [14] is of particular interest.

Hypotheses

This National University project concentrated on two hypotheses:

#1 Complex data-structure concepts are learned faster and more completely when Tablet PCs are used appropriately in the classroom

#2 The use of Tablet PCs in the classroom enables students to remain engaged in learning during the longer classes that are typical of accelerated learning environments.

The first hypothesis expands on the following postulate: the best way for students to learn an information structure is through collaborative and small-group experiments in which students can apply their own "touch and feel" to a concept. Students are more likely to absorb complex information structures if they are given the opportunity immediately to experiment either individually or in small groups with the concepts that have been presented. Increased interaction with each other and with their professors enables them to gain a deeper understanding of these concepts. Tablet PCs are a useful resource especially when students wish to visually pose those questions that are difficult to verbalize and have to be continually available in a discussion forum that is open to all.

Hypothesis #2 is derived from a desire to help students retain and enhance their concentration throughout the time span of the longer classes that are typical of the accelerated learning environment at National University. National University serves a diverse population of adult learners through classes that are each three and a half hours to four and a half hours in length. Retaining the attention of students who are sometimes fatigued after a full work day, along with the concerns of family, children, and jobs, is challenging. The increased interaction with students through the Tablet PCs not only helps students keep up with the instructor, but it continually stimulates their thinking about what is being taught and this, in turn, improves their attention span. Equally important, the faculty instructing the class gains a pulse of the students' understanding of the topic that is covered.

Methodology

Each on-site instructor and every student had a Hewlett Packard Tablet PC equipped with the Microsoft Windows XP operating system, the full Microsoft Office suite including PowerPoint, Excel, Word, and both DyKnow Vision™ [15], [16] and DyKnow Monitor™. Special applications software was also included, as needed, for particular courses. Some later classes had HP Tablets with the Microsoft Windows Vista operating system instead of Windows XP, but the operating system was found to make no difference to this project. All Tablet PCs were connected to each other and to the Internet through an IEEE 802.11g Wireless Access Point. Throughout this project, a DyKnow Vision™ server operated by Indianapolis-based Dynamic Knowledge Transfer, LLC (DyKnow) was accessed via the Internet.

The DyKnow Vision™ server software coupled with DyKnow Vision™ client software on each Tablet PC enabled instructors to "push" charts to all students in a particular class. Class sizes typically ranged from 10 to 20 students, although there were a few smaller classes. Response time, from when an instructor selected a particular chart for students to view until that chart appeared on each student's Tablet PC, was normally no more than a few seconds. Students were able to draw, write, and type directly on their copy of the instructor's charts and they could also make their own personal notes about each chart on a side window. Students saved their notes and annotations on their own USB drive at the end of each class.

Curricula were revised to incorporate interactive exercises developed by the instructor. These exercises challenged students to apply what they had just been taught to solve problems that were often deliberately ill-defined. Individual students and small groups working together submitted their solutions as annotated charts in real time to the instructor via the DyKnow Vision™ server. The instructor could choose selected submissions to display, either anonymously or with attribution, for discussion by the whole class. The instructor also had the option of storing student submissions for later review and grading. The latter was useful for assessing student participation in the discussions.

Interactive Exercises

Table 1 lists courses that were redesigned to incorporate interactive exercises throughout the lectures. The exercises were designed to focus on the information structures under discussion. Four different instructors taught approximately 150 students a total of nine different courses: five graduate courses and four undergraduate courses.

Wireless Systems Security Course – Individual Exercises

The chart shown in Figure 1 was used to explain substitution ciphers in teaching students the building blocks of cryptography in the Wireless Systems Security course. After allowing for any questions from students, students were immediately given the exercise shown in Figure 2.

Table 1: Description of Modified Courses

Graduate courses
- Wireless Security (encryption, algorithms etc.)
- Digital Wireless Fundamentals
- Wireless Coding and Modulation (of radio waves)
- Wireless Economic Topics (How the wireless industry works as a business)
- Unit Processes of Environmental Engineering

Undergraduate courses
- Data Structures & Algorithms
- Linear Algebra & Matrix Computation
- Calculus for Computer Science
- Applied Probability and Statistics

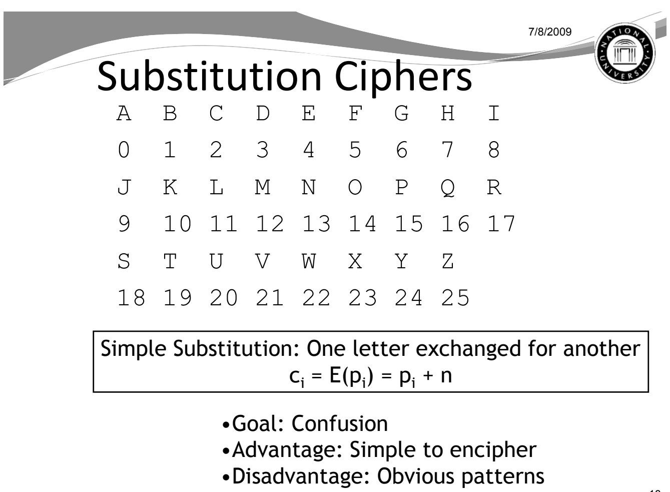

Figure 1. Explanation of Substitution Ciphers in a Wireless Security Course

Students were given three minutes in class to encrypt the short sentence and submit it. The most common problem encountered was confusion about what to do when the value of "n," 5 for this exercise, gave a result larger than 25. A few students did not realize that they simply needed to do the arithmetic modulo 26. This confusion was caught and corrected immediately with this exercise. Another problem that was apparent during this exercise was that students tended to be careless while doing the addition. The correct answer is given in the notes at the end.

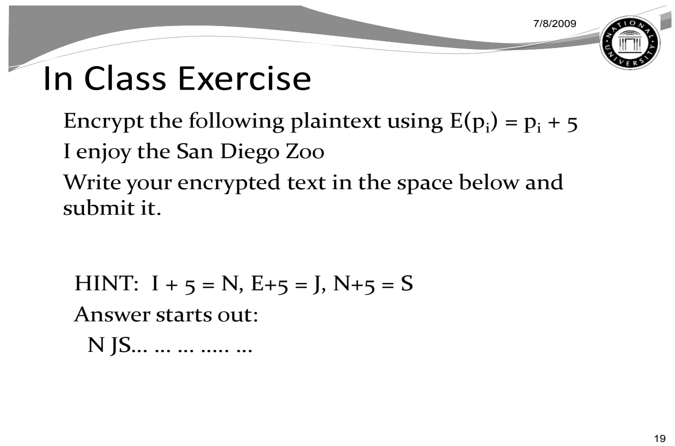

Figure 2. Simple Individual Student Exercise from a Wireless Security Course

A somewhat more complex exercise from the same course is shown in Figure 3. In this exercise, students had to compute the time it would take to mount a brute-force attack on a six-character password, assuming they had a computer and a program that could try 200 passwords per micro-second. In the example in Figure 3, the student used a correct approach to try to solve the problem, but forgot part of the division by 200 and handled the powers of ten incorrectly. As a result, the student came up with the response 2.2 seconds when the correct answer was 11 seconds. This was easily spotted and corrected in class by the instructor.

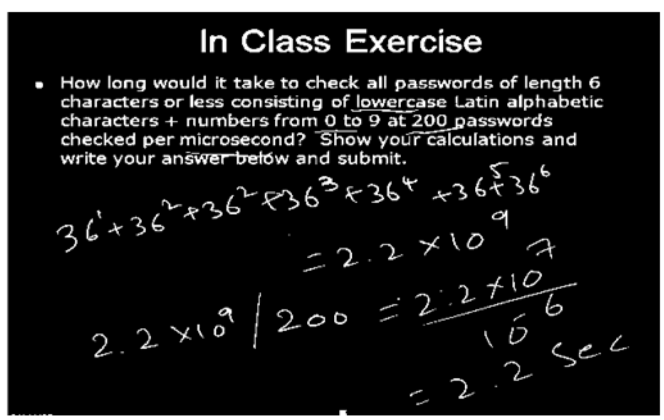

Figure 3. More Complex Individual Exercise

Data Structures and Algorithms Course: Individual Exercises

National University's Data Structures & Algorithms course is a foundation course for baccalaureate-level computer science majors. The course covers standard data structures routinely used in computing applications. Some focal points of the course include developing an understanding of the containers for organizing and storing information along with the algorithms that operate on them. The standard structures to be studied are Lists, Queues, Stacks, and Tree structures and the algorithms that work on them. Often, students misunderstand an algorithm or do not quite understand the underlying data structure's properties.

A sequence of interactive exercises and student responses from this class are depicted in Figures 4 through 7. In Figure 4, students were asked to describe how to insert an element into an array-based implementation of a list structure. The instructor's objective was to motivate students to think about the amount of "work" involved in inserting an element into an array. Almost all students' responses were similar to the one seen in Figure 4a.

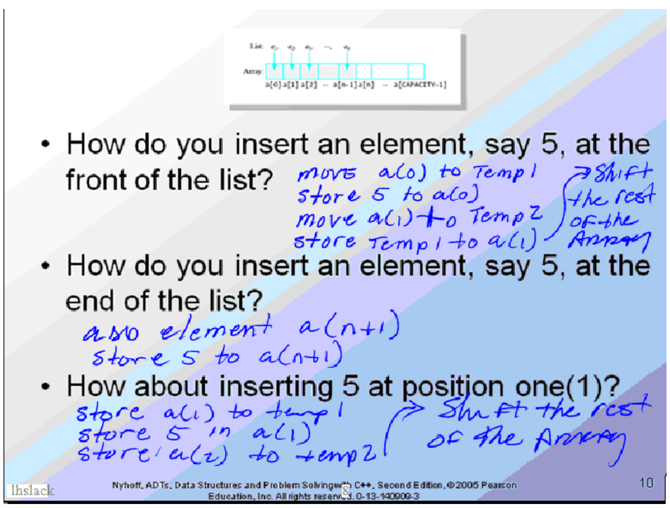

Figure 4a. Insertion Exercise

In this case, answers are correct but not elaborated and there is no hint of the work that is involved in the insertion. Most students presented a sketch of an insertion algorithm; although correct, no one really elaborated on what exactly was involved in shifting the elements. This prompted a discussion on how to shift the elements in an array through a simple loop and what was the best way to define and quantify "work." In Figure 4b, the code for shifting is presented. This code can be used to discuss the work done by the algorithm. Once students grasped the concept of work involved in shifting array elements, their focus immediately changed to how to reduce the work required.

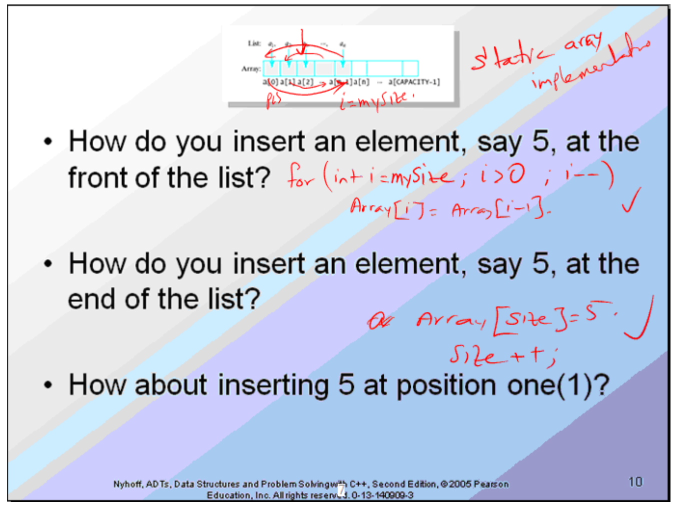

Figure 4b. Code from Instructor

One student suggested placing the current value of the position at the far end of the array (after the last element), and then inserting the new element at the end of the list. Even though it was acknowledged that this strategy would save a lot of time, it was rejected because it was felt that the procedure would not be satisfactory if the array were to remain sorted. Student engagement and participation was very high during the discussions and the interactive nature of the presentation system allowed the instructor to steer students dynamically towards the objective of the activity and to further refine and deepen students' understanding of the material. The instructor was able to sketch diagrams and provide solutions spontaneously in real time, thus engaging and promoting student-directed learning through a creative, interactive, and dynamic process.

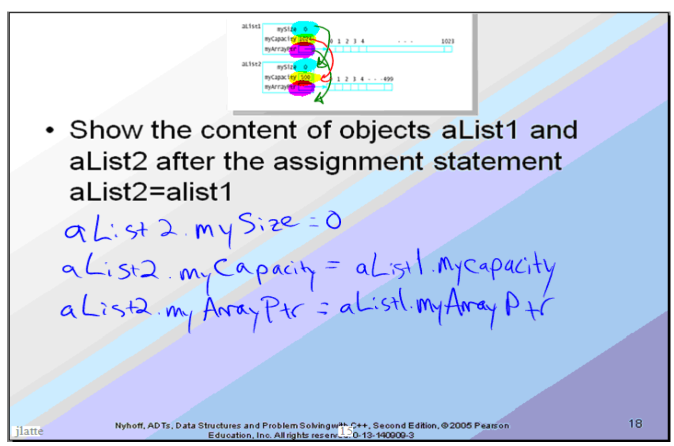

Figure 5a. A Correct Response

In another activity, the instructor's objective was to assess students' understanding of why the assignment operator should be overloaded in structures using dynamically allocated memory. By looking at the students' submissions, the instructor received immediate feedback on students' understanding or misunderstanding of the topics covered. The student responses shown in Figure 5a prompted the instructor to pose more questions, which eventually led to a discussion of shallow vs. deep copying. It also shows a brief, yet correct, response where this student used both graphics and text to summarize the impact of shallow copying.

This activity was designed to be minimal with no elaboration as the instructor was looking for the type of graphics shown in Figure 5b. Denning et al. [2] indicate that students tend to elaborate on minimally required answers, as demonstrated in Figure 5b. They continue to remark that such elaborations are pedagogically desirable for further exploration of the problem and the follow-up discussion points. The student submitting the question on Figure 5c appeared to be lost and needing directions. Nevertheless, an interesting question was raised about the system crashing. Because most structures in a computer science course have a linked implementation, it is essential for students to have a good grasp of pointers.

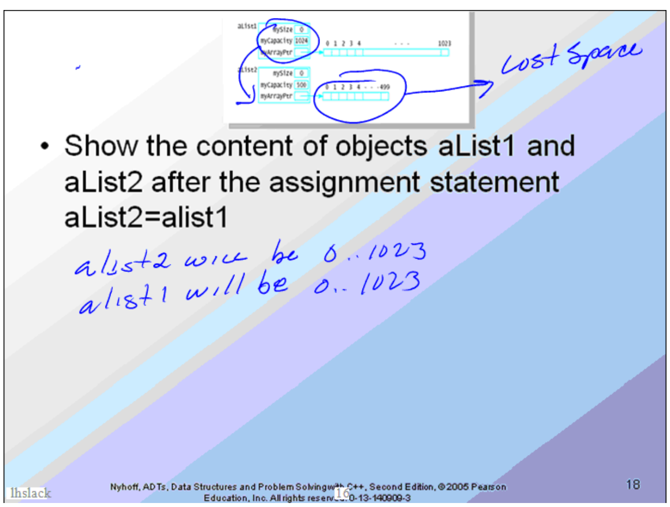

Figure 5b. Shallow versus Deep Copy

In another activity, the instructor asked students to delete a node from a linked list. This required some pointer re-engagement; this is because the order in which the pointers are rearranged is crucial for correct operation. The pointer variable *ptr* is pointing to the node preceding the node to be deleted. This routine process must be well understood by students. Figure 6 shows two submissions. In both cases, the order of steps for deletion is incorrect.

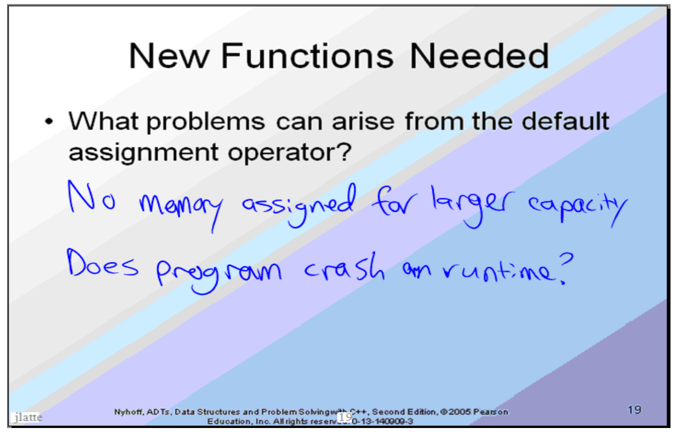

Figure 5c. Interesting Student Question

In Figure 6a, the student is rearranging the pointers out of sequence; in Figure 6b, the list is updated but the node is not returned to the system, i.e., memory leakage. This generated many useful discussion points. The instructor guided students through the code and demonstrated why the code would not work. Enabling students to make a connection between new concepts and their program implementation is an important task in computing education, and that task was made easier by tying the visual representation of the solution to the code.

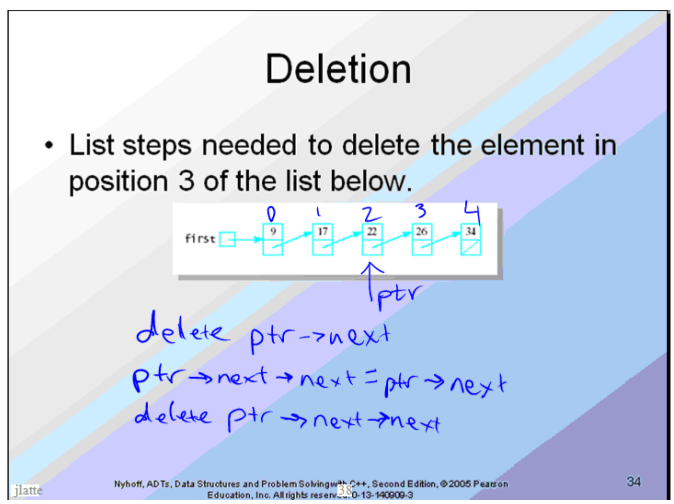

Figure 6a. Linked List Exercise a

In the final example from the Data Structures and Algorithms course, students were asked to insert a key into a heap structure. The objective of the instructor was to force students to reflect on the heap structure and work through a seemingly simple algorithm. Although all the students indicated that they understood the algorithm, a significant number failed to correctly demonstrate the insert algorithm (see the sample submission Figure 7). This is another good example of how student responses enabled the instructor to digress from the planned lesson spontaneously to clarify a point. Surprisingly, one student sent the slide shown in Figure 7a, an array implementation of the heap, which raised a number of interesting discussion points. Unlike other submissions, this student had decided to use the array representation of the heap, which was unusual because the tree representation is more intuitive and more common. This prompted the instructor to ask students to recall the formulation for the left child, right child, and the parent node in an array implementation of a heap. Furthermore, the heap constructed by the student turned out to be a minimum heap when maximum heaps had been the focus of discussion in the class. This enabled the instructor to launch a discussion on the minimum-heap property.

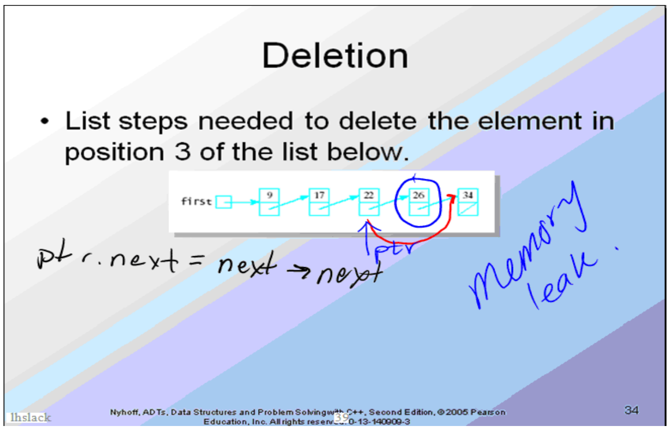

Figure 6b. Linked List Exercise b

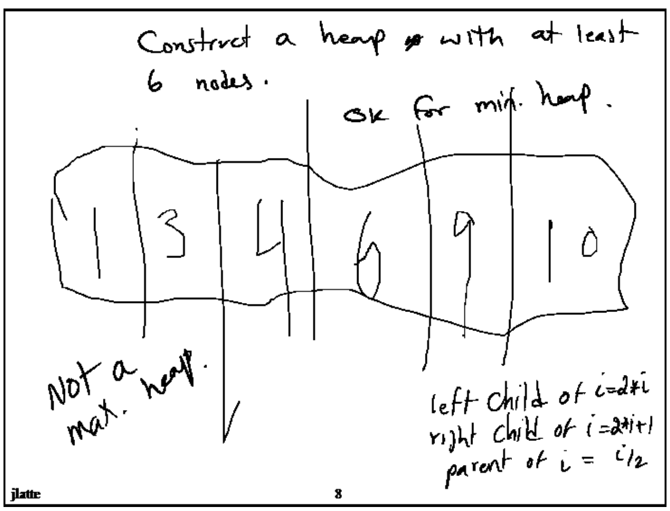

Figure 7a. Array Representation of Heap

In a related activity, students were asked to use the insert algorithm to enter an element into a heap. One submission, shown in Figure 7b, clearly indicated that the student had not followed the discussion of the insert algorithms and had simply used a Binary Search Tree insert algorithm. The interactive slides were highly useful in generating discussion on how to correct student misunderstanding, misinterpretation, and mix-up of structures and algorithms.

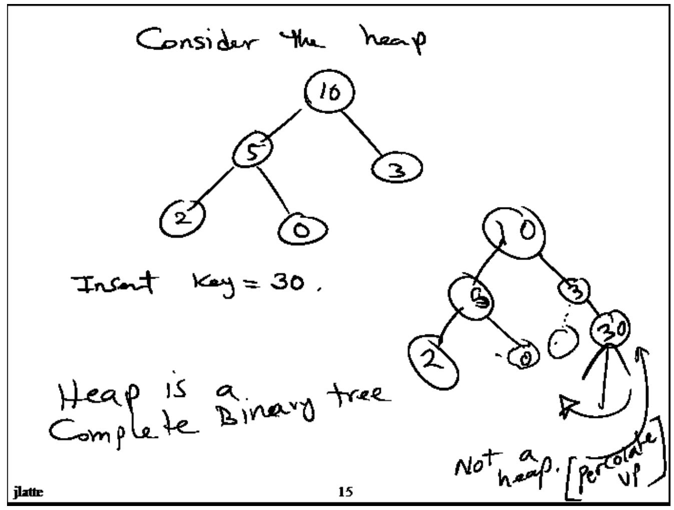

Figure 7b. Adding an Element to a Heap

Wireless Economics Topics Course: Small Group Exercise

The nature of the Wireless Economics Course made it particularly suitable to incorporate small group exercises. During the class, the instructor set up several small groups, each consisting of three to four students working together on exercises like the one shown in Figure 8. This was done through a simple menu on the instructor's Tablet PC.

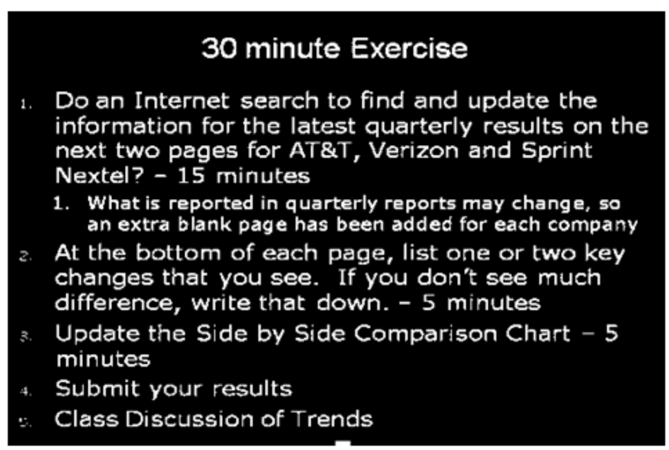

Figure 8. Small Group Exercise

In each small group, the students shared a common screen on their Tablet PCs, so that whatever was drawn, written, or typed on the screen by any student in the group could immediately be seen on the tablets of all students in that group. Small groups were set up among students sitting close to each other in class, so that it would be easier for the group members to carry out their discussions. At the end of the exercise, the small group was dissolved by the instructor so that there was no longer a shared workspace among the students who had been in the group.

The exercise required the small group to find current quarterly report data for a particular wireless operator, compare it with an earlier quarterly report shown by the instructor, and then comment on key changes. Each small group was given a different company to research and discuss. Figure 9 shows the results submitted by one small group. None of the small groups had difficulty finding quarterly report data on the Internet, writing it down, and submitting it; see Figure 9a. However, they were unable to effectively comment on the data or discuss the key differences in the present and previous quarterly reports.

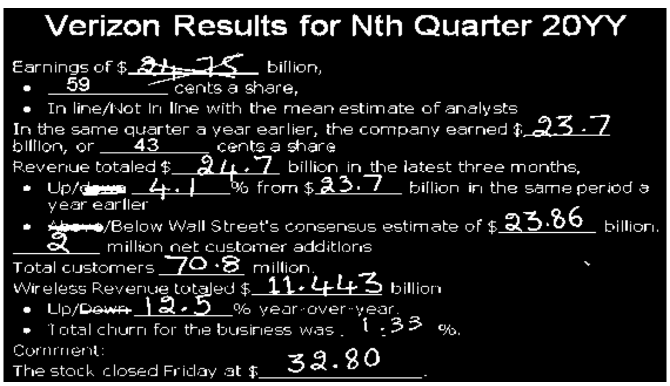

Figure 9a. Quarterly Results Data

Figure 9b. Discussion of Key Changes

The intent of the instructor was that they move to a higher level of Bloom's Taxonomy and come up with a group view of the key differences between one quarterly report and the next. Instead, as shown in Figure 9b, they simply cut and pasted the analysts' comments from news articles they had found. This activity helped highlight one of the key problems in designing good interactive exercises. Students will be lazy about thinking, if they are given the opportunity. Careful design of interactive exercises is needed to get students to synthesize and analyze. Exercises that require more thought are more valuable, but they take more time both to develop and to administer.

