FALL/WINTER 2015

VOLUME 16, NUMBER 1

WWW.TIIJ.ORG

TIIJ International

Technology Interface International Journal

ISSN: 1523-9926

Published by the
International Association of Journals & Conferences

THE LEADING INTERNATIONAL JOURNAL OF ENGINEERING TECHNOLOGY

www.tiij.org

ISSN: 1523-9926

www.iajc.org

TECHNOLOGY INTERFACE INTERNATIONAL JOURNAL

ABOUT TIIJ:

- TIIJ is an official journal of the International Association of Journal and Conferences (IAJC).
- TIIJ is a high-quality, independent journal steered by a distinguished board of directors and supported by an international review board representing many well-known universities, colleges, and corporations in the U.S. and abroad.
- TIIJ has an impact factor of **1.02**, placing it among an elite group of most-cited engineering journals worldwide, and is the #4 visited engineering journal website (according to the National Science Digital Library).

OTHER IJAC JOURNALS:

- The International Journal of Modern Engineering (IJME) For more information visit www.ijme.us
- The International Journal of Engineering Research and Innovation (IJERI) For more information visit www.ijeri.org

TIIJ SUBMISSIONS:

- Manuscripts should be sent electronically to the manuscript editor, Dr. Philip Weinsier, at philipw@bgsu.edu.

  For submission guidelines visit www.tiij.org/submission.htm

TO JOIN THE REVIEW BOARD:

- Contact the chair of the International Review Board, Dr. Philip Weinsier, at philipw@bgsu.edu.

  For more information visit www.tiij.org/editorial.htm

INDEXING ORGANIZATIONS:

- TIIJ is currently indexed by 21 agencies. For a complete listing, please visit us as www.tiij.org.

Contact us:

Philip D. Weinsier, Ed.D.

Editor-in-Chief
Bowling Green State University-Firelands
One University Drive
Huron, OH 44839
Office: (419) 372-0628
Email: philipw@bgsu.edu

TECHNOLOGY INTERFACE INTERNATIONAL JOURNAL

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

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

EDITORIAL OFFICE:

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

THE TECHNOLOGY INTERFACE INTERNATIONAL JOURNAL EDITORS

TABLE OF CONTENTS

The editors and staff at IAJC would like to thank you, our readers, for your continued support, and we look forward to seeing you at the upcoming IAJC conference. For this fifth IAJC conference, we will be partnering again with the International Society of Agile Manufacturing (ISAM). This event will be held at the new Embassy Suites hotel in Orlando, FL, November 6-8, 2016, and is sponsored by IAJC, IEEE, ASEE, **nine high-impact-factor ISI journals**, and the LEAN Institute. These ISI journals will be reviewing our best conference papers for publication in their journals.

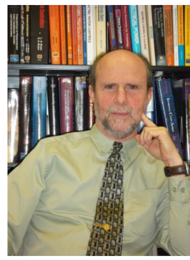
I am also proud to announce that **Thomson Reuters ISI**, the world leader in journal rankings and citation reports, has agreed to consider publication of the highest-quality papers accepted for this conference.

Main Sponsors

Many other papers from the conference will be published in our own high-impact-factor journals: (Google Scholar calculation method) the *International Journal of Modern Engineering* (IF = 3.0), the *International Journal of Engineering Research and Innovation* (IF = 1.58), and the *Technology Interface International Journal* (IF = 1.025). Any IF above 1.0 is considered high, based on the requirements of many top universities, and places the journals among an elite group.

Oftentimes, these papers, along with manuscripts submitted at-large, are reviewed and published in less than half the time of other journals. Publishing guidelines are available at www.iajc.org, where you can read any of our previously published journal issues, as well as obtain information on chapters, membership, and benefits.

The IAJC/ISAM Executive Board is pleased to invite faculty, students, researchers, engineers, and practitioners to present their latest accomplishments and innovations in all areas of engineering, engineering technology, math, science, and related technologies.



EDITOR'S NOTE

Philip Weinsier, TIIJ Editor-in-Chief

Currently, there is no official ranking system for journals that publish engineering-related topics the way that *IJERI* and *IJME* do, but the following still apply:

- Both *IJME* and *IJERI* now are indexed in most well-known indexing databases including DOAJ, which is the most prestigious and comprehensive database for open-access journals worldwide.
- Both journals now are indexed by hundreds of libraries worldwide, and in several states where there is near complete indexing across their university and college libraries.
- Both journals now are indexed in the libraries of all 10 campuses of the University of California system and the 23 campuses of the California State University system.

The biggest achievement, though, is that now both journals also are indexed by all of the top 10 universities in the world:

#1 California Institute of Technology
#2 Harvard
#3 Stanford
#4 University of Oxford
#5 Princeton University
#6 University of Cambridge
#7 Massachusetts Institute of Technology
#8 Imperial College London
#9 University of Chicago
#10 University of California, Berkeley

Indexed In

Editorial Review Board Members

The Academic Impact of Majoring in Technology for First-Generation College Students

E. Shirl Donaldson, University of Texas at Tyler; Ryan N. Favors, Purdue University

Abstract

There has been a strong movement towards improving the numbers of students majoring and graduating from college in the science, technology, engineering