Findings

Impact of Interactive Exercises on Speed and Depth of Student Learning

The experience of the four instructors provided good evidence of the positive impact of interactive exercises on Tablet PCs, but more quantitative evidence is necessary to address hypothesis #1. This was obtained by comparing grades on the same midterm and final-exam questions in the Wireless Systems Security course before and after the introduction of Tablet PCs and interactive exercises. The results are shown in Table 2.

Table 2. Impact of Interactive Exercises

Description of Questions	% of Students Answering Correctly				Average Improvement
	Base line Oct-07	Jan-08	Jul-08	Jan-09	Percent Change
Eselbrücke	22	88	95	71	285
Use Vigenére Tableau	11	81	89	72	633
Polynomial Representation	33	75	95	94	267
Encrypt Short Message	11	69	88	78	503
Cipher Block Chaining	11	50	40	22	339
Average of the five Questions	18	73	81	67	409
Number of Students	9	16	21	16	---
Avg Grade overall	77	84	85	83	9

The results from Table 2 clearly demonstrated that the average improvement varied between 267~ 633%. One of the exam questions for all WCM 605 classes, labeled by the German word "Eselbrucke" in Table 2, required students to generate a passphrase, extract a password from it, then discuss how it satisfied the requirements for strong passwords. Exam scores on this question improved from 22% correct answers for the October 2007 class to 88% correct in January 2008, 95% correct in July 2008, and 71% correct in the January 2009 class. This amounts to an average improvement of 285%. The Wilcoxon signed-rank test, a non-parametric statistical hypothesis test was used to assess whether their population means differ. {T(positive) = 0; n = 8; p < 0.02 (two-tailed) --> Significant difference}

Other questions dealt with concepts such as expressing a digital string as a polynomial; encrypting and decrypting a short message using substitutions and transpositions; using a complex structure known as a Vigenére tableau in encryption and decryption; and, using cipher block chaining for encryption. Results from specific exam questions in the October 2007 class showed that these were all difficult skills for students to acquire. January 2008, July 2008, and January 2009 results of the same questions (with details of the questions suitably altered to prevent cheating), showed dramatic improvement.

Table 2 shows that, on average, the number of students answering the questions correctly improved from an average of 18% correct answers on these five questions in October 2007 exams to a weighted average of 74% correct answers on the combined results of January 2008, July 2008, and January 2009 exams, thus showing a remarkable 409% improvement. In addition, the overall weighted average of grades on the combined results of the January 2008, July 2008, and January 2009 exams improved by 9% from 77.2% to 84.2%. These results are based on a combined enrollment in the three classes of 53 students.

The October 2007 class, with only 9 students, serves as a base in Table 2. A larger base was desirable; however, the results were so encouraging that the university was not willing to penalize students by running a class without using the Tablet PCs, solely to increase the size of the base sample. Unfortunately, data from a July 2007 WCM 605 class was not collected in sufficient detail to analyze individual questions. However, the average grade on the comparable exam, taken by ten students in July 2007, was 80.3%. The use of the Tablet PC approach to teaching the most difficult concepts was undertaken because of the recognition of difficulties encountered by students in both the July and October classes in absorbing these concepts.

The data in Table 2 show some variation of results across the particular questions studied. For example, the ability to encrypt a simple message by hand improved from 69% correct in the January 2008 class to 88% in July and then dropped slightly to 78% in January 2009, while the ability to understand cipher block chaining declined from 50% in the January 2008 class to 40% in the July 2008 class, and then to only 22% in the January 2009 class. But only 11% of the students answered these questions correctly in the base October 2007 class, so the average of a reasonable sample of students showed significant improvement for all questions. These data, taken together with classroom experiences of the four instructors, confirm the first hypothesis, namely that students learn complex data structure concepts faster and more completely when Tablet PCs are used appropriately in the classroom. As discussed by Dey et al. [17], the use of Tablet PCs with interactive software in class introduced a metacognitive strategy that forced students to use or apply concepts almost immediately after the concepts were taught. As a result, their skill in employing the new concepts was made more accessible to them.

Student Questionnaire Results

Following receipt of approval of the survey instrument by the National University Institutional Review Board, 42 students completed anonymous surveys about their experience with using Tablet PCs. These surveys were conducted near the end of the first class in the Master of Science in Wireless Communications (MSWC) degree program, again near the end of a class in the middle of the program and, finally, near the end of the last class before their Masters Research Project. Students answered using a five-point Likert scale. They were also invited to add comments to some of their answers. The text of the survey is shown in Table 3.

Results of the survey are shown in Table 4 and a sample of student comments is shown in Table 5. Students clearly agree that use of the Tablet PCs with DyKnow helped them remain more engaged in learning than in classes without student computers. Of particular interest is that there is a clear consensus among students that classes equipped with Tablet PCs kept them better engaged than those equipped with laptop or desktop computers. It was expected that results for the third question would be somewhat lower than for the second question but, surprisingly, they are nearly the same. A sign test used ($n = 5$, $p = 0.5$; $P(X \le 2) > 0.4$) failed to detect significant difference (p-value > 0.05). Although the sizes of the classes were small, the comments and responses received are significant and consistent, supporting the use of Tablet PC improves student learning. Even with the smaller classrooms, the Dyknow with Tablet

PC provides an opportunity to share student submissions with the entire class on a real-time basis. The sharing facilitates a richer discussion of the topic among class participants, thus improving student learning.

Table 3. Student Survey

- Use of the Tablet PC helps me learn because it supports my learning style better than learning without the tablet.
- Classes taught with a Tablet PC keep me more engaged in learning than classes taught without student computers. Please comment on how the Tablet PC helps you to stay more engaged.
- Classes taught with a Tablet PC keep me more engaged in learning than classes taught with desktop or laptop computers for students. Please comment on how the Tablet PC helps you to stay more engaged than classes taught with desktops/laptops.
- The Tablet PC is a particularly effective tool for small groups working together on case studies.
- I used the feature of DyKnow Vision to review recorded classes.
- The ability to correlate my personal notes with a specific place in a recorded lecture helped me learn better.
- Use of the Tablet PC enabled me to learn new concepts better/faster because I was able to understand the way other students reasoned about a problem
- The ability to make submissions in class through my Tablet PC enabled me to ask questions that would have been hard to put into words.
- The ability to ask questions and/or interact anonymously in class through my Tablet PC enabled me to overcome or circumvent my inhibitions about asking questions in front of my classmates

While the score is slightly lower for student perception of how much faster they are able to learn new concepts (Question 7), it is still high. The results for this survey question may well have been skewed by the phrase, "because I was able to understand the way other students reasoned about a problem" at the end of Question 7. In addition, the significance of the results for Question 7 in the last class is uncertain. Because the sample size was small in the last class, data is continuing to be gathered to determine whether the students' learning experience is not helped as much by the time they reach the end of their degree program, or whether this was simply an aberration, due to the small sample size in the last class.

Table 4. Survey Results – MSWC Program

Program Survey Questions	Initial Class	Middle Class*	Last Class	Weighted average
Number of Responses	10	26	7	-----
Better support for my learning style	4.20	4.36	4.43	4.32
Better engaged in learning than without student computers	4.50	4.42	4.57	4.47
Better engaged using Tablet PCs than with Desktops/ laptops	4.40	4.31	4.71	4.39
Very effective for small groups	4.40	4.15	4.57	4.28
Learned new concepts better/ faster	4.20	4.27	4.0	4.21

Table 5. Sample of Student Comments

- "It was more of an interactive session with students with Tablet PC"
- "…the polls and the problems we needed to solve helped me to stay more engaged in the class"
- "The Tablet PCs help me stay organized"
- "I'm really impressed with the Tablet PC. It's really good for listening in classes."
- "It was new way to learn so it took some time to adjust to it"
- "There are disadvantages with this as I am unable to keep eye contact with the professor"

Overall, the results clearly support the second hypothesis, “Use of Tablet PCs in the classroom enables students to remain engaged in learning during the longer classes that are typical of accelerated learning environments.” And the results are consistent across widely different classes and times in this degree program. A number of student comments on the survey were quite interesting, and several comments supported both hypotheses.

Virtually all students appreciated the increased interaction brought to the class by the combination of Tablet PC and DyKnow software. This led students to stay more engaged. And the ability to associate notes with each chart presented helped students stay more organized. However, students also commented that it took them some time to adjust to a new way of learning. Some others expressed concern about eye contact. This latter problem was addressed by projecting the instructor’s display on a screen at the front of the classroom, simultaneously, with the pushing of charts to students via the wireless connection. One student complained that he preferred a full page rather than the somewhat smaller display of the Tablet PC.

Digital Ink

One additional finding, though not a new finding, came more from instructors than from students. Students and instructors in National University classes who taught with Tablet PCs reported increased empowerment and efficiency, which they credited to the Digital Ink capability of the system. As noted earlier, similar results have been reported by others. [11-13].

Instructors found the added capability to highlight and handwrite clarifying notes—particularly equations—directly onto PowerPoint slides to be highly useful. Instructors found that using a stylus on a Tablet PC is as effective as writing on a physical whiteboard in an on-site class. The ability to emphasize points on a PowerPoint slide by circling the points at the time the instructor is talking about them helps students to follow the lecture better. And, this is a very efficient substitute for the time-consuming process of animating Microsoft Power Points. Digital Ink makes it easy for instructors to amplify points on PowerPoint presentations by writing equations or drawing diagrams directly on the charts.

One instructor, who readily admits to being computer-challenged, stated, "If I can learn how to teach with a tablet, anybody can!" Another instructor said, "The tablet gave me the power to teach." This latter’s comment is a particularly significant statement as it was made by a professor who was selected from approximately 200 faculty members as National University’s Outstanding Teacher of the Year in 2002. After teaching an on-line course with a Tablet PC, one adjunct professor declared that he would not teach another on-line course unless the university always provided him a Tablet PC to use while he taught. On-line students were particularly enthusiastic about the use of Digital Ink by instructors. They stated that it is a "tremendous improvement” in teaching. In principle, on-line instructors can draw on their desktop or laptop computer with a mouse. However, most instructors have not developed the fine motor control that is required to use the mouse this way.

Conclusions

Both hypotheses were confirmed by the results of this two-year-long use of Tablet PCs with DyKnow software in teaching five different graduate courses and four different undergraduate courses. The availability of Tablet PCs is now being extended to all courses taught in the School of Engineering and Technology (SOET). Purchase of a new server for running the DyKnow server software has been completed. This server will be installed in the SOET building to ensure that Internet delays do not cause problems with response time.

The experience with introducing real-time interactive exercises into on-site classes is popular with students and has improved scores on student exams. Equally important, the combined systems promoted critical and innovative thinking by students in the classroom. Sharing and discussing student submissions in real-time enabled deeper discussion of the topic at hand and in clarifying misunderstandings. Students gained a better and a deeper understanding of the material being taught. Not only has this project captured quantitative data to support these assertions, but it has also succeeded in confirming through the results of students’ surveys that both the instructor and his/her students find that using this approach for teaching complex engineering concepts has positive benefits.

The success reported in this project is now being expanded to introduce more realism into classes as student engineering teams compete to develop the “best” engineering designs (networks, radios, etc.) by using interactive games that are designed and built by the students themselves. We anticipate wider acceptance of Tablet PCs in academics.

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INTERCONNECTED SYSTEMS IN ENGINEERING TECHNOLOGY

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Abstract

Systems engineering at the community college level is an often overlooked concept. Educators realize its importance, but the curriculum is already packed with other essential topics. This study looked at three different aspects of a proposed approach to systems engineering concepts at Queensborough Community College. The first application of systems engineering was a communication system project in the Computer and Electrical Devices Applications course. This project introduces the building blocks of a fiber-optic communication system including a transmitter, receiver and an amplifier. The stages were built by independent teams and then integrated to operate as a functional system.

The second example focused on meeting required systems-level specifications for a two-stage amplifier with a power supply. The students were given the specifications for the supply voltage, amplifier gain, and input and output impedances. The design project was divided amongst the teams, who then combined and tested the overall system.

Robotics was the third system application. Students integrated software programming and hardware design to produce a functional robot. Software teams developed and debugged programs which run on the robot's microcontroller. Hardware teams built and tested the hardware independently to ensure proper functionality. The teams synthesized their designs to satisfy the system design challenge.

Introduction

Systems engineering at the community college level is an often-overlooked concept. Even though educators may appreciate the importance of systems engineering concepts, it is somewhat difficult to include this material in an already packed curriculum. An engineering education should include systems engineering concepts because most complex engineering projects today focus heavily on systems engineering elements for their successful completion. These projects include the design of space craft, military weapon systems and both wired and wireless communication systems. One of the earliest mentions of the importance of systems engineering concepts was at AT&T Bell Laboratories in 1940 [1]. In fact, the National Council on Systems Engineering (NCOSE) was formed in 1990 to advocate and further the area of systems engineering.

Community colleges are a rapidly growing part of the U.S. higher education system and will become increasingly important in retraining the American workforce for the 21st Century. President Obama proclaimed that community colleges are vital to America's future competitiveness, and he envisions an additional 5 million graduates from these education institutions by 2020 [2]. This paper highlights the different aspects of our approach to introducing systems engineering concepts to the students at Queensborough Community College.

In the Computer and Electrical Device Applications course, a fiber-optic communication system consisting of a transmitter, receiver and a gain stage amplifier was introduced. The stages are built separately and the students then integrate them and try to get the system to operate from a system point of view. The Electronics I course focuses on electronic device applications such as amplifiers and power supplies. A systems-level analysis project requires the students to analyze a multistage amplifier with a DC power supply. The students analyze the individual circuits and then integrate their results to obtain the systems-level parameters.

In the software and hardware design classes, the concepts of robotics are introduced. The software class focuses on programming fundamentals and the project lab class focuses on hardware concepts. The Robotics Club builds on the fundamentals of the aforementioned classes and integrates the electronic, mechanical, and programming concepts involved in the analysis, design, and construction of robotic systems and focuses on systems integration of these systems.

Fiber Optics Communication System

The Computer and Electrical Devices Applications course places an emphasis on technology topics in computer engineering. The class discusses electronics applications in BJT switching and amplification, and the students perform related experiments. The course also introduces Programmable Logic Devices (PLDs), by using very high speed integrated circuit hardware description language (VHDL) to program a field programmable gate array (FPGA).

The course also includes systems engineering activities. This study focused specifically on this area of the course. The project of interest is one where the students build a simple fiber-optic communication system in discrete stages and then integrate them to make a complete system. The challenges in this experiment are designed to mimic the constraints a student would face in real-world engineering-design problems. These challenges include:

- Time constraints
- System complexity
- Working with multiple teams
- Being judged on the work of the team and NOT the individual team member's performance

This laboratory experiment has to be completed in the three hours allocated. The groups work simultaneously to complete their own sub-systems in a single three-hour lab session at QCC. Typically, students who pace themselves and accept the challenge are able to work efficiently and complete the assignment within the time constraints. However, easily distracted students do meet the time constraints.

One of the challenges of this laboratory exercise is to experience what it is like to function as a team to build a complex system. The individual stages consist of circuits that can all be breadboarded. These circuits contain components such as operational amplifiers (op amps), BJTs, and photodiode transmitter and photodiode receiver pairs. The entire system could be built sequentially by one team of students. However, the work is divided amongst three teams that work simultaneously. This divide-and-conquer method is a common practice for larger engineering projects. The work is divided into smaller, manageable portions in order to shorten the project development time. The team will then combine their work at the end of the experiment to build a larger system. The functionality of the larger system will depend on the success of each individual team's ability to deliver quality work and function as a member of a team. The total system is divided into three sections and each section has a team working to deliver a functional block.

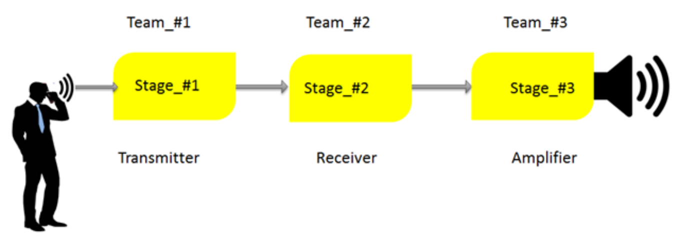

Figure 1. Fiber Optic Communication System

The system is made up of three stages and is divided amongst the three teams, as shown in Figure 1. The success of the system depends on the success of the individual teams. To emphasize this, the teams must combine their individual efforts to obtain an operational system. Each team must build, test and troubleshoot their individual stages. The stages are then combined to build a larger system. This entire system is integrated and tested at a higher level.

The students are judged on the work of the team and NOT the individual team member's performance. The grade for the lab will be evaluated on total, overall team performance and not on individual contribution.

Power Supply and Amplifier System

This section highlights the synthesis of a power supply and cascaded amplifier stages. The goal of the amplifier design is to obtain a voltage amplifier with the following characteristics:

- Relatively high voltage gain magnitude
- Relatively high input impedance
- Relatively low output impedance

The individual stages are synthesized into the amplifier system shown in Figure 2.

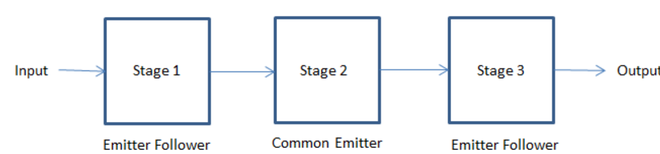

Figure 2. Amplifier System

The amplifier system typically consists of multiple stages, including common-emitter with voltage-divider bias and emitter-follower with emitter-stabilized bias configurations. The students learn that it is necessary to take a systems approach to the amplifier design in order to meet the given specifications of voltage gain, input impedance, and output impedance. The common-emitter stage provides relatively high voltage and current gains. The emitter-follower stages provide high input impedance and low output impedance, with a voltage gain that is typically slightly less than one. Stage one is an emitter-follower with gain $\mathbf{A_{V1}}$ and relatively high input impedance, $\mathbf{Z_{IN1}}$. Stage two is a common-emitter amplifier with relatively high voltage gain, $\mathbf{A_{V2}}$. Stage three is an emitter-follower with gain $\mathbf{A_{V3}}$ and relatively low output impedance, $\mathbf{Z_{OUT}}$.

The overall voltage gain, taking individual stage loading into account, is:

$$A_{V\,SYSTEM} = A_{v1} \times A_{v2} \times A_{v3} \tag{1}$$

The system input impedance is:

$$Z_{IN\,SYSTEM} \approx Z_{IN1} \tag{2}$$

The system output impedance is:

$$Z_{OUT\,SYSTEM} \approx Z_{OUT} \tag{3}$$

Typically, it would not be possible to design a single-stage amplifier with all of the desired characteristics. A block diagram approach is used to provide a synopsis of the amplifier system, and then the amplifier circuitry is analyzed in detail to find the overall voltage gain, input impedance and output impedance, based on each stage and the interaction between stages. The students learn very important system concepts such as the loading effect of each stage on the previous stage. Furthermore, the students learn that the overall voltage gain is the product of the individual voltage gains of the stages, taking loading into account. The amplifier and power-supply designs are synthesized into a complete system, which meets the design criteria.

Also discussed are Bipolar Junction Transistor (BJT) amplifier designs, including both the common-emitter and emitter-follower configurations with fixed-bias, emitter-stabilized bias, voltage-divider bias, and collector-feedback bias. Amplifiers based on Field-Effect Transistors are also discussed in the electronics course. The BJT amplifiers typically use voltage-divider bias for the common-emitter amplifier stage and emitter-stabilized bias for the emitter-follower stage because they provide good biasing stability and allow the Quiescent Operating Point to be centered on the load line for each stage. The students use the superposition theorem to analyze the circuit by first analyzing the DC -biasing circuit and then analyzing the AC equivalent circuit.

The students gain a deeper understanding of systems engineering problems by using component models and approximations, which hold in the normal active region of transistor operation. The fact that the optimum location of the quiescent operating point is at the center of the load line is evaluated in order to obtain the maximum possible symmetrical peak-to-peak unclipped output signal. In addition to the detailed analysis of the amplifier circuit schematic, the two-port representation of an amplifier system and the individual stages is discussed. The students learn that the input circuit of the amplifier can be represented by the input impedance and the output circuit of the amplifier can be represented by a Thévenin equivalent circuit. The two-port model can then be used to represent each stage of a cascaded amplifier system, which can be analyzed using a systems approach.

The discussion is then expanded in the electronics course beyond the amplifier to include the analysis of a linear DC power supply consisting of a transformer, full-wave bridge rectifier, capacitor filter, and voltage-regulator circuit, as shown in the block diagram in Figure 3.

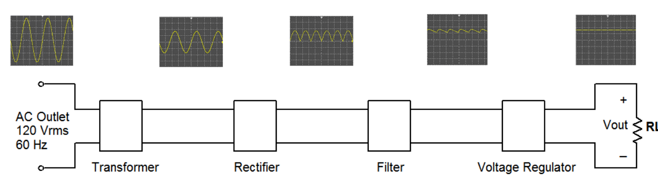

Figure 3. DC Power Supply Block Diagram

The voltage regulator contains a series pass transistor, zener diode, and resistors. The power-supply circuit is analyzed in stages beginning with only a transformer and rectifier and culminating in the analysis of the entire circuit. A block diagram is used to represent the function of each stage and then the power-supply circuitry is analyzed in detail. The DC component and approximate AC ripple-voltage component are calculated at the output of the filter stage and then at the output of the regulator stage. A laboratory experiment is performed where the students analyze and construct an entire DC power supply.

The students solve analysis and design problems related to amplifiers and power supplies on homework assignments. The design problems consist of power supply and amplifier circuits, where the desired currents and voltages are provided and the students have to calculate the required component values or the required power supply voltage for an amplifier. Most of the students are able to complete all of the analysis problems perfectly. However, the design problems present a much greater challenge.

The students build amplifier and power-supply circuits in the laboratory, which they also analyze theoretically. The measured results are compared to the theoretical results using percent difference calculations and the students are asked to explain the sources of discrepancies in their laboratory reports. A systems-level approach is taken in the analysis where, for example, the behavior is compared to home stereo equipment. The operation of an amplifier circuit is also simulated using circuit simulation software and the results are compared to the measured and calculated values. Therefore, the students obtain real-world experience in the systems design process. They also observe the importance of the final system design step, which includes breadboarding, and taking measurements. The final design step will often indicate that the design may need to be modified to function properly.

The amplifier analysis is performed using an ideal model for the DC voltage source in order to simplify the schematic. After performing the complete amplifier analysis, the overall amplifier and power-supply system is represented by a block diagram. The complete schematic of the amplifier and power-supply system is then drawn showing the circuitry of the actual amplifier and power-supply sections in detail. This system is a synthesis of the amplifier and power -supply subsystems, along with many of the concepts presented in the DC circuit course, AC circuit course, and the electronics course.

Robotic Systems

A robotic system is the third example of our approach to teaching systems concepts. The goals are to design robotic systems which utilize the following ideas:

- Hardware modules
- Software concepts
- System Integration of hardware and software

In the hardware project laboratory, the hardware modules that are common to all robots are examined. These include contact and infrared sensors, closed-loop control systems using a microprocessor, servo motors and H-bridge motor interfaces in robotics applications.

Students are required to complete a project laboratory in which they build a programmable robot. The project class is a requirement for students completing the Computer Engineering Technology degree program (A.A.S.). The approach to the hardware project laboratory class at QCC focuses on digital and analog electronic circuit theory, and some mechanical concepts. The learning objectives are for students to understand electronics as related to applications in robotics. Students also obtain practical experience in troubleshooting electronic circuits and motor controllers, as well as using effective instrumentation and measurement techniques. The students should have prior knowledge of digital systems, including memory, memory interfacing and I/O systems. The students also need to know the basic theory and operation of electronic devices including semiconductor switching diodes, zener diodes, and transistors. The students use the schematic and block diagrams to troubleshoot the digital and analog electronic systems of the robot in order to solve any functional problems, as shown in Figure 4.

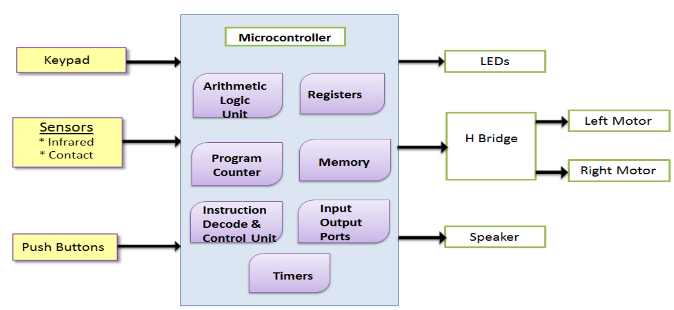

Figure 4. Typical Robotic System Block Diagram

The unique feature of the robot used in the project lab class is that it consists of discrete subsystems, which include power supplies, clock oscillators, memory, digital logic circuits, transistor drivers, and motors. The students build and test each of these subsystems in a sequential manner, and then integrate them into a functional robot. The students build a programmable robot from components in stages, which are then integrated into an autonomous system. The components are soldered to a printed circuit board, which is then mounted to a mechanical chassis assembly that consists of motors and gears. The motors and gears used in the mechanical assembly of the robot provide the steering function. The robot is then programmed by a keypad to follow the designated instructions.

To program this robot, instructions are fed through a keypad that connects directly to the memory load sequence circuit, which incrementally loads each command into memory. The instructions for the robot are programmed into memory in the desired order such that the robot can navigate through its environment. The robot exits the programmable mode and enters the execute mode upon removal of the keypad. The instructions are read from memory in the order in which they were programmed and are repeatedly executed in a continuous loop. This method is fully utilized in a robot that has to perform monotonous tasks such as those on a manufacturing assembly line. Students gain a great deal of exposure to analog, digital and mechanical theory by building this robot. They have the opportunity to observe how all of these systems work individually and together as a whole.

The software class focuses on programming applications as they relate to robotics. The programming class builds on the aforementioned hardware concepts to introduce topics in robotic control from a software point of view. The programming class uses Visual Basic to reinforce programming concepts. Once the students have mastered these topics, they begin to use their knowledge of robotics hardware and software to solve a challenge. Students learn how to control the servo motors by using pulse width modulation (PWM) at the appropriate microcontroller output. Students write the interrupt service routines that will process any interrupts generated. The students apply programming concepts such as looping, decision making, processing and I/O operations to autonomous robotics applications.

After the hardware and software fundamentals are established, the students are given a design challenge. The challenge is to build an autonomous robot that will exhibit random wandering with object detection and avoidance behavior. This challenge is divided into several manageable tasks, which are implemented by various student teams. These tasks include object detection, motor control, obstacle avoidance, and displaying status information.

Object detection can be handled in one of two methods. The students can use a sensor, which is designed to open or close a switch upon contact with an object. The change in the state of the switch generates an interrupt, which is serviced by the microcontroller. An alternate method is to use an infrared sensor to detect a reflected light beam of an object ahead. The preferred method is the non-contact technique, which uses infrared sensors. After the robot has detected its proximity to an approaching object, it uses that information to avoid contact. The robot uses two sensors to detect whether the obstacle is on the left or right side. The robot uses this knowledge to pivot or turn in order to navigate around the object. When necessary, the software is used to alter the direction of the robot's movement by controlling the pulse and duration of either the left or right servo motors. The challenge comes from the student having to generate the code needed to turn the robot by +90, 180, or -90 degrees.

The work done by the three teams is synthesized to obtain an autonomous robot that will execute random wandering with obstruction-avoidance behavior. The microcontroller program must monitor the sensors, process information by executing computation and decision-making statements, and then update outputs. Monitoring the sensors and updating the outputs requires the consideration of real-time constraints, which are unique to embedded systems programming and robotics. The flowchart of Figure 5 demonstrates the algorithm needed to accomplish this task.

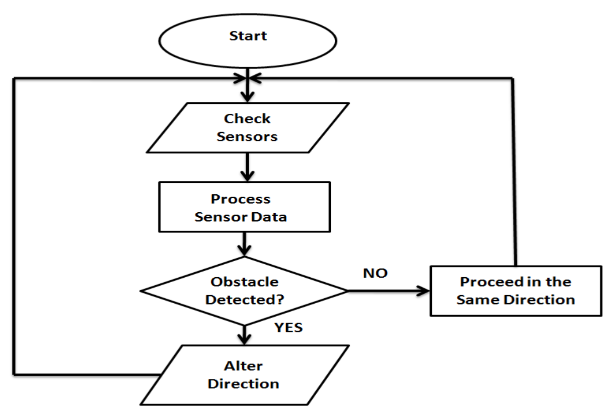

Figure 5. Design Flow Chart

Summary

Systems engineering concepts are divided among various courses in the curriculum at Queensborough Community College, in spite of there not being a dedicated systems engineering program. It is an important, but sometimes overlooked, concept. For the success of any real-world engineering product, hardware and software developers must work in groups for efficacious product design and implementation. The characteristics of a systems engineering approach are: Teams work in parallel to shorten the development cycle; complex projects are broken down into simpler and more manageable modules; and overall success of the project depends on each team delivering a quality subsystem. These subsystems are then synthesized into a larger system. The concept of team recognition is appreciated rather than just recognizing the contributions of the individual members.

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GO FOR AEROSPACE!: RECRUITING THE NEXT GENERATION OF ENGINEERS

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Abstract

For our nation to maintain its competitive edge in the global economy, the pipeline of interested and qualified students prepared to enter science, technology, engineering and math (STEM) careers must be increased. To help address this problem, Central Connecticut State University received funding from NASA to conduct an innovative, extracurricular program, "Go For Aerospace!" (GFA). Currently entering its third year, GFA reaches out to high school juniors, especially those from underrepresented groups, with high potential in math and science and fosters their interest in engineering and related fields.

The year-long program begins in the fall with a kick-off event for students and parents. In the spring, students work with university faculty and students on engineering projects and visit industrial aerospace facilities to tour labs and speak with practicing engineers. The program culminates with a 10-day residential Summer Institute. Students spend four days on campus participating in varied activities, including a rocket design competition and 3-D simulation workshop; they next travel to NASA's Goddard Space Flight Center for a four-day visit where they learn about state-of-the-art technology firsthand from NASA scientists and engineers.

To evaluate the immediate and longer-term impact of GFA, research is being conducted using the National Science Foundation-funded AWE pre-college outreach surveys. Data is also being collected on the future college choices of participating students. Through a follow-up, multi-year study, we will be able to assess the overall effectiveness of our approach and make continual improvements to the program.

Introduction

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

Long-term growth in the number of positions in science and engineering has far exceeded that of the general workforce, with more than four times the annual growth rate of all occupations since 1980 [1]. Recent occupational projections from the Bureau of Labor Statistics [2] forecast that total employment in engineering fields will grow by approximately 10% between 2008 and 2018. While the outlook varies by discipline, aerospace engineering is expected to follow this trend in response to a growing demand for new technologies and new designs for commercial and military aircraft over the next decade. Thus, the employment outlook for aerospace engineers appears favorable.

In spite of these promising job prospects, recruitment for science and engineering programs is a real challenge for most universities nationwide. According to the recent Congressionally requested report, Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future, in South Korea, 38% of all undergraduates receive their degrees in natural science or engineering. In France, the figure is 47%, in China, 50%, and in Singapore, 67%. In the United States, the corresponding figure is only 15% [3]. This is one of the most serious issues our nation will face over the next decade, as the current science and technology workforce retires without a pipeline of workers to replace them. The aerospace industry is one such example of this looming crisis. Of the 600,000+ aerospace workers employed in 2006, ~26% are eligible for retirement this year, but only 40,000 graduating engineers are qualified to work in the industry [4].

Although the number of degrees granted in aerospace engineering has begun to increase after many years of decline, new graduates continue to be needed to replace aerospace engineers who retire or leave the occupation for other reasons [2]. If the United States is to maintain its competitive edge in the global economy, the pipeline of interested and qualified students prepared to enter STEM careers must be increased. Yet recent results from a survey by the American Society for Quality (ASQ) revealed that more than 85% of students today are not considering careers in engineering and that more parents encourage their daughters to become actresses than engineers. Forty-four percent (44%) of survey respondents cited a lack of knowledge around engineering as the top reason they would not pursue such jobs. Another 30% listed the "geek" perception as their top reason, indicating that "engineering would be a boring career," according to the ASQ [5].

Equally alarming, international comparisons of student mathematics and science performance indicate that U.S. students scored below average among industrialized countries [6]. Out of the 57 countries participating in the 2006 Program for International Student Assessment (PISA) examination, which is designed to assess students' abilities to apply scientific and mathematical concepts to real-world problems, U.S. 15-year-olds scored lower than 23 and 31 nations in science and math literacy, respectively [7]. Furthermore, the retention rate for engineering students is one of the lowest among all college majors; one-third of all U.S. students intending to pursue engineering switch majors before graduating [3].

Demographic Disparities in Math and Science Achievement

According to the National Science Board's Science and Engineering Indicators 2008 [6], there are significant racial and ethnic gaps in science and mathematics performance, as evidenced by studies that follow the same groups of students as they progress through school. These studies "reveal performance disparities among demographic subgroups starting when they enter kindergarten… Although all subgroups made gains in mathematics and science during elementary school, the rates of growth varied and some of the achievement gaps widened." Similar gaps were observed in rates of immediate college enrollment for Black and Hispanic students as well as those from low-income and poorly educated families, who trail their white counterparts, or those from high-income and well-educated families [6]. Connecticut has the largest achievement gap between urban and suburban school districts in the country, with the greatest concentration of population in the cities and ring-towns. The largest cohort of our future workforce is comprised of these most at-risk students [8].

The outlook is also bleak in higher education. Nationwide statistics [9] show that in 2003, 68.3% of engineering degrees were awarded to Caucasians, 14% to Asian-Americans, 5.1% to African-Americans, 5.4% to Hispanic students and 7.2% to others. It is important to note that since 1999 there has been a declining trend in the number of Hispanic and African-American students among all engineering graduates. At the same time, the percentage of bachelor's engineering degrees awarded to women is around 20%, another indication of the declining trend. For women in mechanical and aerospace engineering, the numbers are only 13.2% and 18.8% respectively.

Effects of Early Experiences on Interest, Retention, and Success

The idea to engage students in early, hands-on experiences as an authentic scientist or engineer is not a new one. However, it is only in recent years that extensive, formal research examining the outcome of these opportunities has emerged. According to the 2008 Science and Engineering Indicators, "There is now a growing body of literature that examines the results of such efforts and analyzes them for their effect on at least one of the following outcomes: student attitudes toward science, student research skills, student confidence in his or her ability to become a scientist or engineer, and retention of students within the field" [6]. In general, these studies have shown increases in students' interest in and understanding of the research process and the strategies and tools that scientists use to solve problems, and a broader sense of career options in the field [10]. A number of studies found that students with a broader range of abilities as well as underrepresented minority students were more likely to stay in or switch to a science or engineering major and pursue science or engineering graduate education because of an early experience with a working scientist or engineer [11-15].

Local Aerospace Industry Workforce Needs

Connecticut has relied heavily on defense and advanced manufacturing industries to fuel the statewide economy with high-quality, high-paying jobs for several decades. Now, we are facing a critical window for economic transformation from an industrial base to 21st-century high-tech occupations. High-technology companies form a large, growing sector of the state's economy, with growth in STEM occupations projected at 13.5% from 2004 to 2014, compared with Connecticut's overall projected employment increase of 8.5%. The highest numbers of annual openings in STEM occupations are projected in the computer science and engineering fields [16].

There is a particularly strong need for graduates proficient in the area of aerospace engineering in Connecticut. Several large, internationally known companies employing aerospace engineers maintain a significant presence in the state, including General Dynamics and United Technologies Corporation and its subsidiaries: Sikorsky Aircrafts, Hamilton Sundstrand, and Pratt & Whitney. Additionally, there is a significant number of small- to medium-sized high-tech manufacturing companies in Connecticut that represent a critical component of the aerospace and defense industries' supply chain. However, recent statistics from the Connecticut Department of Labor in aerospace, computer and electrical engineering [17] suggest a gap between the projected availability of engineering jobs and the number of qualified graduates to fill them.

In a 2008 interview, the Commissioner of Higher Education in Connecticut drew attention to this gap, noting that while an estimated 754 engineering jobs would become available in the state that year, only 614 qualified graduates would be produced to fill them [18], a condition worsened by the known outflow of engineering graduates from the state [19]. According to regional graduate retention data [19], only 27% of graduates intend to stay in the area, while 45% plan to leave after graduation. This makes the shortage of engineers even more severe than statistics of openings versus graduates illustrate, and further highlights the importance of retaining young engineers in Connecticut.

To help meet our growing workforce needs, it is essential that higher education and industry join together and reach out to students to encourage their interest in the sciences, and provide mentoring and support as they graduate and go on to college. Central Connecticut State University (CCSU), with its cadre of well-qualified faculty, its central location, and its close ties with local industries and schools, can provide this mentoring and outreach and, specifically, can encourage student interest in mechanical/aerospace engineering and provide a quality undergraduate program. According to Connecticut State University System Statistical Reports, over 85% of CCSU's undergraduates and 91% of its graduate students remain in the state, positioning the University as a key player to alleviate shortages in the mechanical engineering/aerospace specialty areas.

Program Description

Overview and Objectives

CCSU received funding from NASA to conduct an innovative, extracurricular program, "Go For Aerospace!" (GFA). This year-round program for high school students and teachers is designed to foster students' interest in and readiness for participation in aerospace engineering and related fields. The GFA program has the following specific goals:

- Expose high school students, especially those from underrepresented groups, to career paths related to aerospace engineering;
- Conduct research about the effects of the GFA program to enable rigorous assessment of this and other student outreach projects; and
- Contribute to the research knowledge base about STEM career preparation through dissemination of information about the program and its resources, and insight gained from the program's development and implementation.

Selection Process

The selection process is an extremely important part of the entire project. Results from surveys of technology students (Figure 1) indicate that math and science teachers can have a significant impact on the decisions of prospective engineers [20]. This important fact defined the strategy that we use to recruit each cohort of students. We began by first assembling the math and science supervisors from several high-need school districts in order to provide them with an overview of our new program and the desired profile of qualified student candidates, i.e., high school juniors with high potential in math and science, who are undecided about their college plans. A recent survey of college graduates showed that 48% of those who chose to pursue engineering did so during grades 11-12 [21]. The district supervisors then passed this information along to their high school math and science teachers, who proceeded to nominate students for the program using application forms we specifically developed for GFA.

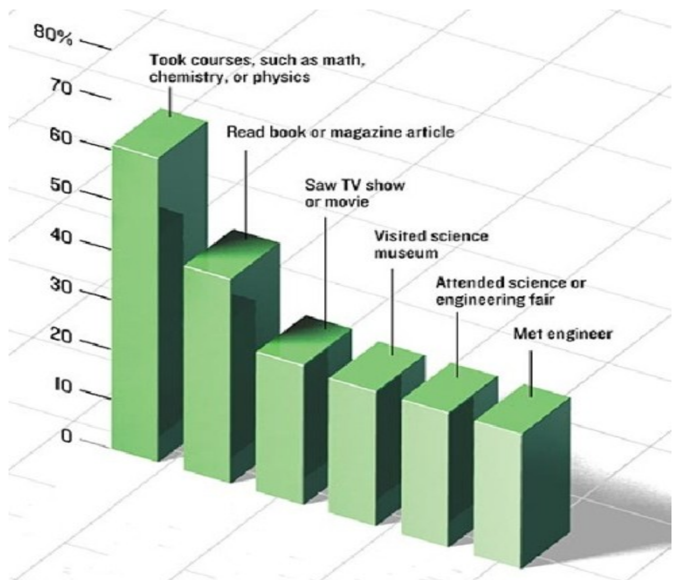

Figure 1. Activities that Inspired Survey Respondents to Consider Being an Engineer/Technology Professional

An overview of the year-long GFA program is provided in Figure 2 and each of its three main components are described below. We are currently in our third year of the program.

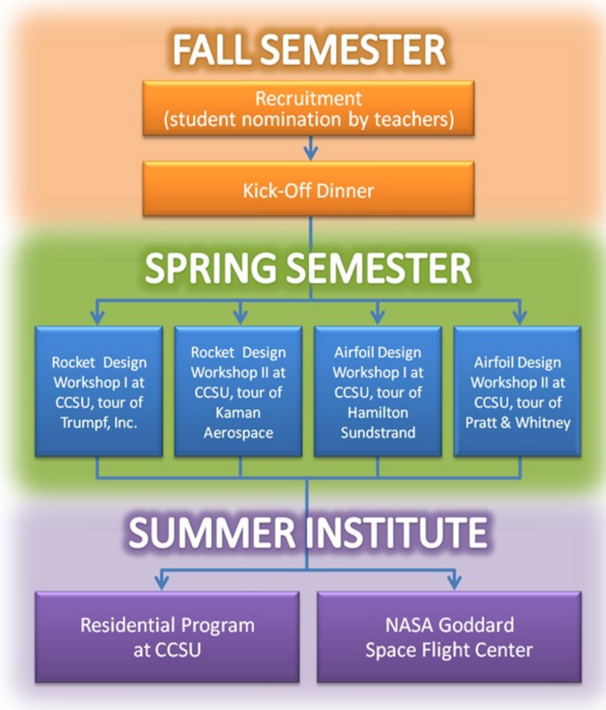

Figure 2. Go For Aerospace! at a Glance

Fall

Recruitment is conducted in early fall of each year of the program. The student selection process is an important part of the project and is accomplished through nomination by math and science teachers in four urban school districts throughout the state. This allows for identification and mentoring of talented students, especially among underrepresented groups, who might otherwise not pursue a degree in engineering and perhaps not even consider a college education at all.

Based on their recommendations, more than 40 high-achieving high school juniors have been selected over the first two years of the program (demographic data provided in Figures 3 and 4) and the current cohort consists of 45 students (demographic data compilation still in progress). Each year, a kick-off dinner has been held on our campus with keynote speakers including a Coast Guard Aviator and NASA Astronaut as well as an aerospace engineer, who designed equipment for multiple NASA missions and a woman, who is one of seven teachers selected nationwide as the first astronaut-teachers to participate in the nonprofit Teachers in Space program. Also in attendance at the kick-off were the University's President, Provost and special guests from industry and public education, as well as many of the students' nominating teachers and parents. In a recent installment in the Harvard Family Research Project's series of evaluation briefs, "Issues and Opportunities in Out-of-School Time," Lauver et al., list effective outreach to families among the key strategies for getting students into programs and sustaining their participation [22]. This underscores the importance of parent involvement.

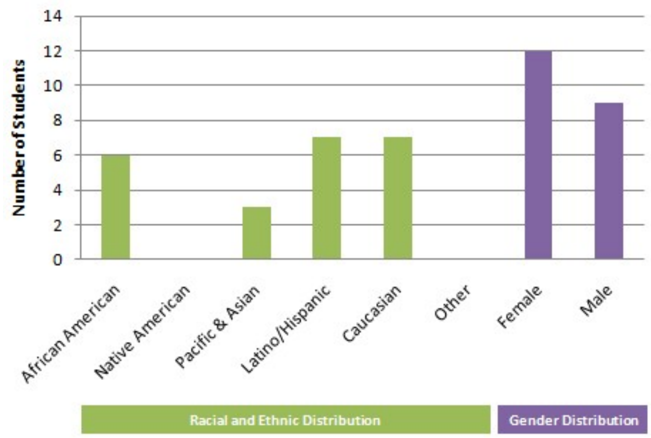

Figure 3. Race/Ethnicity and Gender Distribution of 2008-2009 Go For Aerospace! Participants

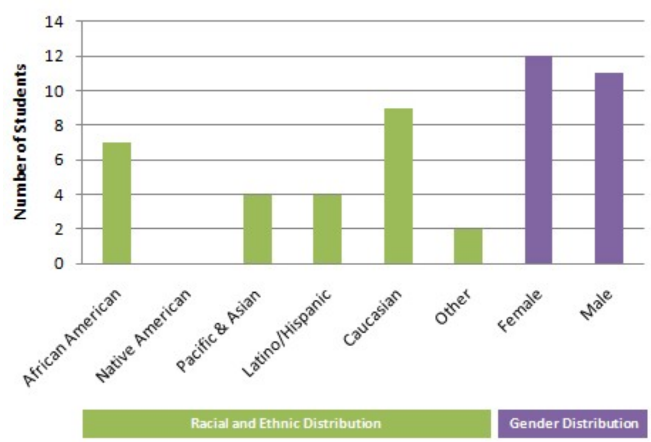

Figure 4. Race/Ethnicity and Gender Distribution of 2009-2010 Go For Aerospace! Participants

Spring

During the spring, students participate in four sessions, the aim of which is to provide an informed understanding of the engineering profession in general, as well as an appreciation of what a typical engineering job in the aerospace industry might involve. One Friday per month between February and May, students are transported from their respective high schools to our campus, where they spend the morning working with University faculty and students on projects related to mechanical and aerospace engineering. After lunch on campus, the students visit industrial aerospace facilities to tour research and manufacturing labs and speak with practicing engineers. Each month the students visit a different company.

Two workshops were developed specifically for the on-campus (morning) component of these spring sessions. Each is divided into two sessions so that the first workshop takes place over the first two visits and the second occurs during the latter half of the semester (see Figure 1, “Go For Aerospace! at a glance”). All workshops begin with a brief lecture introducing students to the relevant theory and its applications.

Rocket Design and Building Workshops

Teams of two students calculate the performance (thrust, altitude and flight time) and main geometrical parameters of a rocket using NASA’s Rocket Modeler software. They next use these parameters to design and build water bottle rockets from 2-liter soda bottles. The final event of this workshop is a launch competition (Figure 5) in which altitude is measured and compared with the calculated (theoretical) altitudes. Student teams receive awards for the highest altitude and best correlation between experimental results and theoretical predictions.

Figure 5. Undergraduate Assistant Helps GFA Student Prepare her Rocket for the Launch Competition

Airfoil Design and Testing Workshops

The objective of this workshop is to introduce students to the main principles behind flight dynamics. Using the fundamental laws of high school physics along with the concepts of lift and drag, students learn which wing and airfoil designs provide high lift and low drag. The main parts of airplanes and their functions are also introduced. These theoretical concepts are reinforced by a hands-on activity in which students use software to choose the geometry of an airfoil, which is then cut and tested to measure its lifting force (Figure 6).

Figure 6. Undergraduate Assistant Helps GFA Students Test Their Airfoil Designs

Summer

The program culminates with a 10-day residential Summer Institute. Students first spend four days on our campus participating in a wide variety of engineering-related activities that require team-building and hands-on inquiry to develop critical-thinking and problem-solving skills and encourage engineering creativity. These include materials testing and wind-tunnel experiments, as well as rides on our student-designed and built “Moon Buggy.” Students are also taken on a guided tour of the New England Air Museum (Figure 7) as well as the Connecticut Center for Advanced Technology, where they participate in a 3-D simulation workshop. An Apollo 13 movie night and planetarium show/observatory viewing are included in the scheduled evening activities, along with some unstructured but supervised time for the students to explore and familiarize themselves with the University campus recreational offerings, including the athletic facilities and student center. Our hope is that this experience will instill more confidence in any students who might feel apprehensive about living on a college campus.

A third faculty-developed workshop is another important element of the on-campus summer program activities. Building on their prior rocket-design challenge, students are this time tasked with designing, assembling and launching a low-thrust solid-propellant rocket. As with the first launch competition, altitude is measured and compared with predicted values and prizes are awarded to the best designs. The event is scheduled for a Saturday afternoon, immediately following a family brunch at which parents are provided with an overview of the itinerary for the upcoming five-day trip to the NASA/Goddard Space Flight Center (GSFC) and then invited to stay for the launch competition.

Figure 7. GFA Students at the New England Air Museum

The next morning, the GFA students, along with participating faculty members and undergraduate assistants, travel to the Goddard Space Flight Center in Greenbelt, MD, for a four-day visit, where they learn about state-of-the-art aerospace technology firsthand from NASA scientists and engineers (Figure 8).

Figure 8. GFA Student with NASA Scientist Aprille Ericsson

Program highlights include a visit to the nearby neutral-buoyancy lab at the University of Maryland, Baltimore County (Figure 9), as well as a guided tour through several of NASA's testing facilities. Students are also taken to the Smithsonian Institution's National Air and Space Museum in Washington, D.C.

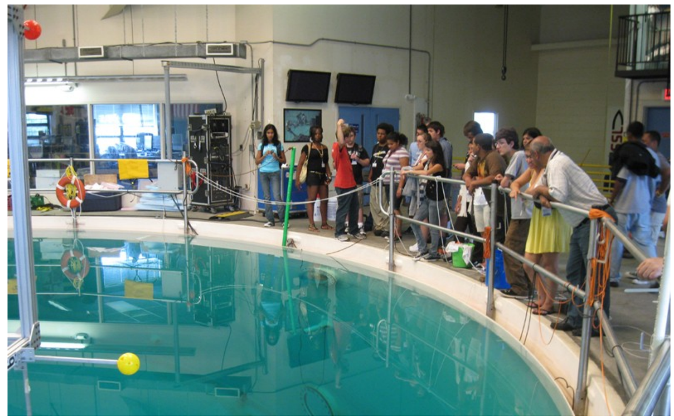

Figure 9. GFA Students at the University of Maryland's Neutral Buoyancy Lab

Program Assessment and Dissemination

A growing body of literature suggests that students' attitudes toward science, research skills, confidence in their ability to become scientists and engineers, and retention in these fields can be positively impacted by early exposure to and engagement with scientists and engineers working in the field. To evaluate the immediate- and longer-term impact of the GFA program activities on students' awareness of and interest in STEM-related fields, as well as their perceived preparedness to pursue STEM-related careers, research is being conducted using the National Science Foundation-funded AWE pre-college outreach surveys, "Pre- and Post-Activity Survey for High-School-Aged Participants – Engineering "[23]. These pre- and post-activity questionnaires are self-report instruments designed to measure the degree to which specific activities aimed at increasing interest in STEM-related careers have achieved their stated objectives.

Pre- and immediate post-program data was collected from participants before and after the 2008-2009 and 2009-2010 programs. Permission was obtained from CCSU's Institutional Review Board and students' identities were kept anonymous by use of identification numbers kept separate from survey instruments. All questions were optional. Figures 10 and 11 show students' responses to the question, "If you go to college, do you think you will pursue a career in an engineering-related field?", both before and after the 2008-2009 and 2009-2010 programs, respectively. Figures 12 and 13 show their responses to the related question, "In your future, do you think you want to be an engineer?" For both questions, the number of students responding "Yes" increased, with even greater gains realized in the second year of the program.

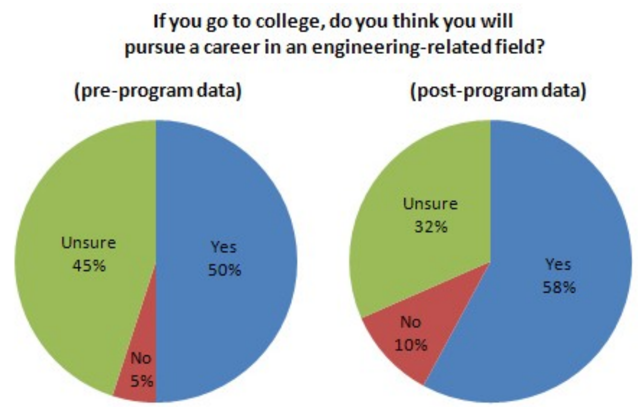

Figure 10. Impact of GFA on Student Plans to Study Engineering in College (2008-2009 data, n=20)

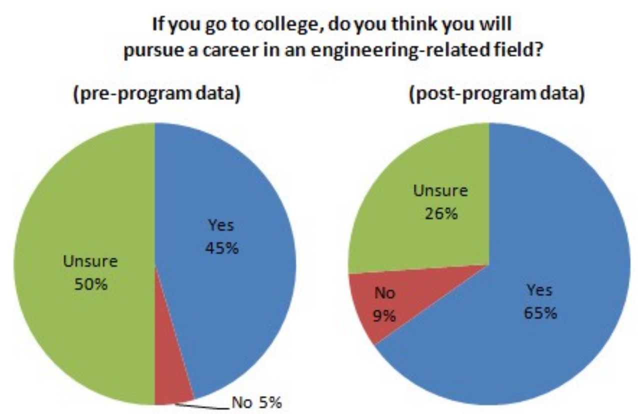

Figure 11. Impact of GFA on Student Plans to Study Engineering in College (2009-2010 data, n=23)

In the immediate post-program survey, students were also asked the question, "How much did participating in this program impact each of the following?", for eight different items related to students' attitudes, plans and understandings: 1) better understanding of engineering, 2) better understanding of career goals, 3) increased interest in studying engineering, 4) thinking more about post high school plans, 5) decided to work harder in school, 6) will take different classes (including college), 7) more confidence to succeed in engineering, 8) more confidence to do engineering activities. In each category, more than half of all students in both cohorts reported that the program had impacted them either moderately or a great deal (see Figures 14 and 15).

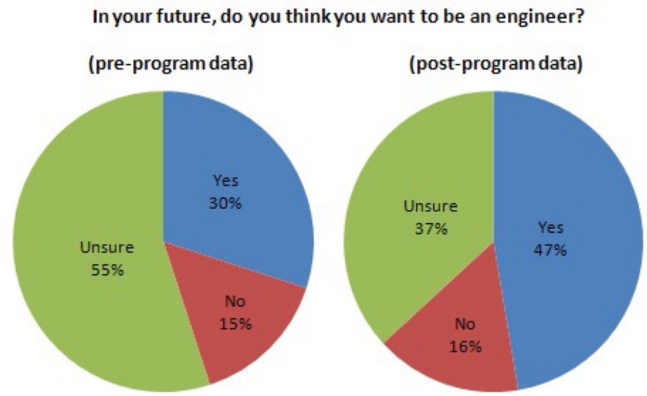

Figure 12. Impact of GFA on Student Plans to Become an Engineer (2008-2009 data, n=20)

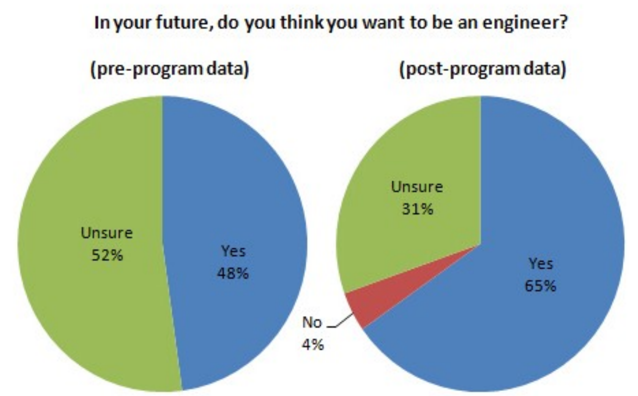

Figure 13. Impact of GFA on Student Plans to Become an Engineer (2009-2010 data, n=23)

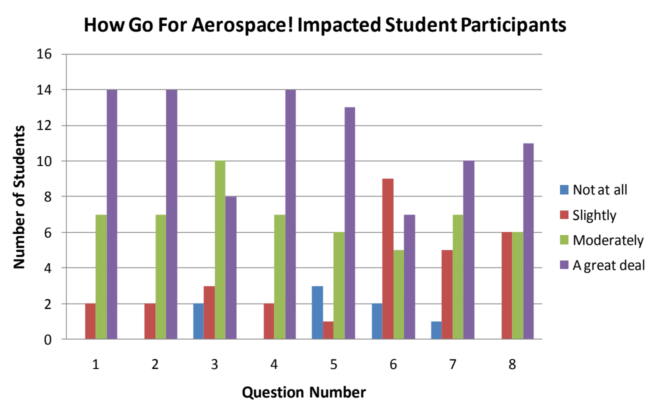

Figure 14. Impact of GFA on Students' Attitudes, Plans and Understandings of Career Goals (2008-2009 data, n=20)

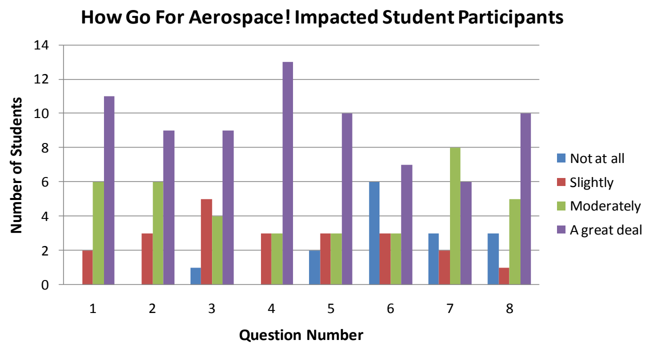

Figure 15. Impact of GFA on Students' Attitudes, Plans and Understandings of Career Goals (2009-2010 data, n=23)

Listed below are several students' responses to the post-program survey question, "What did you like best about this program?"

- "I liked the fact that we got to learn more about the different fields of engineering and were allowed to ask questions in order to clarify the disadvantages and advantages of careers in the engineering fields."
- "I loved being exposed to the whole aerospace industry and seeing all of the different types of jobs involved with it. In addition, I enjoyed meeting kids from other schools who had similar interests to me."
- "I loved the tour of the NASA facility with the Hubble telescope, the Smithsonian visit, and seeing different jobs available to engineers."
- "As a whole, meeting other people, and learning scientific concepts. Specifically, the trip to the planetarium where we learned about inspiration, physics, and astronomy."
- "I liked visiting sites related to aerospace. I learned and saw much of what engineers do."
- "Meeting new people and learning about all the engineering possibilities."
- "I got to meet different kids and learned about engineering."
- "I liked being exposed to careers, people, and ideas that were previously unknown to me."
- "Meeting other students from other schools and learning about career opportunities."
- "I liked the fact that everyone looked out for one another or when needed help and I felt that I learned a lot."
- "All the tours we went on because I was able to inspire my future there; and maybe work there. Also the speakers had great topics that we wanted to learn more! Plus all of the places we went to the entire program were super cool."

Students were also asked, "If you were in charge, how would you change this activity?", and the most popular suggestion was for the program coordinators to increase the number of hands-on activities.

Along with the pre- and immediate post-surveys, the AWE set of instruments also includes a long-term follow-up version, which can be used to record, among other information, students' post-high-school plans. As this data is directly related to our goals, it is of critical importance to us. As such, a third, follow-up version of the AWE survey was sent to the 2008-2009 cohort by mail in February 2009 in hopes of determining which colleges and degree programs our past participants had selected. Disappointingly, no responses were received despite multiple mailings. We next sent out a SurveyMonkey™ version of the same survey via email and through a Facebook™ group, which had been created for that GFA cohort; however, this, too, yielded a very poor response rate (n=2). Ultimately, a much shorter, four-question survey was created using Google™ Docs and distributed via Facebook. This yielded the most successful response rate (n=10) and our results are summarized in Table 1. As the data demonstrates, our program was influential in 4 of the 10 respondents' decisions to pursue a STEM major in college.

Limitations

Although the initial results are promising, our research was not without limitations such as the small sample size of approximately 20 students per year for each of the first two years. While our current cohort is larger (45), the numbers are still somewhat modest. In addition, we had not anticipated the level of difficulty that we encountered in collecting survey information from past participants after they left the program. In the future, we plan to continue to pursue the use of social networking software as a means of collecting follow-up survey data since, not surprisingly, this appears to be the most likely way to reach our target audience. In spite of these limitations, we feel that our results will nonetheless be of interest to members of the community wishing to implement similar programs at their institutions.

Conclusions and Future Directions

Overall, we feel that the GFA Program has been successful. However, based on student feedback as well as our own observations, we have made several modifications along the way. For instance, we have added more hands-on activities, especially during the Summer Institute, and allotted more time to familiarize students with the equipment available in our University labs. We have also interchanged the two spring workshops so that the rocket launch, which must be conducted outdoors, will take place during the warmer months.

Table 1. Long-term Follow-up Survey Results (2008-2009 data)

Currently you are…	If you are attending a university, which are you attending?	What is your major?	Did participating in the program influence your decision in picking a school or major?
Attending a university	Boston University	Chemistry	Yes
Attending a University	University of Connecticut	Electrical Engineering	Yes
Attending a University	Rensselaer Polytechnic Institute	Information Technology and Web Science	No
Attending a University	Saint Joseph College	Biology/Pre-Pharmacy	No
Attending a University	University of Connecticut	Molecular & Cell Biology	No
Work and college	Naugatuck Valley Community College	Chemistry	Yes
Attending a University	Boston College	Biology	No
Attending a University	Stevens Institute Of Technology	Electrical Engineering	I already knew what I wanted to major in and why. The program helped broaden my knowledge on engineering as whole.
Attending a University	University of Connecticut	Biological Sciences/Allied Health	No
Attending a university	Boston University	Mathematics	Yes, it made me like math.

Our data collection is ongoing and we plan to continue to disseminate our results. Through a follow-up, multi-year study, we will be able to assess the overall effectiveness of our approach and make continual improvements to the program. The results of our research will also be important in identifying potential strategies for similar outreach programs and will, thereby, impact the STEM education field in general. Ultimately, it is hoped that information derived from this project will demonstrate how the GFA program can be adapted by other organizations and to other STEM disciplines, thus further growing and developing the STEM talent pipeline.

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INCREASING HISPANIC ENGAGEMENT IN COMPUTING THROUGH SERVICE LEARNING

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Abstract

The Hispanic Computer Brigade (HCB) program at San José State University (SJSU) is aimed at recruiting and retaining Hispanic high school students into computing. Designed as an informal education program, it incorporated socio-cultural methodologies and best practices that have been found to be effective with Hispanic learners. The HCB program consisted of a one-week residential summer camp, the Silicon Valley Computer Camp, and after-school HCB Clubs. The Camp taught students basic computing hardware and software skills and the HCB Clubs engaged them in using these skills to undertake computing service-learning projects throughout the academic year. To support their learning, we created a network of peers, teachers, family members, mentors, and computer professionals.

The goals of the HCB program were to: 1) generate awareness among students and parents about higher education and career opportunities in computing, and 2) increase the recruitment of Hispanic students in computing. The preliminary results from the HCB program are promising. The camp provided students with an opportunity to learn basic computing skills and the HCB Clubs encouraged them to work on computing projects throughout the year. The assessment indicated that establishing club environments where students' interest in computing could grow and thrive required smaller incremental steps than originally planned. Although initial challenges were faced in establishing HCB Clubs at two local high schools, the students were enthused about participating in the Silicon Valley Computer Camp and HCB activities, which was reflected by the increase in the number of students, from 22 to 39, during a one-year period.

Introduction

The United States is facing a crisis in the computing workforce. According to the U.S. Department of Labor, jobs in computer-related fields are expected to be among the fastest growing occupations in the next decade with an estimated need for 700,000 additional technology workers in the United States [1]. Shortages of well-qualified computer graduates imperil the nation's ability to remain competitive in a global economy increasingly driven by technology innovations. Promoting computer studies is a national imperative, particularly among Hispanics—the fastest growing U.S. workforce segment and projected to account for 50% of the California workforce by 2020 [2]. By 2050, the Hispanic population is projected to triple in the United States [3], [4] with 25% of the U.S. population being of Hispanic/ Latino origin [5].

San José State University (SJSU), in the heart of Silicon Valley, is in a unique position to attract Hispanic students to computing fields. Among all regions in the nation, Silicon Valley has the highest percentage (13%) of its workforce in technological occupations. It is the technology center of the world, known for advancing technology frontiers from semiconductors to networking to software to internet technologies. Also, SJSU is situated in a region with a diverse population from which it draws most of its students. Specifically, the 1.8 million residents of Santa Clara County, where SJSU is located, are 44% white, 26% Asian, 24% Latino/a, and 3% African American. Leveraging the intellectual resources in Silicon Valley and the high percentage of K-12 Hispanic students gives SJSU a unique advantage in attracting and educating the next generation of Hispanic computing engineers.

Leveraging the connections with Silicon Valley companies and existing outreach to the Hispanic community, the Charles W. Davidson College of Engineering (CoE) at SJSU initiated the Hispanic Computer Brigade project for recruiting Hispanic students into computing studies and careers. The HCB project is an informal education program that consists of a one-week residential computer summer camp, Silicon Valley Computer Camp, and year-long service learning computer projects, which are supported by Hispanic Computing Brigades Clubs in two local high schools. At the summer camp (held on June 22-26, 2009), 22 students built their own computers and learned a range of fundamental computer software and hardware skills. Moreover, they acquired a network of peers, teachers, mentors, and industry professionals. These skills and support networks provide them a foundation upon which to undertake service learning projects throughout the 2009-2010 academic year. The reason why HCB chose service-learning projects instead of robot competitions, which are used in most high school outreach activities, was to take into consideration Hispanic students' intrinsic interest in connecting with others, especially those in their community. The second segment of this pilot project was the Hispanic Computer Brigade Clubs. The students who participated in the Silicon Valley Computer Camp held after-school Hispanic Computer Brigade Club meetings at their respective high schools to work on community-oriented computing projects.

Engaging Students through Informal Learning Environments

Informal learning has been identified by the Academic Competitiveness Council as one of the three key components (along with K-12 and higher education) to ensure that U.S. educational institutions produce citizens who are literate in STEM concepts, and future scientists and engineers who will secure continued U.S. economic competitiveness [6]. Informal education—such as after-school programs, clubs, science centers, camps, and museums—is believed to increase student inquiry, enjoyment, and a sense that science learning can be personally relevant and rewarding. A 2009 National Research Council (NRC) report [7] indicates that informal environments can make substantial contributions to STEM education and broaden participation. The Hispanic Computer Brigade program incorporated the methodology and best practices cited in the NRC report, in particular, the "strands of science learning" framework to organize and assess science learning supported by informal environments. Strands 1 and 6 of that framework have singular application to the Hispanic Computer Brigade program:

Strand 1—Identifies personal interest and enthusiasm as being important to student involvement in science learning. Examples that support this strand include interest groups and after-school programs. Its assessment is based on the participant's interest and motivation to undertake activities that promote learning and emotional associations, with interest as the major factor helping students learn and retain.

Strand 6—Emphasizes the science learners' concept of themselves as individuals who know about, use, and sometimes contribute to science. "Enculturation" involves developing one's identity as part of a community and informal environments can influence one's developing identities as science learners. Educational programs that help students develop identities, solidify social networks, and provide access to scientific communities and careers address this strand. An example is that a long-term study found that science-center interns who received mentoring and support experienced enhanced personal learning that led them to choose science-related careers.

The Hispanic Computer Brigade project adopted the precepts of Strands 1 and 6 through activities generating excitement and interest, and integration of achievable hands-on projects appropriate to the student level and abilities. Student involvement in Silicon Valley Computer Camp and weekly HCB Clubs, in which they had extensive and repeated exposure to mentors and role models, encouraged the enculturation factor of Strand 6. Through this integration of activities, we hoped to examine the different cultural and familial factors that influence environments impacting individuals' identities as science learners.

Motivating Hispanic Students through Social Applications

The Hispanic Computer Brigade program was anchored in the theoretical foundation that the future of computing education must include practical student experiences. Students require "not only the knowledge needed but how to use the knowledge in authentic contexts" [8]. Several studies over the past decade [9-11] have led to the same recommendation for engineering education: engineering students need to acquire traditional engineering fundamentals, but also must develop skills to use their disciplinary knowledge in real-world situations.

As for the types of projects that are most appealing to Hispanic students, it was found that traditional engineering projects such as building robots and bridges are not the most effective with students of color and women [12], [13]. In other words, an approach using "technology for technology's sake" does not appear to work for women and Hispanic students. To date, most educators have been using this approach, but several studies [14-16] show that Hispanic students generally have greater intrinsic motivation or underlying interests in social and relational issues; that is, they could be attracted to computing if it were presented in a social context as a means to solve community problems that were meaningful to them. Therefore, one key component for the Hispanic Computer Brigade program was to engage students in the use of computers to advance their personal interests in serving humanity or giving back to the community. As they learned of the utility of computing, they were inspired to further the development of technology to meet their desire to serve, thereby aligning their personal interests with the pursuit of computing.

Another key component for the Hispanic Computer Brigade was the design and implementation of a social support network for the students to develop a sense of belonging, which is necessary for their expansion into and maintenance of computing interests. Networking with teachers, mentors, and their peers not only provided them with a sense of belonging but also changed the culture of computing at their high schools. Hispanic Computer Brigade Club activities incorporated a supportive approach through hands-on projects and activities emphasizing collaborative teamwork and support from the Hispanic Computer Brigade mentors. Based upon research that shows that school-based, structured, extracurricular activities are associated with positive adolescent outcomes [17], and additional research that reveals that adolescents both teach and learn from each other [18], [19], the Silicon Valley Computer Camp structure encouraged peer interactions and the development of student support systems. That concept was broadened in the Hispanic Computer Brigade Clubs through weekly meetings with peer mentors to implement community service projects.

HCB Project Goals

The purpose of the Hispanic Computer Brigade project is to develop an innovative approach of stimulating and sustaining Hispanic students' interest in learning and applying computing and embed this project in SJSU College of Engineering's demonstrably successful efforts in recruiting and retaining Hispanic students. The goals of this project are to provide a program that:

- **L**inks service learning to participants' interests in computing disciplines;
- **E**xposes participants to accessible and relatable role models in computing;
- **A**dvances participants' likelihood to pursue careers in computing; and,
- **D**evelops (or enhances) participants' positive attitudes towards computing.

Description of the Silicon Valley Computer Camp

The Silicon Valley Computer Camp was a collaborative project between schoolteachers and administrators, industry leaders, and university professors. It took six months to design and implement a residential camp experience at SJSU, which comprised both programmatic components and support networks. The summer camp was the first step in building a sense of community within the student's high schools and at the college level that might positively affect their college aspirations.

We adapted our camp curriculum from the Colorado School of Mines [20], [21]. The Colorado School of Mines utilized basic computer programs to teach middle school students about computer engineering and programming, including ALICE basic programming software [22], Lego Mindstorms robot kits, FrontPage website design, and GPS (Global Positioning System) tracking systems. Silicon Valley Computer Camp students built their own computers, which they were invited to keep (a particularly powerful appeal given that less than one in two Hispanics own home computers [23]).

An important aspect of our summer camp was the inclusion of student mentors. The student mentors were divided into three categories to provide different interactions with the high school students: 1) computing mentors, 2) residential leaders, and 3) social mentors. Each category had a different responsibility and purpose within the camp structure. For example, the residential leaders supervised the high school students during nighttime hours, the social mentors were recruited from the SJSU student chapter of SOLES (Society of Latino Engineers & Scientists) to participate in evening activities (e.g., bowling, board games, and movies), and the computer mentors assisted with all computer-related lesson plans. The purpose of the student mentors was to bridge the gap between high school and college. In many ways, the high school students could relate to the university students and could learn about college through casual conversations. Through this intensive mentoring, we hoped to expand the students' perceptions of their communities and provide them with links to the university.

Figure 1. Computer Mentor (left) Guided Students Through Computing Activities

Many of the student mentors were recruited from engineering disciplines and could draw upon their own educational experiences to encourage and mentor the high school students. Each mentor was trained by Dr. Andrew Wood, Director of the SJSU Peer Mentor Program. The mentors attended a one-day session, which prepared them to be effective mentors and positive influences on the high school students. Topics in the peer-mentor training included: principles of mentoring, effective listening, personal assessment of learning styles, dealing with stress while mentoring, motivational strategies, boundary setting, and code of conduct.

On Day 1 of the summer camp, activities focused on building a computer. To control for gender stereotyping, the students were separated by gender into two adjacent work rooms as research shows that women are socially conditioned to avoid technology [24]. When they participate in STEM fields, they do not expect to succeed because of gender stereotyping [25]. By separating the participants, the girls were encouraged to work together to solve computer-related issues.

On Day 2, students installed software onto their computers. An afternoon visit to The Tech Museum of Innovation in downtown San Jose afforded students a hands-on and interactive learning experience. Computer programming was the focus on Day 3. ALICE software was selected because it benefits students with weak math skills and/or little programming backgrounds, enabling their success in computing [26]. Students continued to practice programming skills by constructing PicoCricket robots on Day 4. This program includes a drag-and-drop interface, which reduces human error, creating a positive learning environment that has greater student appeal than traditional robot kits [27].

After dinner each night, corporate representatives from high-tech companies such as Google, IBM, Microsoft, and AnyBot were invited to speak to the students about careers in computers (see Table 1). Many of the speakers were of Hispanic origin, and they were encouraged to discuss their pathway into computing and offer advice for minority students. The guest lecturers had the opportunity to connect with young students and share some advice that might prepare students for computing careers. The students were excited to meet the guest lecturers and learn, firsthand, exactly what a computing career might entail.

Table 1. List of Industry Speakers

Company	Representative
IBM	Dulce Ponceleón
Google	Gaby Aguilleras, Luiz Mendes, Raquel Romano
AnyBot	Benjie Nelson
Microsoft	Claudia Galvan

Also during the camp, a student panel was hosted with several of the SJSU student mentors as well as faculty. Collectively, the student mentors represented five engineering disciplines within the College of Engineering, and they discussed their career goals and why they chose engineering. Halfway through the panel, the high school students asked the camp instructors about their areas of expertise. The high school students wanted to know what led the faculty to become teachers and what degrees they had earned. The student panel fostered a discussion with the students about their own plans for college and what fields of study they might like to pursue.

On the final day, students brainstormed activities for the Hispanic Computer Brigade Clubs and presented their projects to their parents. The week concluded with a banquet attended by student participants, staff, faculty, and the students' families. Many siblings and extended family members attended to celebrate the students' accomplishments. Each student received a certificate and SJSU memorabilia.

As a follow-up to the summer computer camp, Microsoft hosted a daylong event on its Silicon Valley campus for Hispanic Computer Brigade participants (as well as 13 other Hispanic students) on October 25, 2009. For most students, visiting one of the world's leading high-tech companies located just miles from their homes was an exciting, memorable experience.

Description of the Year 1 Hispanic Computer Brigade Club Activities

Figure 2. HCB Students Teaching PicoCricket to Elementary Students

During the 2009-2010 academic year, participants formed the Hispanic Computer Brigade Clubs at their high schools to continue learning about computing. School 1 met weekly and School 2 met every two weeks to develop community service projects that positively affected their local communities (see Table 2). Community was defined to include the students' peers, their schools, families, neighborhoods, and, ultimately, the larger community. The Hispanic Computer Brigade Club activities were situated in a learning ecology framework, which posited that student learning takes place across multiple settings including school, home, and the community [28-30]. These community environments constituted the socio-cultural learning environments for the Hispanic Computer Brigade students.

In June, 2010, Hispanic Computer Brigade students presented their projects to an audience of high school teachers, SJSU faculty, parents/guardians, and community members, as the culmination of a year of learning and growth. Students received awards recognizing their accomplishments in planning and implementing community projects, and learning new skills within the Clubs.

Assessment of the Hispanic Computer Brigade Program

Steve Schneider and Susan Arbuckle of West Ed served as the evaluation team for the Hispanic Computer Brigade program. The evaluators employed multiple methods following the implementation of the Silicon Valley Computer Camp and Year 1 of the Hispanic Computer Brigade Clubs. Two online surveys were created and given to the students at the beginning and end of their one-week summer session. The tests measured attitude, interest, use, self-efficacy, and student perception of the utility and value of the week's content and organization. Two observations were made during the Silicon Valley Computer Camp including the welcoming and closing ceremonies, computing lessons, hands-on activities, and parent presentations. Interviews were conducted with the project director, two SJSU student mentors, and 3 high school club advisors. One club meeting at School 1 was observed.

From the outset, implementation of the Silicon Valley Computer Camp presented real challenges to the project director, which she handled with fluidity. Bringing a co-ed group of 24 high school students (ages 14 – 17; 9 girls and 15 boys; 21 Latino/a and 3 African American), who did not already know one another, to spend 4 nights and 5 days living at the university; arranging for a number of professors, mentors, counselors, guest speakers, meals, social activities, tours, and field trips; and supplying all the hands-on materials for each computing activity, required extensive planning and execution. There were four students who did not show up and were replaced by students on the waitlist; one student dropped out after the first day; and estimated time schedules had to be tweaked to allow for unanticipated needs and delays.

Table 2. HCB Club Projects During 2009-2010

Project Title, School	**Description**
HCB Club Websites, School 1& 2	The students at both schools spent several weeks learning HTML code and website management. Their websites were designed to keep their peers, family, and community members informed of the club's activities.
Dove Hill Robotics Club, School 2	Twice a month, students from School 2 walked to an elementary school to provide support to their local elementary school robotics club. In the process of mentoring elementary students, the high school students improved their programming skills, learned more about robotics, and encouraged children to pursue math and science.
Technology Forum, School 2	The students designed an online forum to share computer information with their peers, families, and teachers. The forum topics included fixing and building a computer, making a website, software assistance, and technology "slick" deals.
Sports Database, School 1	The students created a Microsoft Access database to track student athletes. The purpose of the database is to monitor the athletes' positions, identify which sports they play, record their academic eligibility, and note whether they have received recognition. This database will accumulate information over time and generate more detailed reports each year.
Adult Education Workshop, School 1	The students had a chance to place themselves in their teachers' shoes by giving two adult education workshops to Latino/a adults in their local community. The workshops focused on creating and using email accounts. The students planned the presentation, reserved the computer lab in the high school library, and gave bilingual lessons to dozens of adults.
PicoCricket Kids Workshop, School 1	The students gave two one-hour workshops for elementary children (ages 5 to 10) with interactive "PicoCricket" robots. Using play dough, food, and computer sensors, the elementary children created their own music instruments.
Online Math Workshop, School 1	The students gave a tutorial to children (ages 5 to 10) on where to find and play online math games. These games are an educational and fun way for children to improve their math skills.

Overall, the mechanics and logistics proceeded relatively smoothly, with quick thinking and behind-the-scene actions on the part of the project director and her staff.

The Hispanic Computer Brigade Clubs in Year 1 evolved differently at each school, with School 1 experiencing more success than School 2. At both sites, the respective mentors and advisors made an effort to guide club members and simultaneously enable them to implement their community service project. Attendance and interest at School 2 was initially low, and the reasons were varied. At School 2, the club met in a large computer lab that felt less like a home base. Lack of involvement was addressed in earnest by players at all levels. The mentors, advisors and the project director made special visits and phone calls to student homes.

At School 1, where club attendance was higher and more regular, club members were able to meet in the classroom of an accommodating science teacher who made herself available for extended hours, and who heads the Advancement Via Individual Determination (AVID) program. The second advisor at this school was a counselor who already worked in outreach and with parents. However, even in this supportive setting, there was a delay in the Hispanic Computer Brigade Club activities because the students had no easy access to computers until SJSU worked through the school district's requirements to allow the installation of five new computers dedicated to the Hispanic Computer Brigade Club.

Starting with a blank slate was perhaps more overwhelming for novice students than it was conducive to their creativity and engagement. If the plan of the club was for its members to devise and execute a community service project based on computer use, the students may have felt daunted before they even began. It is difficult to think in terms of helping others in a field in which you yourself are a novice. One student cited the desire for the club to be already "up and running" in order to attract her, while another attributed his lack of interest to the fact that little was accomplished since few attended.

The assessment indicated that establishing club environments, where student interest in computing could grow and thrive, was a slower building process that necessitated much smaller incremental steps than originally planned. As one advisor stated, "More focus is needed on getting the club started. Roles should be defined and leadership skills honed. Our community needs basic technology help first." Advisors at School 1 were confident that this first year of the program constituted a steep learning curve and that now they knew which obstacles to tackle so that during the following year significant progress could be made with student engagement.

The predicament of lower-than-expected student engagement could be partially understood through this target population's lack of immersion in a wide variety of computer use in their daily life. Authors of a recent study [31] point to the existence of a multidimensional construct that goes beyond the simplicity of the digital divide notion. It is not only the lack of computers and Internet in the home but also an encompassing array of factors that distance students from jumping into the Hispanic Computer Brigade offerings.

Even though these students are growing up in Silicon Valley, their cultural and socioeconomic situations isolate them from the full impact of the technological revolution and result in shallow breadth and depth of technological encounters. Students from the participating schools were less likely than students from more affluent communities to have parents who use computers for work, who buy technology and bring it into the household, who offer direct explanations for technological tools or phenomenon, or who create opportunities for their children to find out more about computers through activities, camps, clubs, neighbors, relatives, and peers. This lack of experience and access tended to deflate students' confidence and interest in computing. The students' learning ecology, defined as the interdependencies between the student and his/her environment, was somewhat barren. The learning opportunities provided by the Hispanic Computer Brigade program may have the power to mediate student reluctance once a critical number of students are engaged and projects are undertaken. The energy of peer networking (committed friends attract other friends to actively join in) may carry the momentum as long as logistical barriers such as scheduling conflicts or lack of equipment are not prohibitive.

Description of the Year 2 Hispanic Computer Brigade Club Activities

Certain elements of the pilot's deployment in Year 1—in particular, the operation of Hispanic Computer Brigade Clubs—revealed areas for improvement. For example, allowing students to select an open range of community service projects was not a successful strategy as students were sometimes uncertain about what to do, and some of their selected projects were outside their technical competencies. As a result, the students were not as engaged in those club activities and tended to lose motivation.

The Year 2 Hispanic Computer Brigade Club design for academic year 2010-2011 incorporated programmatic changes based on preliminary evaluation results from our external evaluators. For example, the Hispanic Computer Brigade Clubs during Year 2 included new computing modules with higher rates for achieving successful outcomes and a redefinition of community service in relation to student projects.

During the first year, challenges were identified that hindered Club progress. In Fall, 2009, School 2 found it difficult to establish Club activities due to poor leadership, whereas School 1 successfully engaged students in Club activities by drawing upon a network of resources. It was learned that successful Club leadership did not necessarily correlate with computer experience; rather, Club advisors needed the agility to navigate academic bureaucracy to implement and plan Club activities.

Another major challenge was a lack of confidence by students in directing Club activities. In Spring, 2010, the Hispanic Computer Brigade student mentors began to create mini-lessons that they presented to the students at each Club meeting. A revised Hispanic Computer Brigade Club approach for Year 2 let students choose their curriculum within a series of pre-selected community projects, or modules, starting with simple to progressively harder activities over the year. Modules included removing malicious spyware, refurbishing old computers, creating websites, and programming smart phones. Research has shown that these types of activities increase fluency in computing and are compelling for youth [32], [33].

The Hispanic Computer Brigade Club projects in the Fall 2010 semester were focused on benefiting the local school community. Spring-semester projects targeted family members and students' neighborhoods. The modules reflected a systematic program change that allowed students to progress from beginning computer concepts to more difficult concepts over the span of one year, as research has indicated that adolescents will be more motivated to be involved in activities in which they feel competent [34].

Conclusion

The reasons underlying lower entry numbers of Hispanic students into computing professions are varied and complex [35]. Negative attitudes developed toward science by the time of secondary education can contribute to low entry numbers in STEM fields [36]. Studies reveal that certain methodologies are effective in developing Hispanic student interest in STEM subjects and in motivating them to continue in those studies.

The Hispanic Computer Brigade program advances knowledge and understanding of effective methods to recruit and retain Hispanics to computing fields. It enhances Hispanic students' interest in computing by enabling them to apply their growing mastery of hardware and software to solving problems in their community, thus making their computer education immediately relevant and culturally rewarding. Being an informal learning program, it offers an innovative model on how immersive and personal outcomes-based learning environments can engage students' interest in and motivation for learning skills and knowledge related to computing.

Based upon our assessment of Hispanic Computer Brigade students' high school transcripts, many Hispanic Computer Brigade students have persisted in their math and science courses. Fully 70% of HCB students (13 out of 20) have passed their math courses in the previous two semesters, and 55% of HCB students (11 out of 20) have taken advanced math and science courses that exceed their high school graduation requirements. Over half of the Hispanic Computer Brigade students are preparing themselves for careers in computing disciplines. Among our two high school graduates, one has already decided to pursue computer engineering at the University of California, Davis.

Given these promising results, our Hispanic Computer Brigade model might be extended to attract students from other underrepresented groups into computing, as it utilizes students' intrinsic motivations and social process for learning. The result will be a larger talent pool that is critical for the U.S. to maintain and advance its technological leadership. For more information: http://www.engr.sjsu.edu/hc. This material is based upon work supported by the National Science Foundation Grant 0837821.

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Biographies

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JANET SUNDRUD is a graduate student in the Department of Communication Studies. She studies issues related to gendered identities, intercultural diversity, and critical assessment. Since 2008, she has worked with the SJSU College of Engineering on several college-wide initiatives and assisted in the implementation of the HCB program.

COMPARISON OF AN INTRODUCTORY ENGINEERING COURSE WITH AND WITHOUT LEGO MINDSTORMS ROBOTS

Harold N. Scholz, Pennsylvania State University Lehigh Valley; Kevin McFall, Pennsylvania State University Lehigh Valley

Abstract

An introductory engineering course was run in two concurrent terms, one without LEGO Mindstorms robots, and one with. A comparison was performed between the two approaches considering teamwork, leadership, and engineering problem solving. In both groups, the project covered the engineering design process from customer needs through a working prototype.

The first semester, student design teams were allowed to choose any toy-related project. In the second, they were required to use the LEGO robots to navigate a maze, find a colored ball, and return it to the starting point. During the non-robotic semester, one or two members of each team tended to dominate the group, with some members seldom contributing. With the robotics groups, leadership changed throughout the engineering process as expertise of different individuals became important. The students were involved throughout the project as prototypes did not work and both mechanical and software changes were required. The robotics project required not just mechanical expertise, but also the ability to program. The LEGO system also introduced many of the students to programming for the first time through a graphical interface that allowed everyone to participate.

Introduction

An engineering class designed for incoming freshmen has been modified to be project-based. The class, Introduction to Engineering Design, was administered in two consecutive semesters at Penn State University Lehigh Valley during the 2009–2010 academic year.

The goal of the course is to expose students to the engineering design process, methods, and decision-making. A team-based approach was adopted with grades based on team presentations, written journals, and a successful project. The course covers the design process in detail from customer needs to a working prototype as shown in Figure 1. Students are required to generate presentations for customer needs, product specifications, concepts, and intermediate and final prototypes. The scope of projects during the first semester was virtually unlimited. The only restrictions were that the project be a toy and that it be approved as realistic. One of the potential approaches was to use the LEGO Mindstorms robots (http://mindstorms.lego.com/en-us/default.asp).

During the second semester, projects were restricted to generating a robot to navigate a maze, find a red ball within the maze, and bring it back to the starting point. The robots also had to ignore any blue balls along the way. Each team was still required to define the form of the robot, method of movement, etc., and incorporate customer needs.

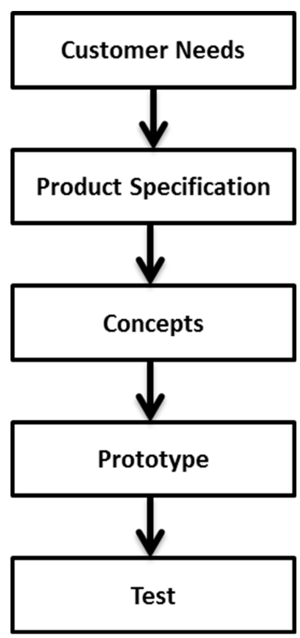

Figure 1: Design Process

Semester 1 Observations

During the first semester, each team started with four members. Teams were generated based on the skill sets of the members of the class. All students were administered a survey to assess their mechanical, electrical, and programming abilities [1]. Based on the survey results, teams were selected in an attempt to equilibrate skills across teams. Each team was instructed to build a prototype of one toy. They had to decide what toy they wanted to design and obtain input on customer needs to determine the right product. Requiring students to define the product proved to be an important step, as they were asked to narrow a broad spectrum of choices. The students used resources such as the Internet, visiting elementary school classes, and talking to people they knew. This portion of the project provided a good challenge to the students and produced relatively good results.

Generating product specifications forced the teams to define all aspects of the selected toy. This activity held the attention of the majority of students and produced good results. The concept phase was also successful in terms of results and participation of most of the students. However, as this phase unfolded, one or two students in each group began to take over as leaders. In each case, the leaders pushed the projects in a direction where they had some expertise. In the prototyping stages, the same one or two team leaders continued dominating the project in two-thirds of the teams. While two of those teams did produce prototypes similar to their concepts, none of them worked as planned. One team did produce a working prototype, but it was lacking the full function prescribed by the concept.

The group that decided to do a LEGO robot project also fell short of their goals, but the dynamics of that group changed from the start to the final prototype. In the beginning, one group member was leading the group. Once the construction of the robot was completed, the leadership shifted to another member of the group during the programming phase. All group members of the robotic project were highly involved in at least some portion of the prototyping phase.

Semester 2 Observations

Teams were generated in a similar manner as in the preceding semester. When teams were divided, the first priority was programming experience. Next priorities were mechanical and other general skills. Each team was instructed that they were to build a toy that had a specific task to perform. It was to navigate a maze and capture a red ball, bringing it back to the start. This had to be accomplished using the LEGO robotics set provided. Teams were also allowed to build additional parts if required.

During the customer needs phase, students had some difficulty compared with the previous semester, in which free reign was given over what to build. In this case, teams were not nearly as imaginative and did not do as well at surveying potential customers. The product specification phase was also weaker during the second semester, possibly due to the lack of excitement of building ideas of their own. Two of the six groups had reasonable product specifications on the first attempt, but the other four did not.

Once the specifications were completed, teams were introduced to the LEGO sets. At this point, they began developing their concepts. The concepts did follow ideas obtained from customer needs and developed relatively well. Some of the ideas generated were concerned with locomotion; for example, tracks vs. wheels and how to configure them. Other ideas dealt with how to capture the ball. All the groups failed to document concepts on how to program the robot.

Another interesting learning situation occurred once students were given the LEGO sets. Many teams began building prototypes as opposed to generating as many concepts as possible. This did help them quickly narrow down the final concept that they presented, but most made fairly major changes to the designs as they progressed into the testing phase. The presentations for the concept phase were strong. Students could visualize what they were going to design/ build and had pictures as well as text in their slides. During the concept phase, one or two leaders of each group essentially controlled the direction.

During the prototyping phase, the same leaders of each group led during the mechanical build phase. In two-thirds of the groups, the leadership changed once the robotics programming began. Students that had been fairly reserved and not significant contributors to this point became the leaders of the group. Other team members were still heavily involved, since all groups had unforeseen mechanical issues as well as continued software modifications.

The programming used a simple drag-and-drop graphical interface, as shown in Figure 2, so it was not beyond the abilities of the students. Also demonstrated in Figure 2 is a continuous loop with a conditional statement that turns left if the button is pushed, otherwise it turns right. This program eliminated the need to learn sophisticated syntax and students could focus on the problems and algorithms. This benefit of graphical programming has been reported by multiple authors [2-4]. On several occasions, the main programmer was missing for a portion or all of a class. Teammates would pick up and make updates to the programs. In some cases, these team members had no prior programming experience.

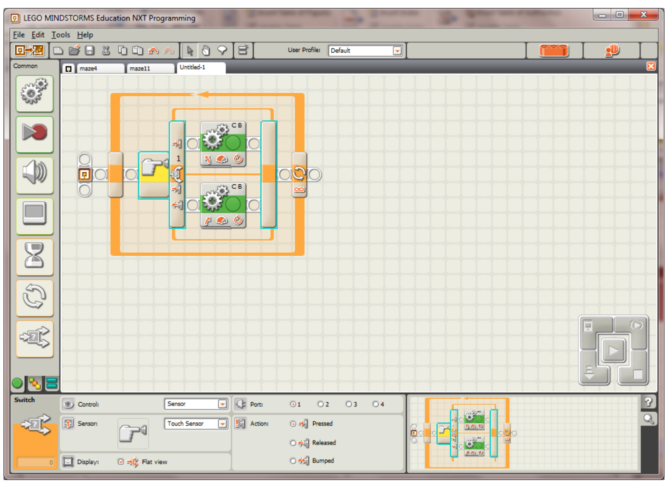

Figure 2. Graphical Drag-and-Drop Programming Interface and Program

Size constraints arose as unexpected issues were faced by the groups. The maze was rather constricting compared to the size of the robotics. This caused numerous redesigns for all the groups. They also encountered stability issues where the robots would tip over while cornering or when striking a wall. Also, teams realized that the “simple” mechanism originally planned for capturing the ball was not as easy as it first appeared.

The teams met with multiple challenges in developing the software. A simple gap in the outer wall of the maze would cause robots to turn into the wall. Navigating in a straight line would not work as planned, since the motors of both wheels did not always turn at the same rate. Most of these issues required including feedback or damping the reaction to a sensor change. Besides learning engineering skills during this phase, students learned to work together as a team. Each team member had different skills to bring to the project at different points. Also, the time to build and program the robots was short enough to instill a real sense of urgency.

At the end of the project, one group successfully navigated the maze and captured the red ball. All of the groups were able to navigate the maze with varying degrees of sophistication. A better measure of success, however, was that all groups worked together as teams and made good progress towards a goal. The last day of class, the maze and robots were on display in a central area of the campus where the final projects were demonstrated for students, faculty, and staff.

Comparisons

Allowing students the freedom to choose any project definitely produced more interest during the initial phases of the project. Through the concept phase, non-robotics students were more enthusiastic and creative than students with a robotic project. However, the non-robotics groups got bogged down during the prototyping stages, and all but one group seemed to lose track of what they were trying to accomplish. Contributing to the confusion was the fact that the goals set out when defining product specifications were more difficult than envisioned. As freshmen, they did not have the appropriate skills to actually complete the projects as specified. On the other hand, the robotics students showed increased enthusiasm as they started working with the LEGO robots during the concept development phase.

The robotics teams knew it was possible to build a robot to do what was being asked of them, and they could see other groups getting closer to the solution. Since all teams had the same raw materials available, it put them on equal footing. This definitely helped them to focus and work hard to get their projects to function. Participation in the non-robotics group stagnated, with one to two people from each group leading from start to finish. The robotics groups, however, saw at least three of the four members take control at some time in all but one of the groups.

Conclusion

Use of LEGO robotics provided an attainable engineering challenge for freshman engineering students. They were reasonably engaged during the customer needs and product specifications phases. During the concepts and prototyping phases, the vast majority of students were heavily engaged in solving the many problems associated with the project. Many more students were involved in leading their respective teams with the robotics than with the non-robotics projects. This was due to the variety of work that had to be accomplished in a relatively short time.

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Biographies

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WHERE IS THE TRANSFORMATIONAL LEADERSHIP IN ENGINEERING EDUCATION?

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Abstract

Leaders in both industry and academia agree that to meet the needs of the 21st century, more and better engineers are needed. To provide them, schools must change how their engineering students are taught to better prepare them for the new global challenges that they face. This will literally require us to transform our system of educating engineers. To transform engineering education, we need what students of leadership studies recognize as transformational leadership. Yet a review of the current leaders in the field of engineering education reveals that no one seems to address the appropriate theories, skills and behaviors that can be learned from leadership studies. This leaves us with the question: Where is the transformational leadership in engineering education?

Introduction

Engineers transform society on a regular basis. They transform the structures in which we live, play and work; the transportation used to get from place to place; and the tools used in every part of our lives. In essence, the things engineers design and build change the way we live. Engineering educators shape the skills and thought processes that the next generation of engineers will use to create societal changes.

The National Academy of Engineering (NAE) has published a book entitled *Educating the Engineer of 2020*, which is a compilation of the results of a project administered by the Committee on Engineering Education of the NAE [1]. The goal of the project was to answer the question: "What will or should engineering education be like today or in the near future to prepare the next generation of students for effective engagement in the engineering profession in 2020?" By its nature, the authoring committee is made up of many of the leaders in the field of engineering education. They point out that some huge changes are necessary, including:

1. There needs to be a complete overhaul of the BS/MS degree system in engineering education, such that the BS degree becomes essentially an "Engineer-in-Training" degree and the MS degree becomes mandatory as the required professional degree. Thus, similar to the medical profession, advanced degrees would be required before one would be recognized as being ready for practice in industry.
2. Universities need to accept that educational research is equally valid and equally valuable when compared with pure technical research in engineering schools. The emphasis on advanced engineering research at Research One (R1) universities is not benefiting the training of the vast majority of new engineers entering the U.S. workforce.
3. Engineering education programs need to become more interdisciplinary, including exposure to liberal arts, humanities, and social sciences.
4. Universities should supply significant support to the Science, Technology, Engineering, and Math (STEM) education programs in the pre-collegiate programs at the K-12 grade levels. This is a significant change in direction since most R1 universities maintain a focus that bypasses the bachelor's degree and focuses on advanced degrees and advanced research. Most schools provide little support from their engineering faculty to the growth of STEM education in grades K-12.

The report also states that addressing these issues is going to be a challenge, because there are "lurking concerns about the institutional inertia, whether in the form of faculty resistance to change, or the challenges of moving the 'battleship' of the modern research university" [1].

Progressive leadership would seem to be called for in the leadership of engineering educators. Yet, one can attend the major and minor conferences of the American Society of Engineering Education (ASEE) and the Institute for Electrical and Electronics Engineers (IEEE), or the annual Frontiers in Engineering Conference (jointly sanctioned by ASEE/IEEE), or read the journals of engineering education research, and find virtually no mention of the fundamental leadership theories and concepts of today's age, particularly the one that provides the strongest asset to changing the current environment of technical education: transformational leadership. This raises the question: "Where is the transformational leadership in engineering education?"

The Need for Change in Engineering Education

James Melsa, the past president of ASEE, discussed the need for ASEE to take a leadership role in the changes needed for engineering education in a recent guest editorial [2]. Thomas Litzinger, director of the Leonhard Center for the Enhancement of Engineering Education, used the same forum to discuss changes that needed to occur within the field that the center oversees [3]. Charles Vest, president of the NAE, has done likewise [4]. The research team of Farr and Brazil recapped the history of engineering education, up to and including the previously referenced NAE report of 2005, discussing the need for leadership training both for the educators and for the students being trained for industry [5]. The team of Jesiek, Newswander, and Borreg discussed extensively the new trend in developing engineering education research [6]. In 2008, the *Journal of Engineering Education* ran a special issue regarding the changes that are currently occurring (or need to be) in this specialized academic field. Yet, in none of these instances is general leadership theory even mentioned. It appears that the leaders in engineering education are well aware of the need for change and for creative leadership to create that change. However, they do not appear to be drawing on the benefits and knowledge associated with normally accepted leadership theories.

Shirley Ann Jackson, president of Rensselaer Polytechnic Institute traces the history of divergence between engineering and technology and the liberal arts, philosophy, sociology and psychology fields (often referred to collectively as the "soft sciences" by engineers) [7]. Maria Paradisio presents the case that engineering and the social sciences have long been on opposite sides of a chasm, which has prevented them from benefiting from each other [8]. Although communication and the recognition of inter-societal needs has begun to close that gap, the fact of the matter is that engineers in general still tend to give little respect to the work performed in the humanities and social sciences. This is a probable explanation for why engineering leadership is slow to take hold of the theories of leadership studies, since these studies would be viewed as coming from the "soft", i.e., non-technical, sciences.

Perhaps the biggest change being recommended for engineering educators is a readjustment of the focus that engineering faculty should apply. Currently, tenured engineering faculty tend to focus on technical research projects as their major contribution to the university, frequently teaching as few as one undergraduate class per semester. In fact, in many cases, research faculty may be able to completely buy their way out of teaching commitments using funds coming from industry consulting or research grants. The NAE report states that faculty members need to redirect their efforts toward improving the education of undergraduate students, reducing the focus on performing research. These faculty must play a major role in the changes that need to take place, yet "providing incentives for their support is challenged by the present faculty reward system, which bases decisions for tenure primarily on research" [1]. By this, the report is referring to technical research in engineering specializations. The NAE summary continues to say that many major advances in both business innovation and improvement in lifestyle are the result of engineering research, yet "this has not necessarily translated into excellence in undergraduate education" [1]. To make the necessary improvements in the way engineering students are educated, there must be a realignment. The curriculum must align better with the challenges and opportunities of the workplace, and the faculty must align better with the skill sets necessary to deliver that curriculum.

Crawley, Malmqvist, Ostlund and Brodeur [9] state that "Part of the change process will require strengthening the competence of faculty in skills and in active experiential learning and student assessment. There is little reason to expect a faculty that has been recruited as a cadre of researchers to be proficient in many of the skills of engineering practice. And there is absolutely no reason to believe that these faculty researchers would be able to teach these skills." Mathieu, Pfund, and Gillian-Daniel [10] address the differences in the way research faculty and teaching faculty look at their instructional preparations. Academic leaders in higher education must deal with the fact that there are distinctly different types of instructors on their staff, with very different approaches and objectives. Balancing these differences in a manner that creates a homogeneous whole is a significant leadership challenge.

Tenure continues to be awarded, at most engineering universities, primarily for success in technical research. Funding for faculty projects and faculty salaries tends also to be based on success in the technical research arena. At some R1 universities, applicants for new faculty tenure-track positions are not even considered if they are not deemed adequately qualified for the task of advancing the school's technical-research agenda. Engineering educators are being told that they need to change, both at the national level and the individual faculty level. They are being told, by the priorities of tenure, that there is a need for them to change, but they are not being incentivized to make those changes occur.

The Need for Leadership Theories

For all of the significant changes that need to occur in engineering education, there appears to be no use of transformational leadership theory in attempting to solicit faculty buy-in to advance the change. Nielsen, Randall, Yanker, and Brennan [11] state, "Transformational leaders may have a profound impact on followers' perceptions of their work characteristics, because they provide personal attention to providing development through individualized consideration, enable new ways of working, encourage novel problem solving, provide coaching, and encourage specific behaviors of subordinates through intellectual stimulation". All of these attributes would seem to mesh well with engineering academia, indicating that transformational leadership could be a strong tool in the hands of leadership. Transformational leaders are generally viewed as "being innovative and less likely to support the current situation, seeking opportunities in the face of risk, and attempting to shape and create" [12]. These are descriptors of precisely the kind of leadership that is needed in engineering academia if the transformative changes described earlier are to be achieved.

Mark Sanders, keynote speaker at a recent conference of the International Technology Education Association (ITEA), provided observations and reflections on leadership within engineering and technology education [13]. Consistent with the previous discussion, he made no recognition of transformational leadership, or other leadership theories. From a general position, he proposed that all effective leaders must be motivated by passion. Sanders recognized that this passion can be for either good or ill, saying, "It may be their quiet passion to improve the human condition…or their loud passion for wealth, power, control, fame, or some even more ignoble purpose." Miller defines both transformational and charismatic leadership traits and discusses the concept of love as a motivating factor in transformational leadership [14]. It would be a semantic error, in many instances, to confuse these two authors' use of the words passion and love. However, in this case, they are both talking about the motivating factor for creating transformative leadership. In fact, both authors give examples of leaders motivated in this way, and the lists share names such as Nelson Mandela and Mother Teresa. Sanders also lists names as examples of the dark side of passionate leadership, such as Stalin and Hitler. While Miller gives no negative examples, those of Sanders would clearly fit her description of a non-transformational (charismatic) leader whose objective is self-elevation and self-fulfillment. The two authors show considerable similarity of thought. Yet, Sanders shows no acknowledgement of leadership theory. So it is not surprising that there is no discussion of how these new leaders of engineering education will inspire their followers to change their direction and follow their leaders on a course to change the way we educate new engineers. There is no conversation regarding the mutual benefit that academia will gain by improving the education process, and society will gain by having a generation of better-educated engineers, or what will influence engineering educators to bring about the change.

Syndell points out the role that emotional intelligence plays in transformational leadership [15]. This involves:

> The ability to monitor one's own and others' feelings and emotions that focuses on an array of emotional and social abilities, including the ability to be aware of, understand, and express oneself; the ability to be aware of, understand, and relate to others; the ability to deal with strong emotions; and the ability to adapt to change and solve problems of a social or personal nature.

Those possessing this would clearly fall onto the positive side of the slate created by Miller and Sanders, rather than the negative side. Those on the negative side would avoid any feelings whatsoever for those they lead, while those on the positive side would focus on mutual elevation, which is a key transformational-leadership trait. Hopewell, McNeely, Kuiler and Hahm [16] explain the role of engineering education leaders this way:

> Academic leaders are charged with, for the most part, a cadre of scholars and analysts immersed in the pursuit of diverse interests encompassing both research and teaching. However, academic leaders also must represent the interests to the non-academic community to garner support and sustain institutional legitimacy. Thus, academic leaders must move their institutions and communities forward with both tangible and intangible motivators.

Typical of articles emanating from engineering academia, there is no discussion of the leadership types that would be best used in motivating and attaining these goals. However, by comparing the articles, it is obvious that the characteristics needed in engineering academia are those characteristics generally associated in leadership studies as transformational leadership. Transformational leaders change the organizations they lead by educating and involving their followers in the changes needed and the reasons behind those changes, then relying on those followers to institute the changes while supplying the support and encouragement necessary to ensure that the changes are indeed enacted, thus elevating their followers to a new level so as to advance the entire organization. With no other incentive, and no recognition of transformational leadership behaviors, the current academic leadership has very little chance of actually achieving the needed change. Let us continue to examine how other leadership theories could potentially assist engineering academia in this process.

There is an argument that could be made that transactional, rather than transformational, leadership might be useful in this scenario. Singer and Singer point out that "organic organizations" (i.e., those with non-rigid goals and structures, highly educated members, and a need for innovation), frequently function best under transactional leadership [17]. Certainly, engineering academia meets the description for an organic organization. However, the cost-benefit aspect of transactional leadership, in which the leader motivates subordinates by exchanging rewards for behaviors and results, is inconsistent with the university's need for the financial benefits associated with advanced research; therefore, the transactional approach probably has little applicability in our scenario.

One might think that instructional leadership theory would be applicable to those teaching engineering. However, Hallinger points out that this model really "focuses predominantly on the role of a public school principal in coordinating, controlling, supervising, and developing curriculum and instruction in the school" [18]. This does not really apply to our discussion, because university deans and chancellors play virtually no role in these aspects, instead leaving it to the faculty to develop virtually everything about not only the individual class instruction, but also what classes make up the required plan of study.

Participative leader behavior, as described by House, is directed at encouraging subordinates by including them in the decision-making process and taking into consideration their opinions [19]. This is not likely to be viable in our scenario, as the current faculty at most engineering schools are strongly biased toward the existing research model and they have a vested interest in maintaining that situation. Thus, their participation in the decision process is likely to leave the ship grounded exactly where it sits rather than floating it on a new course.

There is also no leader-member leadership effect visibly at play in trying to motivate educators to change the current model, because rewards to faculty (both financial and promotional) continue to be mostly handed out for success in technical research [20]. This reward system maintains the status quo rather than instilling a drive for change. There is, therefore, no organizational citizenship effect to prompt the faculty to put in extra effort to enhance their teaching in addition to their primary focus on research [21]. Likewise, schools are not incentivized to educate. Under growing funding cuts from government (local, state, and federal) they are incentivized to sell their research skills to industry, pursue valuable high-tech research grants, or perform research on new products that can be entrepreneurially marketed to their financial benefit.

Path-goal approaches as described by House might well prove useful in this situation, if we assume that leaders will show faculty a path to mutual improvement, define their role in following that path, and give them the training necessary to move forward on that path [19]. But there is currently no apparent use of path-goal leadership to effect change in the system because, despite what is said about change, administrators continue to steer faculty on a research path, and tenure and promotion requirements continue to indicate that the path to success is through engineering research.

Equity leadership theory, as described by Deluga, indicates that if research faculty and teaching faculty in engineering education were treated equally, with regards to rewards such as tenure, promotion, project financing and, of course, salary, then there would be a much stronger incentive to improve instructional skills and teach more classes [22]. Of course, this would also imply that universities would hire more faculty members for tenure-track teaching positions equitably with tenure-track research positions, but this does not seem to be the case. So once again, the theories from leadership studies, which might prove beneficial to engineering academia, appear to be getting too little attention within engineering academia.

The merits of situational leadership versus contingency leadership as applied to the presented scenario of engineering education deserve some consideration. Situational leadership theory, as described by Graeff [23], suggests that as situations change and evolve, leaders must be able to be flexible and adapt to the needs of each situation. Since universities differ to greater or lesser degrees, as national leaders work to institute changes across the range of engineering schools, there will be a strong need to be flexible in working with the programs at each school. On the other hand, at any given school, it may be necessary to apply contingency leadership philosophy which says, it may be necessary to put new leadership in charge in order to see changes successfully implemented in order to adjust to the need to totally revamp the way that the school's administration approaches tenure and promotion, and the way that faculty members approach teaching as opposed to research. This would be a case of applying contingency leadership approaches locally and situational approaches globally within engineering education leadership.

Conclusions

It appears that the leaders of engineering education are not familiarizing themselves with relevant theories from the field of leadership studies. This leaves them ill-equipped to institute the changes needed in the engineering education field today. For this reason, it is strongly suggested that leaders in engineering academia spend time examining the extensive work available on leadership styles and behaviors. The skills and approaches generally associated with transformational leadership (by students of leadership) appear to offer the greatest strength as tools for engineering education leadership. If those in leading roles in engineering academia were to learn and apply transformational leadership approaches, the job of changing the education environment to meet the needs of the future could be much easier.

This study points out a lack of exposure to accepted leadership theory by engineering education leaders, even though it is clear from their writings that the attributes they consider desirable are consistent with leadership studies. This can be taken as an example of engineering leaders not utilizing the work produced by those in what technical personnel frequently refer to as the soft sciences. This lack of transfer of potentially valuable knowledge and experience appears to be due to a long-standing view by those in the technical fields that somehow the less quantifiable work in these non-technical fields is of lesser value. A more liberal-minded position is required, wherein engineers and engineering educators acknowledge the shortcomings of their own solution approaches and the potential benefit of utilizing the results of research conducted outside the engineering arena. This points toward a strategic weakness in the way engineering education leaders are attempting to provide progressive leadership for the future and indicates a need for more understanding and recognition of general leadership studies by engineering education leaders.

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Biography

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SOUNDING THE DEPTHS: ASSESSING CADET KNOWLEDGE OF ENGINEERING ETHICS

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Abstract

Science teaches what can be done, law teaches what may be done, and ethics teaches what should be done. All four United States Coast Guard Academy (USCGA) Engineering Programs are accredited by the Accreditation Board for Engineering and Technology (ABET); accreditation requires all cadets majoring in engineering to have additional coursework in engineering ethics. Since ethics is among the core curricula at USCGA, all cadets are required to complete a general course in ethics. Over the past several years, engineering ethics has been taught as a module of capstone design courses in each major. This is an alternative to teaching engineering ethics as a separate course. Assessing student knowledge of engineering ethics is a concern. USCGA has used assessments like the Ethics Luncheons to give cadets an opportunity to interactively discuss ethics, and more traditional approaches such as written assignments that include papers analyzing the engineering ethics involved in creating weapons. Two rubrics have been developed to assess ABET Criteria 3c and 3f. The ED03 Rubric attempts to generate assessment data for ABET 3c by assessing five factors: economic, ethical, safety, manufacturability and social/ political /environmental/sustainability. The ED06 Rubric attempts to generate data to assess ABET 3f by assessing two factors: student understanding of the code of ethics and ethical judgment. USCGA is working towards developing a reliable method for assessing ethical knowledge.

Introduction

The United States Coast Guard Academy (USCGA) is one of five Service Academies training and educating future officers for service. USCGA offers eight majors, with four of the eight in engineering (Civil, Electrical, Mechanical and Naval Architecture and Marine Engineering). USCGA seeks accreditation for all programs, including ABET accreditation for its engineering programs.

Prior to the last ABET visit in 2007, three of the four engineering programs had very short plans for addressing 3f [1-3]. Electrical Engineering had a more robust plan, but the faculty were uncomfortable with many of the items included in the assessment because the program had no control over most of the items [4]. The problem was relying on other departments and divisions to support engineering programs when and if changes need to be made. It is much easier to include only assessments in courses controlled by the programs.

The Need to Assess Ethical Knowledge

Institutions seeking ABET accreditation for engineering programs must publish and document student success at mastering student-specific outcomes. Table 1 outlines ABET's list of required student outcomes. As noted by ABET, student outcomes should lead to program graduates attaining the program's educational objectives. Each degree program should list and prepare documentation for each outcome (a-k). If a program has additional student outcomes, they should be included. Notable among the student outcomes is Criteria 3f, an understanding of professional and ethical responsibility. Different institutions and programs interpret 3a-k differently. This is accepted as part of the ABET accreditation process, and allows institutions and programs to address its interpretation and approach to addressing these outcomes.

Since the latest ABET criterion allows each program to define its own performance indicators for these outcomes, every institution struggles to define their approach to developing outcome measures, and USCGA is no exception. Some ABET Criterion-3 requirements are easier to document than others because they are measured at several points, so there are many more opportunities to assess these skills. For example, Criterion 3a—an ability to apply knowledge of mathematics, science and engineering—can be assessed in any number of math, science and engineering courses.

Table 1. ABET Criterion 3 Outcomes [5]

(a) an ability to apply knowledge of mathematics, science, and engineering
(b) an ability to design and conduct experiments, as well as to analyze and interpret data
(c) an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability
(d) an ability to function on multidisciplinary teams
(e) an ability to identify, formulate, and solve engineering problems
(f) an understanding of professional and ethical responsibility
(g) an ability to communicate effectively
(h) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context
(i) a recognition of the need for, and an ability to engage in life-long learning
(j) a knowledge of contemporary issues
(k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

Proving an institution or program prepares students to solve various problems using their engineering, science and mathematics knowledge can be as simple as having standardized examination questions on several exams in different classes. How does a program measure its students' understanding of professional and ethical responsibilities? What does it mean for a student to demonstrate understanding versus an ability to do something?

Bloom's Taxonomy of the Cognitive Domain may prove helpful in addressing these questions. Bloom's Taxonomy was developed by a group of educational psychologists to classify cognitive skills. In short, Bloom's Taxonomy is a guide for measuring how well someone has learned some subject matter. Table 2 outlines Bloom's Revised Taxonomy.

Table 2. Bloom's Revised Taxonomy [6]

Cognitive Skill	Expectations/Objectives	Verbs for Objectives
Remember	Shallow processing, drawing out factual answers, testing recall and recognition	Choose, describe, define, identify, label, list, locate, name, recite, select, state
Understand	Translating, interpreting and extrapolating	Classify, defend, demonstrate, distinguish, explain, express, extend, indicate, infer, match, judge, paraphrase, present, restate, rewrite, select, summarize
Apply	Knowing when to apply; why to apply; recognizing patterns of transfer to situations that are new, unfamiliar or have a new slant for students	Apply, choose, explain, generalize, judge, organize, prepare, produce, select, show, sketch, solve, use
Analyze	Breaking down into parts, forms	Analyze, categorize, classify, compare, differentiate, distinguish, identify, infer, survey
Evaluate	Evaluation based on some set of criteria, and state why	Appraise, judge, criticize, defend, compare
Create	Combining elements into a pattern not clearly there before	Choose, combine, compose, construct, create, design, develop, do, formulate, invent, make, make up, originate, plan, produce, tell

By applying Bloom's Taxonomy to ABET's Criterion 3f, an understanding of professional and ethical knowledge would be a lower-level cognitive skill. The expectation may be that students are not able to resolve all ethical dilemmas presented to them, but are at least be able to recognize dilemmas, understand why the dilemmas exist, and know where to seek help to resolve those dilemmas.

In assessing student understanding, faculty can use Bloom to develop an assessment of a higher cognitive skill to measure a lower one. For example, cadets' understanding could be measured by having them read cases and write a judgment as a board of ethical review, based on an engineering code of ethics (ASCE, ASME, IEEE, NAME or NCEES). In this exercise, cadets would have to be able to recognize dilemmas, understand why the dilemmas exist and, based on an engineering code of ethics, decide if the action taken by the engineers in the case was acceptable.

Can, May and Should

Figure 1 is an attempt to graphically capture the education to which cadets are exposed. Science teaches what can be done, law teaches what may be done, and ethics teaches what should be done. As part of the core curriculum, cadets take courses in Maritime Law Enforcement, Criminal Justice and Morals and Ethical Philosophy. In addition to coursework, cadets participate in ethics training provided through the Cadet Division. This training includes the Ethics Forum, which is a day-long series of ethics addresses by individuals with military, medical, philosophical and engineering backgrounds.

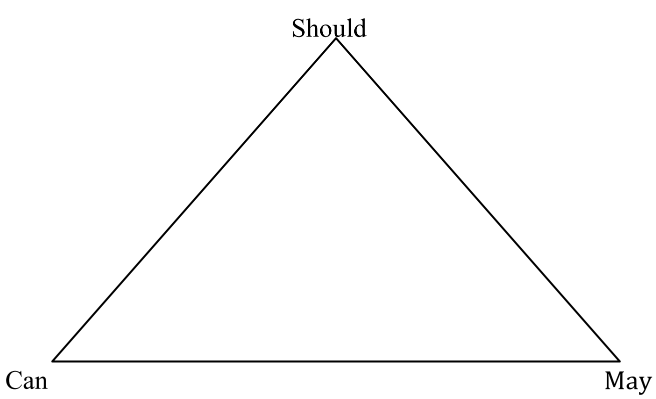

Figure 1. Cadet Education and Training

The combination of academic coursework and military experiences such as Cadet Honor Concept, Cadet Honor Board and Ethics Forum give cadets a big-picture understanding of where the lines between legal/illegal and ethical/unethical behavior are. The introduction of profession-specific ethics, e.g.,, Engineering Ethics, is included in senior-level courses. A proposal was offered previously to modify the Morals and Ethics course to include a section on profession-specific ethics. The proposal called for 85-90% of Morals and Ethics to be taught by humanities faculty, and the remaining portion of the class to be taught by faculty from the majors. This proposal would have required major-specific sections of Morals and Ethics, as well as identifying faculty that could absorb additional teaching assignments. The proposal failed.

The Engineering Department has also used an Ethics Luncheon as a method of exposing cadets to engineering ethics. The Ethics Luncheons were designed to have faculty discuss ethics with cadets in a casual, roundtable setting. The luncheons were held every semester, with First Class Cadets required to attend three of the four luncheons offered during the semester and write a paper discussing the ethics of a particular case. In the first year, the luncheon was very successful. First Class Cadets enjoyed the informal ethics discussions with faculty. As the luncheons were modified, the amount of work increased, and as faculty members rotated to new duty assignments, interest in continuing the program waned.

A course in Engineering Ethics could be developed and offered very quickly. The course would extend exploration of topics covered in Morals and Ethical Philosophy, and then focus on engineering-based ethics and case studies. To add this course to the curriculum would require the loss of the only free elective cadets in engineering majors currently have. According to the current course catalog, two of the four engineering majors only have one elective—the free elective. The other two majors have either one free and two major electives, or two free electives [7]. Given the amount of coursework and training devoted to the subject of Ethics, keeping the Ethics in Capstone Design and Construction Management class is probably the best choice.

Measuring an Understanding of Ethics

As programs have settled on when assessments will be done, rubrics have been developed to measure understanding. Both ABET 3c and 3f have ethics as a component. Two rubrics currently under development attempt to measure an understanding of ethics as well as the ability to design with constraints including ethics. The rubric addressing 3f is in Appendix 1: ED06 Rubric Addressing ABET Criteria 3f.

Rubrics for outcomes 3c and 3f were developed using "silent brainstorming" and "grouped affinity" activities. Outcome 3f was judged to be sufficiently general such that all four of CGA's engineering programs could reasonably share common performance indicators and levels of performance. Therefore, the rubric for outcome 3f was developed by a department-wide assessment committee for use by all four programs. However, outcome 3c, which deals with design, was judged to be program-specific and, accordingly, the development of the rubric was best addressed by the respective program faculty.

Both rubrics are structured as analytic rubrics. The rubric for outcome 3f features two performance indicators: 1) awareness and understanding of the code of ethics, and 2) Ethical Judgment, including problem recognition and solution description. The first performance indicator is structured to exactly meet the minimum requirements for "understanding" and is structured to assess mere awareness or knowledge of any professional society's engineering code, as is actually focused at the "remember" level of achievement (a level below "understanding") to determine if awareness itself is potentially a contributing factor to a hypothetical cadet's failure to achieve the desired level of this outcome. This was deemed important because, as mentioned above, cadets receive extensive exposure to ethics, exposure which includes rigorous academic preparation and practical training exercises in the course of their military duties. However, this training is either general in nature or tailored to the Coast Guard profession, which means that it is not necessarily tailored to the engineering profession specifically. The "awareness" line of the rubric, then, provides a means to assess if the existing four-year program of study adequately exposes the cadets to professional society codes of ethics.

The "ethical judgment" performance indicator actually exceeds the minimum level of "understanding" and instead specifies problem recognition and problem solving as the minimum levels of performance. As such, this performance indicator actually specifies a level of performance in excess of that required by ABET. However, considering the mission of the institution and the objectives of the programs, which include successful service as a U.S. military officer, the higher level of attainment was deemed appropriate and necessary to enable ultimate achievement of these objectives.

This higher level of attainment is also evident in the performance indicators associated with outcome 3c. Here, the causal relationship between objective and performance indicator is not as obvious. Specifically, outcome 3c defines the "ability to design...within realistic constraints such as ...ethical..." This raises the question: What level of attainment of ethics is necessary to allow its consideration as a design constraint? Is this "understanding" or a higher level on Bloom's taxonomy?

The program faculty considered this carefully and decided that to include ethical considerations in design actually involved the application of ethics; in other words, a level of attainment on Bloom's taxonomy above "understanding". The performance indicators for this rubric (which is also an analytic rubric) address "awareness" (much as for the outcome 3f rubric) but extend the concept of attainment in the ethics performance indicator to include "end use". This performance indicator implies that the level of attainment of an engineer for ethics needs to be at the "application" level above "understanding" as specified in outcome 3f.

The tie between the level of performance expected of an individual in ethics at the U.S. Coast Guard Academy is therefore driven by two factors: 1) A level of performance that includes "application" that is driven by the institution's mission and the objective of military service for its graduates; and 2) a level of performance that is driven by the ability to "apply" ethics to design—an expectation of "application" that is driven by the program objective of producing an engineer.

Therefore, the level of achievement of "ethics" for an engineer at the Coast Guard Academy needs to be at the "application" level for two reasons: 1) to prepare the cadet for service as a Coast Guard Officer; and 2) to prepare the cadet to perform as an engineer capable of considering ethics as a realistic design constraint. Significantly, even without the military mission of the Academy, this second reason still implies that all engineers should be capable of applying ethics to their designs, which implies that the wording of outcome 3f is such that the level of expected attainment ("understanding") is set too low.

Conclusions

The Engineering Department at the United States Coast Guard Academy is in the early stages of assessing ABET's 3c and 3f Criteria for ethics. With the creation of two rubrics, the department has the ability to start gathering data. The department's next step is to map the performance indicators associated with these rubrics to appropriate courses in the existing curriculum to identify opportunities to assess each performance indicator. The department anticipates that new opportunities—most likely in the form of locally-prepared assignments, but possibly also focus group, interview, or other types of assessment opportunities—will have to be created in order to assess some of the performance indicators since gaps between the performance indicators and existing program will likely become visible as a result of the mapping process. Once assessment opportunities have been either identified or created for all of the performance indicators, a second set of assessment opportunities may be created for select performance indicators in order to triangulate data. The necessity for, and manner of, triangulation will be determined after inspection of the preliminary assessment results.

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Appendix

Appendix 1. ED06: Rubric addressing ABET Criteria 3f

Code of Ethics - Awareness		
Unsatisfactory	**Satisfactory**	**Excellent**
Unaware of Engineer's Code of Ethics	Aware of Engineer's Code of Ethics	Aware of Engineer's Code of ethics and can name several key components from memory
Code of Ethics - Understanding		
Unsatisfactory	**Satisfactory**	**Excellent**
No understanding of Engineer's Code of Ethics	Understands key portions of Engineer's code of ethics	Can explain interrelationship between components of code
Ethical Judgment - Problem Recognition		
Unsatisfactory	**Satisfactory**	**Excellent**
Fails to recognize the ethical problems with a given situation	Recognizes key ethical problems (honesty, fairness, conflict of interest) in a given situation	Recognizes key ethical problems and other related ethical issues, and can articulate the trade-off between apparently conflicting ethical positions.
Ethical Judgment - Solution		
Unsatisfactory	**Satisfactory**	**Excellent**
Fails to describe an ethical solution to even the simplest of problems	Can describe an ethical solution to problems involving one ethical dimension	Can describe an ethical solution to problems involving multiple or apparently conflicting ethical dimensions

Survey of Professional Development Opportunities for Two-Year-Institution and Community College Faculty

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Abstract

In August and September of 2010, members of the Engineering Technology Division of ASEE and the New York State Engineering Technology Association listservs were asked to complete an online survey. The survey was designed to probe the professional development funding opportunities for faculty members of two-year institutions and community colleges. Seventy-eight responses were received within one month. Out of 78 responses, 56 respondents indicated their institution affiliation, which resulted in 50 non-duplicated institutions being represented out of 344 institutions from the listservs. Based on the information collected, 14.1% of respondents are responsible for obtaining their own funding for professional development, out of which 45.5% are paying out of pocket. This could be a tremendous burden on new faculty members, who traditionally start at a low salary and need professional development the most. The remaining respondent pool was divided as follows: 16.7% are funded on the departmental level, 20.5% are funded on the divisional level, and 48.7% are funded on the college level. According to expectations, a high percentage of faculty members from private technical schools (more than 30%) are responsible for their own funding. Surprisingly, faculty at state-affiliated schools face a similar problem with more than 18% being forced to come up with funding for their professional development activities. There is an inverse relationship between department size and the funding opportunities provided at the department, division, or college level. It was also determined that 49% of all respondents have to pay their own professional organizations' membership dues.

Introduction

A request to complete an online survey was sent to members of the Engineering Technology Division of ASEE and the New York State Engineering Technology Association listservs in August and September of 2010. Members of two-year colleges were asked to complete a survey about how professional development activities such as conferences, workshops, and seminars were funded at their institutions. Additional information was requested such as the size of the department and college, program accreditation, private or public institution (and affiliation with county or state for public institutions), the number of department faculty members, and the number of students enrolled in the institution. Members were also asked to list their college to verify that respondents were from a two-year school. In a four-week period, 78 people responded, 56 of which indicated their college affiliation. This resulted in 50 different colleges being represented in the survey results out of 344 originally questioned. The results of the survey are presented and analyzed here, which is organized as follows. First, the motivation for the survey, criteria evaluated in the survey, and overall results obtained relevant to the funding opportunities and restrictions for the two-year institution and community college faculty are discussed. Then, the thorough analysis of correlation between the funding opportunities and limitations and the institutional accreditation status is conducted. Next, a similar analysis is conducted to evaluate correlations between the funding and the institutional affiliation, such as state, county, or private. Furthermore, the correlations between funding issues and institution and department size are evaluated. Finally, additional input on the funding strategies and main conclusions are outlined.

Analysis of Funding Opportunities and Restrictions for Two-Year-Institution and Community College Faculty

The survey was conducted to gather information on how other schools fund professional development with the goal of presenting the information to our administration. ABET Criterion 6 addresses the requirement of ongoing professional development, and we hoped to get a funding increase with the data obtained from the survey [1]. The survey questions were based on how funding is derived at Erie Community College and on the limited knowledge available about how professional development was funded at other two-year colleges. The ASEE Engineering Technology Division listserv was chosen after seeing the large number of responses to several surveys related to engineering technology programs [2-4]. The NYSETA listserv was surveyed as well, even though the number of two-year schools was much smaller.

The study was set up to determine if membership dues for professional organizations were funded, and what limits, if any, were imposed on the amount of dues paid. The survey was designed to gather information in order to determine what factors were potentially related to funding. Some factors that could potentially be relevant were program accreditation, type of affiliation, size of school, and number of faculty in the department. The survey questions and corresponding logical organization of the survey are shown in Figure 1.

It was determined that 14.1% of all respondents are responsible for obtaining their own funding. Additionally, 85.9% of respondents indicated that they have access to the following institutional funding sources: 16.7% are predominantly funded on the departmental level, 20.5% are predominantly funded on the divisional level, and 48.7% are predominantly funded on the college level. Out of the self-funding category, 45.5% of faculty members have to pay for the professional development activities out of their own pockets, 54.5% have access to federal and/or state grants, 9.1% have access to various corporate and/or foundational grants, and 9.1% are able to benefit from NEA/AFT or other union-related grants. It was also found that 49.3% of all surveyed faculty members have a yearly limit on the number of conferences, workshops, or seminars they can attend; the number varies from 1 to 5 events per year, with the majority of faculty being limited to 1 or 2 professional development activities per year. More than 65% of the surveyed faculty indicated that they have a dollar limit on the individually funded activities, which varies greatly with 50% of faculty being limited to less than $1,000 per year, 47% being limited to $1,000-$3,000 per year, and 3% being able to use $3,000 or more per year.

Around 80% of the surveyed faculty members are allowed to attend local, state, regional, or national conferences using the funding sources from their institutions or from grants. However, only 20% are actually allowed to attend any kind of international conference or forum if funded through their institution or by grants. Only a small percentage of the surveyed faculty (13.2%) is restricted in the number of days per year allowed for professional development, which range from 3 to 10 days per year. Another category of the survey evaluated dues paid to professional organizations and how these dues are funded. About 36.5% of respondents indicated that all dues are paid by their institution, 49.2% claimed that all dues are paid out of pocket, and 14.3% said that only a portion of the dues (ranging from 12% to 80%) is paid by their corresponding institution.

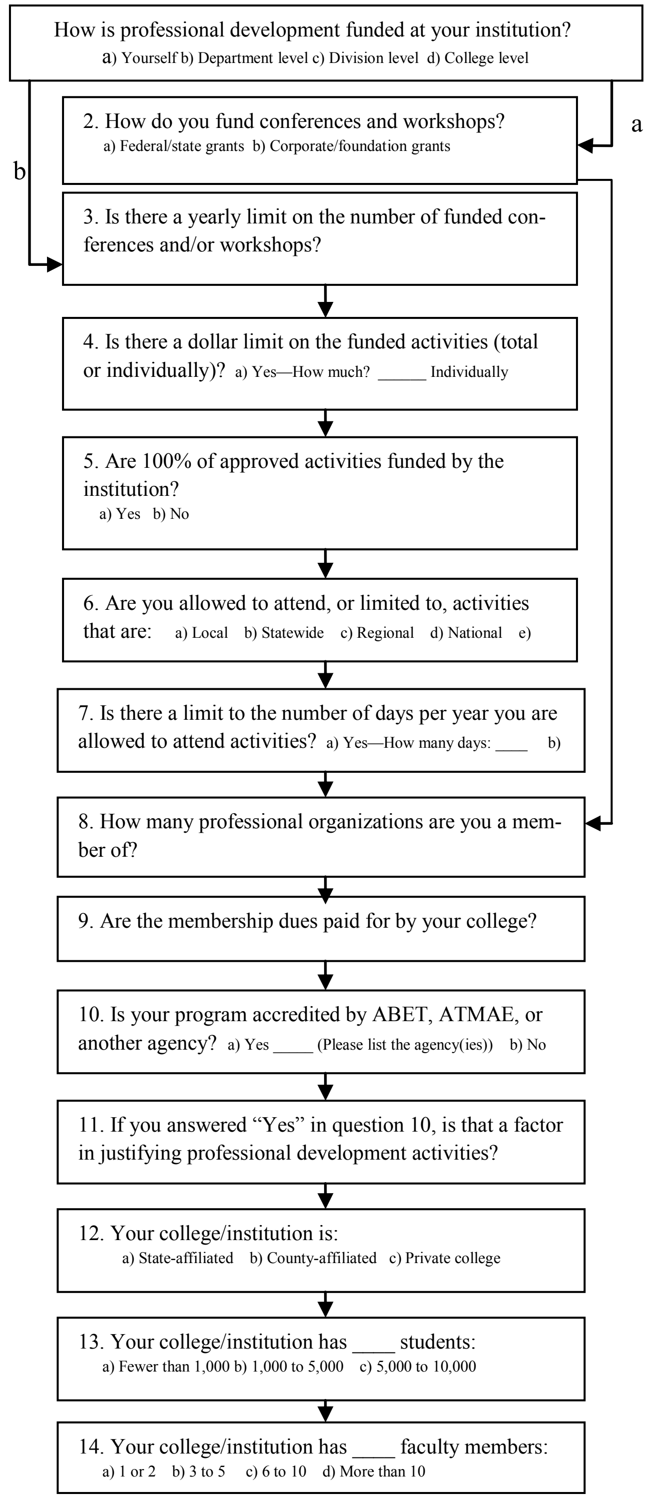

Figure 1. Survey Questions and Survey Logical Organization

Funding Opportunities and Restrictions Based on Institutional Accreditation

In the following analysis, category "All" refers to all responses collected; category "Accredited" refers to the faculty from externally accredited programs through ABET, ATMAE, or similar agencies; category "Not accredited" refers to the faculty from non-accredited programs; and category "Not sure" refers to the faculty who failed to specify the accreditation status altogether.

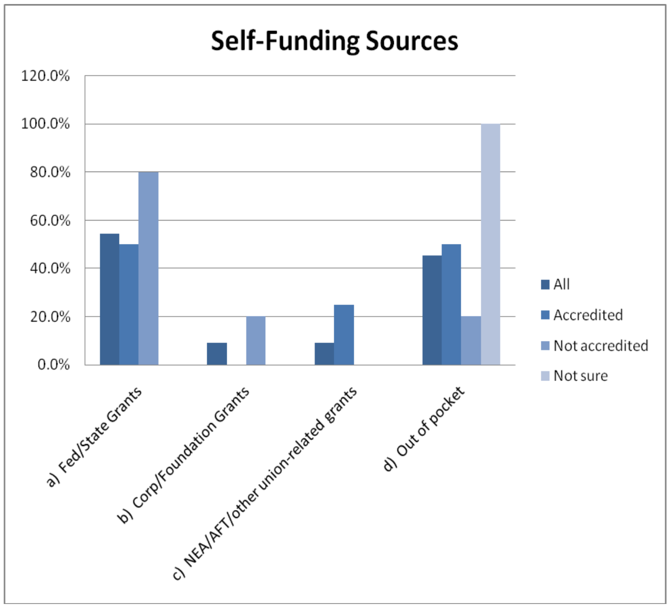

Figure 2. Funding Sources Used by Self-Funded Faculty

On the basis of the collected data, about 15.4% of the faculty members from the accredited programs are responsible for their own funding, as shown in Figure 2. This is only slightly higher than the 14.1% of the number of faculty that participated in the survey, who have to obtain their own funding. Surprisingly enough, the self-financing faculty from accredited programs are more likely to pay out of pocket (50%) than the faculty from non-accredited programs (20%). It also seems that faculty from non-accredited programs have better access to federal/state grants (80%) than their counterparts from the accredited programs (50%). The "Not-sure" category, which did not indicate being either accredited or not accredited by the external accreditation bodies, indicated an even higher percentage of self-funded activities being paid out of pocket. Based on the comments given at the end of each survey, we speculate that most of the faculty members in this category are either newly hired (and are not familiar with all the details about their corresponding programs) or part-time faculty. This is disturbing since new faculty members, who typically need more professional development than senior faculty and have notably lower salaries, may be forced to pay out of pocket. It is also disturbing to find that faculty from accredited programs have less access to federal and state grants than their counterparts from non-accredited programs, since the burden of keeping the accreditation current in their appropriate field requires more professional development.

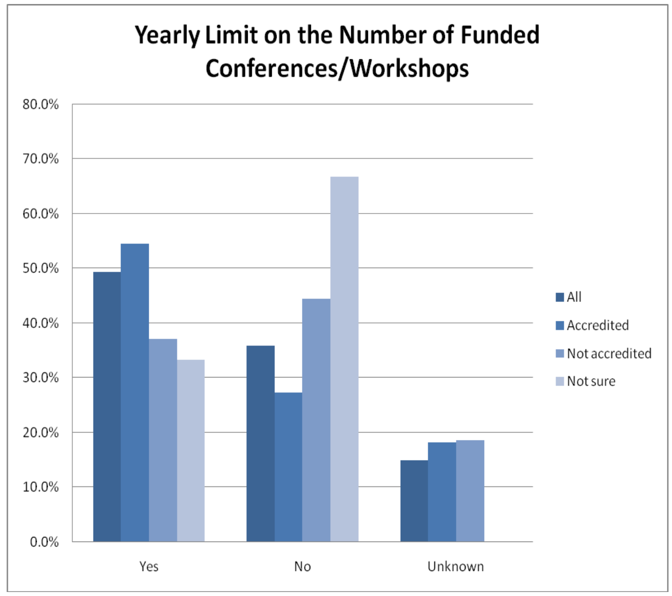

Figure 3. Analysis of the Yearly Limit on the Number of Funded Conferences and Workshops Based on the Accreditation Status of the Institution

Figure 3 indicates that the faculty from accredited programs have more stringent limitations on the number of conferences and workshops they can attend on a yearly basis as a part of professional development. Of accredited programs, 54.5% of the faculty have yearly limitations on the number of funded conferences/workshops they can attend, in comparison with only 37% of the faculty from non-accredited programs. Furthermore, a higher percentage of faculty from accredited programs have limits on the number of days per year allowed (18.2%) relative to the faculty from non-accredited programs (11.1%). However, faculty from accredited programs have a higher percentage of approved activities, which are 100% funded, compared to those from non-accredited programs (45.5% versus 40.7%), as presented by Figure 4. On a similar note, 42.3% of the faculty from accredited programs have their institutions paying membership dues in their professional organizations versus only 37.5% of the faculty from non-accredited programs.

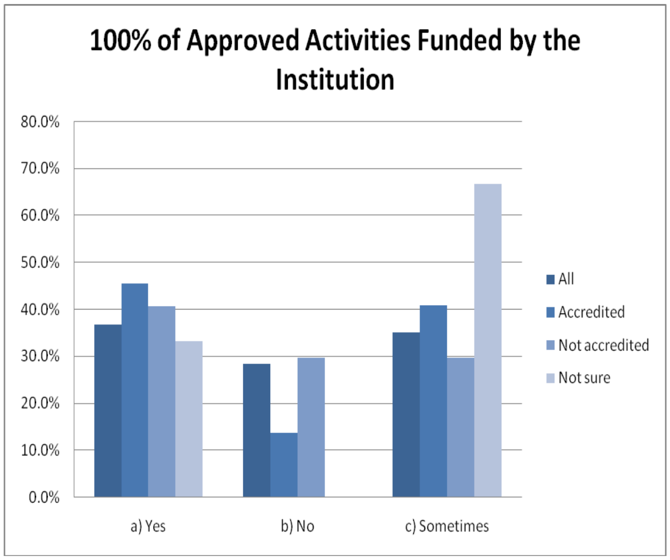

Figure 4. Analysis of the Percentage of Completely Funded Approved Activities versus Accreditation Status of the Institution

Funding Opportunities and Restrictions Based on Institutional Affiliation

In the following section, the correlation between the funding situation and institutional affiliation, such as "state," "county," or "private", was considered. Out of the total number of responses, 63.3% came from state-affiliated institutions, 25% from county-affiliated institutions, and 11.7% from private schools and colleges. It was somewhat surprising to find out that only 10% of self-funded faculty members are affiliated with county institutions, as Figure 5 indicates. Considering that county-affiliated institutions make up 25% of the respondent pool, the fraction of self-funded faculty in county-affiliated institutions is much smaller than in the state-affiliated institutions (80% of self-funded faculty come from state-affiliated colleges that make up 63.3% of the total respondent pool). So, a higher percentage of state-affiliated faculty members are responsible for their own funding in comparison with the county-affiliated. The situation for private institutions is similar to the state-affiliated institutions.

As Figure 6 indicates, 53.3% of county-affiliated institutions cover professional membership dues for their faculty completely. A much smaller percentage of state-affiliated institutions (28.9%) and private institutions (43%) cover professional membership dues fully. An equal percentage of state-affiliated, county-affiliated, and private institutions cover only the portion of the professional membership dues. The partial percentage of membership dues covered varies from 12% to 80%, depending on the individual institution.

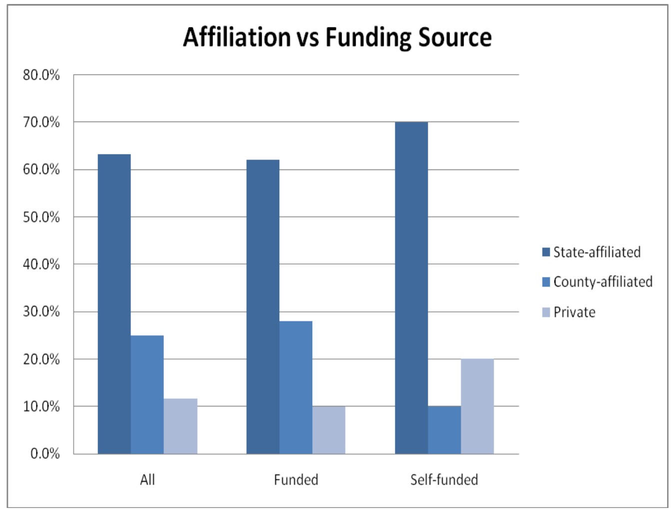

Figure 5. Breakdown of Funding Categories by the Institutional Affiliation

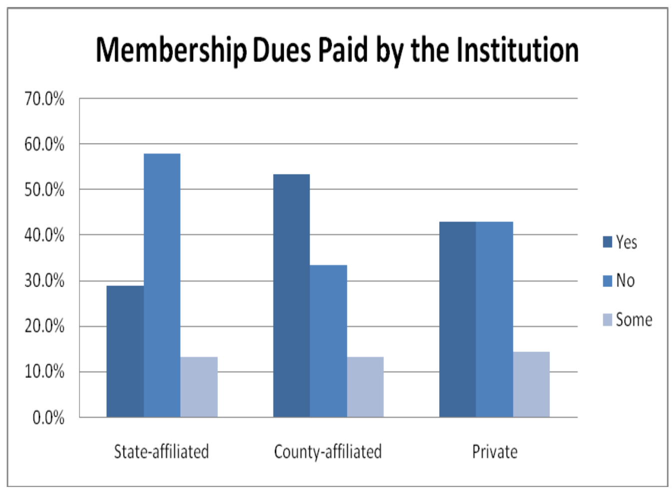

Figure 6. Professional Membership Dues Paid by the Institution Compared to the Institution Affiliation

Figure 7 shows that county-affiliated institutions impose much more stringent limitations on the number of days per year allowed to attend professional development activities (21.4%), in comparison with the state-affiliated institutions (12.9%). The data for private institutions is inconclusive, with 60% of respondents from such institutions indicating that they are not familiar with the limitations on the number of days allotted for professional development per year.

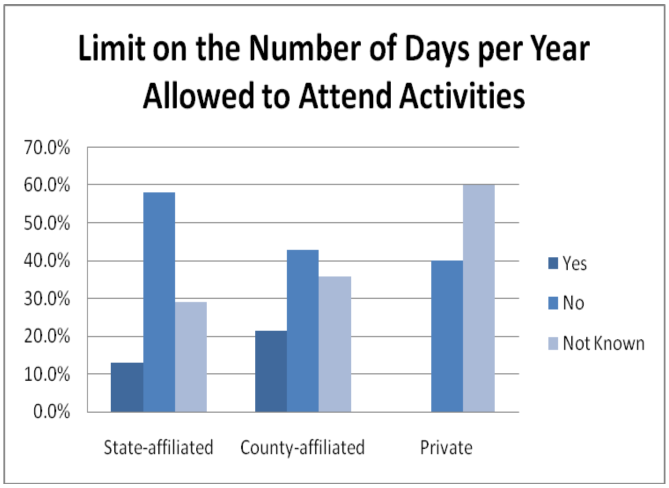

Figure 7. Limits on the Number of Days Allowed for Professional Development Activities for Various Institution Affiliations

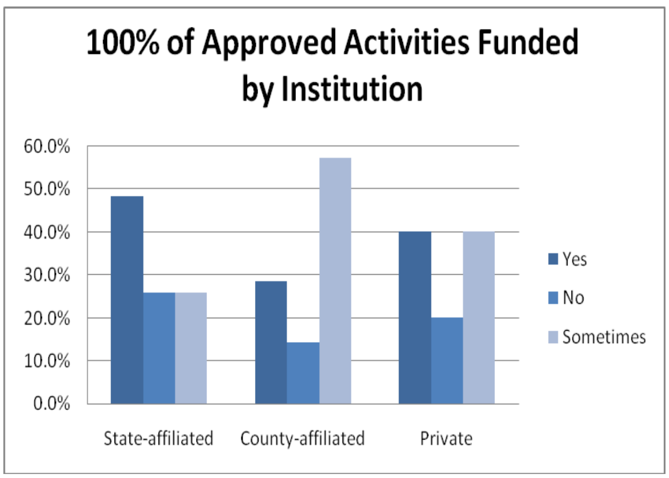

Figure 8. Funding of Approved Professional Development Activities for State Affiliated, County Affiliated and Private Institutions

Finally, state-affiliated institutions tend to fund more overall approved professional development activities (48.4%) than county-affiliated institutions (28.6%), with private institutions falling in between (40%), as shown in Figure 8.

Analysis of Funding versus Institution and Department Size

In this section, the analysis of the possible dependence of funding sources for faculty professional development on the size of the two-year institution is presented. The following categories were tracked based on the total number of students enrolled in the institution: fewer than 1,000 students, 1,000 to 5,000 students, 5,001 to 10,000 students, and more than 10,000 students. The results indicate that a larger fraction of faculty from small schools (with fewer than 1,000 students) and from very large schools (with more than 10,000 students) are responsible for their own funding for professional development activities, compared to colleges with an intermediate number of students enrolled (1,000 to 10,000). Out of faculty responsible for their own funding sources, 100% of respondents from institutions with fewer than 1,000 students have to finance most of their professional development activities out of pocket, followed by 60% of faculty from the largest colleges (with more than 10,000 students), and only 33% of faculty from the intermediate colleges (with 5,001 to 10,000 students).

The survey results also indicated that funding sources vary based on the number of faculty in each individual department. The largest percentage of faculty members (23.5%) from departments with more than 10 faculty members are responsible for their own funding, followed by 21.1% of faculty from departments with 6 to 10 faculty members, 9.1% of faculty from departments with 1 to 2 members, and 7.7% of faculty from departments with 3 to 5 faculty members. Out of these faculty members who must self-fund their professional development activities, 75% of faculty from departments with more than 10 members and 40% of faculty from departments with 6 to 10 members must pay out of pocket. Considering the fact that the starting salary for two-year schools is generally poor, this could substantially hinder the professional development of the faculty members and, as a result, the quality of education (especially in the technology fields).

Additional Comments on the Funding Schemes Represented

The survey developed for this study was designed as a probe of alternative funding strategies employed by two-year institutions. It offered a limited selection of possible answers for each question in an attempt to keep the length of the survey down to a level that would not constrain the number of completed surveys. At the end of the survey, the respondents were presented with the opportunity to put in additional comments about their funding situations. Some of the most interesting comments on the funding strategies are summarized below:

- Some institutions only pay conference registration costs.
- Some institutions' funding is from the contract agreement up to $1,000 per individual, with another $1,000 if it is not all used by others. Addi-

tional funds for workshops and conferences are also available from other sources inside and outside the college.

- Most colleges do not provide professional development funding for adjunct faculty.
- Another funding scheme includes a travel grant that can be applied for and has the maximum amount available. This amount can be spent on one or more conferences. Any expenses over that maximum amount are paid out of pocket.
- Many colleges indicated that funding is available from multiple sources, for example departmental funds together with grants.
- Other colleges allocate a certain amount per faculty (usually less than $1,000). However, if all the funds are not allocated, faculty may attend events that cost more than $1,000.
- Another strategy includes a special foundation, which will fund up to $500 per year for up to two people within each division to attend development activities that the school will not fund. The interested faculty applying for these funds must donate at least $10 a month to the foundation.
- According to the next strategy, a contract ensures that each faculty member is allocated several hundred dollars per year for travel and dues. Faculty may transfer funds to each other and any unused funds are pooled at the end of the year to cover expenses beyond the original amount per faculty.
- Last group of colleges allots funds to bring speakers from outside the college for professional development in addition to funding conferences and workshops. This situation was not offered as part of this survey to be evaluated, since it is not a typical strategy for two-year colleges.

Summary

Presented in this paper are the results and analysis of the funding opportunities, sources, and restrictions for various two-year institutions offering technology programs. It was found that a high percentage of faculty members are forced to self-finance (including out-of-pocket financing) their professional development activities. In this respect, the faculty members from institutions with fewer than 1,000 students and with more than 10,000 students, as well as faculty from larger departments, are affected the most. In conjunction with generally low salary ranges for two-year college faculty, this could present a substantial barrier for sufficient faculty development, especially in the technology departments. This could potentially lead to the deterioration of the quality of education.

Other sources of funding, as well as various limitations on professional development activities, were analyzed, and interesting correlations with institutional affiliation and accreditation were determined. At the present time, conducting a follow-up survey may be warranted by the possibility of gathering more information to clarify funding strategies involving multiple levels of funding of professional development activities.

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Biographies

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DEVELOPMENT OF AN AHP-BASED METHODOLOGY FOR SELECTING A PROJECT MANAGER

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Abstract

Assigning projects to project managers is one of the most important activities in an organization. It can strongly affect the performance of organizations or the results of their teams. Most projects are normally assigned to project managers according to their expertise and experiences in organizations. In this study, the authors looked at a model based on the Analytical Hierarchy Process (AHP) to assign a project manager. It is based on the quantitative and qualitative managerial competencies of people who are candidates for becoming team leaders and project managers. This approach is more efficient when the scope of the project is broad and none of the functional departments take the lead over the project. In this case, the methodology can make the work of assigning a project to a project manager more scientific and fair. Also presented is a subject illustrated case for selecting the best project manager for a given project out of four candidates.

Introduction

The purpose of this study was to develop a model based on the Analytical Hierarchy Process (AHP) methodology to select an appropriate project manager based on project needs and project manager characteristics for low- to high-complexity projects in various organizations. AHP is a well-known decision theory model developed by Saaty during the 1980's [1]. Its main attribute is ranking alternatives by quantifying relative priorities for a given set of alternatives on a ratio scale, based on the judgment of a decision maker [2]. "The AHP provides a flexible, systematic, and repeatable evaluation procedure that can easily be understood by the decision maker" [3] in selecting an appropriate project manager for an organization. This work establishes a framework for decision makers to compare individual project mangers based on their managerial capabilities. By using this framework, decision makers can increase the chance of selecting the most effective person for projects. A project manager is also chosen based on skills and competencies that match the project needs.

Selecting a good project manager is one of the most important factors of a project. The project manager has a direct influence on and can lead a project to success. The project manager is the person who applies knowledge, skills, tools, and techniques to project activities to meet project requirements. The project manager is the person who is responsible "for accomplishing the project objectives"[4]. It is obvious that the role of a project manager is inevitable in project achievements, but the role of a project manager has become not only one of coordinating the technical track of a project but also dealing with the human dimensions of projects [5]. The human dimensions help a project manager keep organizational culture and build relationships, a key factor for success in many organizations. For cases in which all project managers have the same capabilities over the technical track, the decision makers are looking for those project managers who can understand their own boundaries and the boundaries of other people involved in projects.

Selecting a project manager in an organization does not have a certain process because projects are unique undertakings. The advantage of this model is specifically pronounced when the scope of the project is broad and none of the functional departments take the dominant managerial, technical or technological lead. In this case, it is very important for decision makers who are assigning projects to a project manager for an organization to select an appropriate person expected to lead the project to success. Despite the voluminous research done on AHP, there is limited literature on its application in selecting a project manager in organizations.

This study is organized as follows: first, a comprehensive literature review of similar studies in this field is presented, followed by a short explanation of the AHP-based model. Then, an overview of project-manager competencies is presented, followed by the development of an AHP methodology to select an appropriate project manager. Next, an illustrative example, applying this proposed methodology, is presented along with a discussion of the conclusions of the study.

Literature Review

A review of the literature shows that applications of the AHP-based model have been utilized in the scope of project management in different ways. For example, Al-Harbi has used the AHP-based model in the area of project management mainly for contractor prequalification problems [2].

He uses this model to consider multiple “tangible” and “intangible” criteria in a systematic way. He stated that the AHP-based model can aid decision makers in the efficient use of their funds for more capable contractors. Anagnostopoulos et al. have also utilized the AHP-based model specifically for the prequalification of construction contractors “in order to enhance the performance levels of selected contractors and minimize failure in meeting client’s objectives” [6]. They find that AHP is a valuable tool for dealing with complex issues because it allows the decision makers to decompose hierarchically the decision problem to its constituent parts. Norita Ahmad utilized the AHP-based approach in order to select appropriate software by using the most common features as the selection criteria in ranking project software management [3].

Since AHP is a relatively easy process for decision making, many authors have used this method in different applications. William Ho studied integrated AHP in its myriad applications [7]. He conducted an extensive literature review of the application of AHP in many specific areas by different approaches. He aided researchers and decision makers in applying the integrated AHPs effectively by displaying how they are used in various sectors. Bi Xing et al. used the Fuzzy AHP-model based on triangular fuzzy numbers to mathematically and quantitatively evaluate project managers’ abilities [8]. They believe that FAHP can give decision makers the ability to convert the way they select project managers by using qualitative evaluation instead of quantitative analysis. Mian et al. used the AHP model as a decision making model in choosing a project manager by focusing on technical, administrative, and interpersonal competencies [9].

There is an extensive body of literature available for selecting a project manager based on other methods. For example, Zhao Hui et al. introduced the principal component analysis (PCA) to select the most suitable project manager [10]. Peerasit Patanakul et al. used the integer programming model as a decision support model for assigning projects to project managers [11]. In some studies, authors believe that the Emotional Intelligence of project managers contributes to projects success. For example, Turner et al. addressed the impact of Emotional Intelligence on project success [12].

Other studies show that human personality factors are critical for selecting project managers in order to lead a project to success. Bedingfield et al. researched the role of the big five personality traits of project managers in project success in the United States Department of Defense [13]. They explored the links between personality and the effectiveness of project managers. They also did an extensive study on the big five personality characteristics: extraversion, openness, conscientiousness, agreeableness, and neuroticism and how they contribute to the success of the different areas of a project. Petterson has also identified problem solving, administration, supervision, team management, interpersonal relationships, and other personal relationships as key attributes that are valuable for project manager selection [14]. Valencia summarized the key attributes of successful project managers that were discussed in several different studies [15]. He considers leadership skills, communication skills, decision-making skills, administrative skills, coping ability, analytical thinking, and technical competence as the most common attributes for selecting a successful project manager.

AHP Framework

After providing a critical review of existing literature, we recognize that the AHP-based model can be used to select a project manager in an organization by quantifying relative priorities among project manager competencies and characteristics. The AHP technique is a useful, powerful, and important methodology in the decision-making process. Due to its relatively easy use, and its wide application, the AHP has been applied in ranking, selecting, evaluating, and optimizing decision alternatives by many researchers over past three decades. In this study, an AHP-based model was developed in order to select a project manager within an organization by various managerial competencies, which are important for project performance out of a number of alternatives. The AHP technique can be demonstrated in greater detail using a case in which is it assumed that there are m objectives; the AHP technique performs the multi-objective decision by the following steps [16]:

Table 1. Pair-wise Comparisons Scale

Verbal Scale	Numerical Values
Equally important, likely or preferred	1
Equally to moderately important, likely or preferred	2
Moderately more important, likely or preferred	3
Moderately to strongly important, likely or preferred	4
Strongly more important, likely or preferred	5
Strongly to very strongly important, likely or preferred	6
Very strongly more important, likely or preferred	7
Very strongly to extremely important, likely or preferred	8
Extremely more important, likely or preferred	9

1. Arrange the problem elements into hierarchical order
2. Complete pair-wise comparison at each level by comparing pairs of criteria using the fundamental scale by using Table 1 [16]
3. Calculate eigenvectors by the weight of the criteria
4. Verify the consistency of the pair-wise comparisons

First, in order to structure the problem elements into a hierarchy, the criteria that highly affect the study goal must be identified. After structuring the problem into levels of hierarchy, the pair-wise comparison matrix A for m objectives as shown in Equation 1 is filled in using a nine-point scale calculated from Table 1, as shown above.

$$A = \begin{bmatrix} \mathbf{a}_{11} & \mathbf{a}_{12} & \cdots & \mathbf{a}_{1m} \\ \mathbf{a}_{21} & \mathbf{a}_{22} & \dots & \mathbf{a}_{2m} \\ \vdots & \vdots & \ddots & \vdots \\ \mathbf{a}_{m1} & \mathbf{a}_{m2} & \dots & \mathbf{a}_{mm} \end{bmatrix} \qquad (1)$$

where, a_{ij} is the relative importance of the i^{th} objective compared to the j^{th} objective. This calculation is used for constructing the column vector of importance weighing. Then, set a_{ii} = 1 as it is equally important. Next if we set a_{ij} = k, then we will set a_{ji} = 1/k. Next each value of column i in matrix A is divided by the sum of the values in column i to arrive at the new matrix A_w as shown in Equation 2. In this matrix, A_w the sum of the entries in each column will be 1.

$$A_w = \begin{bmatrix} \frac{\mathbf{a}_{11}}{\sum_{i=1}^{m} a_{i1}} & \frac{\mathbf{a}_{12}}{\sum_{i=1}^{m} a_{i2}} & \cdots & \frac{\mathbf{a}_{1m}}{\sum_{i=1}^{m} a_{im}} \\ \vdots & \vdots & \cdots & \vdots \\ \vdots & \vdots & \ddots & \vdots \\ \frac{\mathbf{a}_{m1}}{\sum_{i=1}^{m} a_{i1}} & \frac{\mathbf{a}_{m2}}{\sum_{i=1}^{m} a_{i2}} & \cdots & \frac{\mathbf{a}_{mm}}{\sum_{i=1}^{m} a_{im}} \end{bmatrix} \qquad (2)$$

Next the relative degree of importance is computed as C_i, which is given by the average of the entries in row i of A_w, which in turn yields column vector C shown on Equation 3.

The consistency in a pair-wise comparison matrix can be checked by carrying out the following sub-steps:

1. The first step is to compute the product of matrix A and matrix C as shown in Equation 4:

$$C = \begin{bmatrix} c_1 \\ \vdots \\ \vdots \\ \vdots \\ \vdots \\ \vdots \\ c_m \end{bmatrix} = \begin{bmatrix} \dfrac{\frac{\mathbf{a}_{11}}{\sum_{i=1}^{m} a_{i1}} + \frac{\mathbf{a}_{12}}{\sum_{i=1}^{m} a_{i2}} + \cdots + \frac{\mathbf{a}_{1m}}{\sum_{i=1}^{m} a_{im}}}{m} \\ \vdots \\ \dfrac{\frac{\mathbf{a}_{m1}}{\sum_{i=1}^{m} a_{i1}} + \frac{\mathbf{a}_{m2}}{\sum_{i=1}^{m} a_{i2}} + \cdots + \frac{\mathbf{a}_{mm}}{\sum_{i=1}^{m} a_{im}}}{m} \end{bmatrix} \qquad (3)$$

$$AC = \begin{bmatrix} \mathbf{a}_{11} & \mathbf{a}_{12} & \cdots & \mathbf{a}_{1m} \\ \mathbf{a}_{21} & \mathbf{a}_{22} & \dots & \mathbf{a}_{2m} \\ \vdots & \vdots & \ddots & \vdots \\ \mathbf{a}_{m1} & \mathbf{a}_{m2} & \dots & \mathbf{a}_{mm} \end{bmatrix} \begin{bmatrix} c_1 \\ c_2 \\ \vdots \\ c_m \end{bmatrix} = \begin{bmatrix} x_1 \\ x_2 \\ \vdots \\ x_m \end{bmatrix} \qquad (4)$$

2. The second step would be to compute δ, as shown in Equation 5:

$$\delta = \frac{1}{m} \sum_{i=1}^{m} \frac{i^{th} \, entry \; in \; A.C}{i^{th} \, entry \; in \; C} = \frac{1}{m} \sum_{i=1}^{m} \frac{x_i}{c_i} \qquad (5)$$

3. The third step would be to compute the consistency index (CI), as shown in Equation 6:

$$CI = \frac{\delta - m}{m - 1} \qquad (6)$$

4. The fourth step is to compare the consistency index (CI) to the random index (RI) for the appropriate value of m to determine if the degree of consistency is satisfactory. Table 2 shows the value of average random consistency (RI). If the consistency index (CI) happens to be small enough, it means that the comparisons are likely to be consistent enough to give useful estimates of the weights for the objective function. If CI/RI < 0.10, the degree of consistency is said to be satisfactory, but if CI/RI > 0.10, it implies that serious inconsistencies may exist, and that the AHP is not likely to give useful and valid results.

Table 2. The Reference Values of the Average Random Consistency (RI) for Different Number of m

M	2	3	4	5	6	7	8	9	10
R		0.5	0.9	1.1		1.3	1.4	1.4	1.5
I	0	8	0	2	1.24	2	1	5	1

5. Finally, using the results of the AHP technique, an overall score for each of the project managers is computed by using Equation 7:

$$S_j = \sum_{i=1}^{n} w_{jN} * e_{ij} \tag{7}$$

where,

S_j = Overall score for the j^{th} candidate project managers (j = 1, 2, . . .n).

w_{jN} = Normalized importance degree of the j^{th} project management criterion.

e_{ij} = Evaluating score of the j^{th} candidate project manager on the i^{th} project management criterion computed by the AHP process.

In the next section, the project manager characteristics will be implemented in the AHP-based model.

Project Manager Characteristics

Competency characteristics of project managers are highly relied upon in projects. The role of a project manager varies in different projects depending on the organization structure and project complexity. The authority of a project manager can be defined as limited to high, based on a variety of matrix structures at various levels which are identified in organizations. Even though in many cases the role of a project manager is to plan, organize, direct, and control [4] the technical track of projects, researchers believe that a project manager should be more focused on the human behavioral and team perspective factors of a project. These competencies are becoming more and more important to the success of projects and project management in today's organizations [5]. Therefore, some researchers believe the best project managers are those who not only deliver projects on time, within budget, and meet or exceed stakeholders' expectations, but also have different attributes such as being strongly organized, visionary, having good communication skills, empathetic and pragmatic, as well as know how to lead their team [17]. In many cases, researchers believe that sometimes the project needs project managers to act more as coaches, coordinators, and facilitators to help their team complete the project. Other times project managers should act as shapers, directors and completers to keep their team on the right track. In many cases, project managers must assume a leadership role in order to accomplish project goals. Therefore, the decision maker has to select the right characteristics for the project manager based on his vision for the project in order to fit the project needs and help the project manager lead the project to success.

There are several frameworks that indicate which characteristics lead a project manager to success. For example Mersino believes that "Success with projects depends largely on the level of emotional intelligence" of a project manager [18]. He mentions that project managers who master emotional intelligence will be able to achieve more with the same team. One of the reasons that emotional intelligence is critical for project managers is that projects are unique, temporary, and must be done in the allocated time. Therefore, in a very short amount of time, project managers have to develop strong relationships and make a positive environment for their team members. Using this framework, the project manager will be a better fit to a project, be able to better manage his project, and be a better leader of people in organizational environments [18]. Weiss states that self-management can highly influence management of any kind. He believes by developing self-management skills that managers can dramatically influence their organizations and their teams. He believes that organizations can be more democratized "by developing self management skills." He considers self-management as a personal power that project managers can gain to achieve project goals and objectives. He introduces six competencies which provide a framework to measures self management skills. The framework consists of: wholeness, self-confidence, self awareness, drive, self-esteem and respect for others. Such characteristics help increase their power to achieve their organizational goals [19].

In this study, we invited decision makers to create their framework by selecting competency characteristics for a project manager based on their vision of project needs. Moreover, we believe that the most important aspect of selecting a project manager using the AHP-based methodology is the selection criteria. There is a variety of studies available on these subjects: Emotional Intelligence, Personality Characteristics, and Human Personality Factors for project managers. In this study, however, the following characteristics shown in Table 3 were selected in order to compare and evaluate project managers. Even though the criteria presented here are listed as discrete elements, they may interact with each other. We define them separately in order to identify project manager competency characteristics. The interaction between these elements merits its own voluminous research in the future. These sets of criteria are by no means the only ones possible. These characteristics can be changed, and the purpose of this work was not to create a definitive set of skills that apply to every single project. They were chosen because in many cases they are identified as the most important attributes for a project manager. Such criteria have lead project managers to perform effectively. Table 3 lists the competency characteristics criteria.

There is an extensive body of literature available on selecting characteristics of a project manager [4], [18-21]. Criteria selected by decision makers would be useful for a project manager in order to plan, create, direct and shape the culture of the project for his organization. In the next section, we develop the AHP-based methodology for selecting the best project manager.

Development of AHP-based Methodology

The structure of this research model consists of a three-level hierarchy, as shown in Figure 1. The top level is the goal of selecting a project manager. The second level is the nine skills identified in the previous section. The third level is for the alternatives consisting of available project managers.

An Illustrated Case for Application of the Development Methodology

Presented here is an example of this methodology in selecting the best project manager for a given project. To simplify the calculations, we chose only four different project managers as alternatives. But each organization could use this methodology based on its own set of available project managers and its own project needs.

First, the nine evaluation characteristics should be measured for each available project manager. We evaluated each project manager based on different sets of questions that measure their abilities for each skill. There is an extensive body of literature that covers the evaluation process [18], [20], [22]. Decision makers can create their own set of questions for each criterion and start assessing their project managers.

The best way is to use the assessment that provides a decision maker the information he needs. This assessment could be designed as a self evaluation, peer evaluation or a 360-degree feedback assessment of project managers which covers all superior, subordinates, peers, and customer evaluations [20], [23]. In order to perform a comprehensive assessment, all of the selection criteria should be measured by extensive testing methods to compare project managers in each criterion. For example, in order to assess the teamwork and relationship building skills of four project managers, we developed a set of questions shown in Table 4. The decision maker provides the questions to a number of project managers and assesses them basing each question on a scale of 0 to 10 (ten being the best, and zero the least). The result would be the integer value of the average score that each project manager gets in questions. The result of assessing the first criteria for the first project manager is shown in Table 4. It must be noted that the set of questions is not complete, but was used as a sample to illustrate the case in order to simplify the calculation.

Table 3. Project Manager Competency Characteristics Criteria

Characteristic	Definition	References
Teamwork and Relationship Building Skills	Ability to encourage his group to make efforts toward building up relationship, positive interaction and trust among all of the team members by sharing his skills and expertise	[4,18,20]
Problem Solving Skills	Ability to effectively confront problems definitions and make decisions among alternatives	[4]
Communicating Skills	Ability to exchange information accurately among various levels of people who are involved in a project	[4]
Negotiating Skills	Ability to effectively communicate with others to come to terms with them and gain their support by using personal power and influence	[4,20]
Conflict managing Skills	Abilities to resolve conflicts made by opposite expectations between deferent parties involved in a project	[4]
Influencing the Organization	Ability to use power and politics in order to get things done by gaining acceptance of a plan	[4,20]
Risk Taking Skills	Ability to take risks by going beyond comfort zone	[20]
Organizing Skills	Ability to prioritize responsibilities based on relative importance of objectives	[17]
Interpersonal Skills	Ability to have effective communication, active listening, support to opposing viewpoints, and build capacity to value the success of individual team members	[20,21]

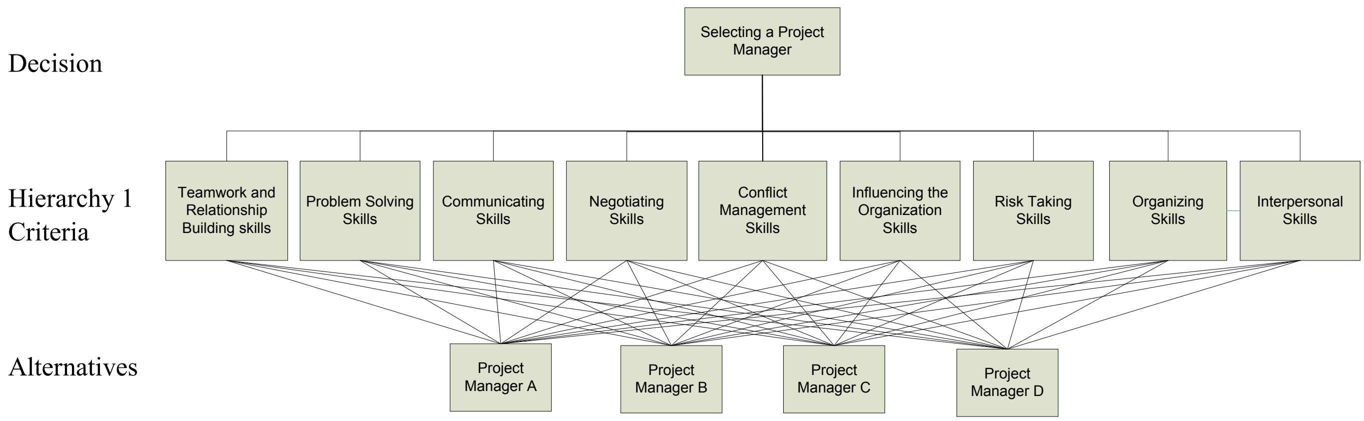

Figure 1 – Development of AHP-Based Methodology

Table 4. Competency Characteristics Assessment for Teamwork and Relationship Building Criteria for Project Manager 1

	Describe Project Manager				
	Not at all	**Very Often**	**Somewhat**	**Well**	**Very well**
Question	**0**	**2**	**5**	**8**	**10**
Maintains a relationship during and after a project					√
Builds spirit in his/her relationships			√		
Stays calm when he sees someone resistant to him/her					√
Effectively reacts when a group decide to go with solution that he/she disagrees with				√	
Promotes group work instead of individual work					√
Builds trust with his group co-workers					√
Effectively reacts when he/she feel there is a dispute between two members					√
Effectively reacts when he/she sees someone in his/her group unreasonably stand on their opinion			√		
Effectively reacts when he/she feel someone attacks him/her in a group setting					√
Changes the negative attitude of a person in his/her group		√			
Result calculation would be (10+5+10+8+10+10+10+5+10+2) / 10 =					**8**
Total Score for Teamwork and relationship Building Skills of First Project Manager:					**8**

The total score obtained from Table 4 is inserted into Table 5 as result of competency characteristics assessment for Teamwork and Relationship Building criteria for the first project manager. The rest of the results shown in Table 5 are random values to illustrate the application of the process. However, in real life, in order to assess other criteria, similar tests must be given by the decision maker to assess project managers' competencies. Table 5 shows the end result of the characteristic evaluation process on the scale of 0 to 10 for four project managers.

In the next step, the nine evaluation factors identified in the second level of the hierarchy are compared with each other in order to determine the relative importance of each factor with regard to the overall project goals and needs. The most structured way of doing this is to ask decision makers to apply pair-wise comparisons between each factor by using a fundamental scale, which is introduced in the AHP framework section. Fill in the matrix with numerical values denoting the importance of the factors on the left relative to the importance of the factors at the top. A high value means that the factor on the left is more important than the factor at the top. In Table 6, for example, teamwork and relationship-building skills are considered equally to moderately as important as problem-solving skills. It is also obvious that when a factor is compared to itself, the result of the comparison is one. Therefore, all of the results on the diagonal line across the matrix are one.

Once the decision makers complete the comparisons, the numbers from the matrix in Figure 2 can be used to obtain an overall priority value for each factor. In order to do this, the matrix, as shown in Figure 3, must first be normalized by dividing each element by its column total. For example, in Figure 2, the total for the first column is 5. So, the normalized value for the first entry of the matrix in Figure 3 is 0.2 and is obtained by dividing 1 by 5. The priority vector in Table 7 comes from the row average of the normalized matrix.

In order to maintain a good level of consistency, the computed consistency index (CI) must be divided by the reference value of the consistency (RI) in Table 2. The results are shown in Equation 8. In this case, the degree of consistency is satisfied because it is less than 0.1. If the consistency ratio is more than the acceptable value, the evaluation process should be reviewed by the decision makers because an unacceptable level of inconsistency may have occurred in the pair-wise comparison [1].

$$\delta = 10.04,\ CI = 0.13,\ RI = 1.45,\quad CI/RI = 0.090034 < 0.1 \tag{8}$$

After determining priorities for each attribute of project-manager characteristics by the decision makers, the last step of the selection process is to obtain the overall ranking of the four alternatives. A project manager's total score is calculated by summing the rank and multiplying by the priority vector of each attribute. Then, project managers are ranked based on their total score. The results are shown in Table 8. Based on our hypothetical AHP-based evaluation project, manager number 2 ranked highest.

Conclusion

In this study, a widely used problem-solving method, the AHP-based methodology for selecting a project manager in an organizational based project was studied. We presented the AHP model, discussed selection criteria, and presented a sample case. The result of this methodology indicates that the AHP model is a powerful method for selecting a project manager for any given project in all organizations when the scope of a project is broad.

By using this methodology, project managers would be assigned to the type of project that they are most likely to manage successfully in their organizations. We presented a sample case, where four project manager alternatives existed for a project. Using this framework allows decision makers to constantly make individual comparisons over project manager competencies. Moreover, it can give decision makers feedback based on the consistency of comparisons. It may also help decision makers accurately relate every important characteristic of a project manager to a project needs.

The AHP-base model utilizes competency criteria to select the best project manager. The criteria selected for the model are very important. This study focused mainly on the selection process rather than evaluating the selection criteria. However, we presented one example using teamwork and relationship building as the selection criteria. This study can be further enhanced by using other methods to evaluate the assessment of different selection criteria.

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Table 5. Evaluation Project Managers Competencies

	Project Manager			
Characteristic	**1**	**2**	**3**	**4**
1. Teamwork and Relationship Building Skills	à8	9	3	10
2. Problem Solving skills	4	10	5	7
3. Communicating skills	5	5	9	4
4. Negotiating Skills	8	4	10	3
5. Conflict managing skills	4	8	6	6
6. Influencing the organization	10	2	9	9
7. Risk taking skills	6	8	4	8
8. Organizing Skills	6	7	5	8
9. Interpersonal skills	7	5	10	6

Table 6. Pair-wise Comparison Matrix

	Teamwork and Relationship Building skills	Problem Solving Skills	Communicating Skills	Negotiating Skills	Conflict Management Skills	Influencing the organization Skills	Risk Taking Skills	Organizing Skills	Interpersonal Skills
Teamwork and Relationship Building skills	1	2	1	2	2	4	2	6	2
Problem Solving Skills	1/2	1	2	1/2	4	4	1	2	1
Communicating Skills	1	1/2	1	2	2	2	2	3	2
Negotiating Skills	1/2	2	1/2	1	1	3	3	1/2	1/3
Conflict Management Skills	1/2	1/4	1/2	1	1	2	1/2	1/2	3
Influencing the organization Skills	1/4	1/4	1/2	1/3	1/2	1	1	1/2	1/2
Risk Taking Skills	1/2	1	1/2	1/3	2	1	1	1	1/3
Organizing Skills	1/6	1/2	1/3	2	2	2	1	1	1
Interpersonal Skills	1/2	1	1/2	3	1/3	2	3	1	1

Table 7. Normalized Matrix and Priority Vector

	Teamwork and Relationship	Problem Solving Skills	Communicating Skills	Negotiating Skills	Conflict Management	Influencing the organization	Risk Taking Skills	Organizing Skills	Interpersonal Skills	**Priority Vector**
Teamwork and Relationship Building	0.2034	0.2353	0.1463	0.1644	0.1348	0.1905	0.1379	0.3871	0.1791	0.1976
Problem Solving Skills	0.1017	0.1176	0.2927	0.0411	0.2697	0.1905	0.0690	0.1290	0.0896	0.1445
Communicating Skills	0.2034	0.0588	0.1463	0.1644	0.1348	0.0952	0.1379	0.1935	0.1791	0.1460
Negotiating Skills	0.1017	0.2353	0.0732	0.0822	0.0674	0.1429	0.2069	0.0323	0.0299	0.1080
Conflict Management Skills	0.1017	0.0294	0.0732	0.0822	0.0674	0.0952	0.0345	0.0323	0.2687	0.0872
Influencing the organization Skills	0.0508	0.0294	0.0732	0.0274	0.0337	0.0476	0.0690	0.0323	0.0448	0.0454
Risk Taking Skills	0.1017	0.1176	0.0732	0.0274	0.1348	0.0476	0.0690	0.0645	0.0299	0.0740
Organizing Skills	0.0339	0.0588	0.0488	0.1644	0.1348	0.0952	0.0690	0.0645	0.0896	0.0843
Interpersonal Skills	0.1017	0.1176	0.0732	0.2466	0.0225	0.0952	0.2069	0.0645	0.0896	0.1131

Table 8. Overall Priority Matrix for Selecting a Project Manager

Characteristic	Priority Vector	Project Manager			
		1	2	3	4
1. Teamwork and Relationship Building Skills	19.8%	8	9	3	10
2. Problem Solving skills	14.5%	4	10	5	7
3. Communicating skills	14.6%	5	5	9	4
4. Negotiating Skills	10.8%	8	4	10	3
5. Conflict managing skills	8.7%	4	8	6	6
6. Influencing the organization	4.5%	10	2	9	9
7. Risk taking skills	7.4%	6	8	4	8
8. Organizing Skills	8.4%	6	7	5	8
9. Interpersonal skills	11.3%	7	5	10	6
Total Score by Using the AHP-based Methodology		6.29	6.92	6.49	6.78
Final Rank		4	1	3	2

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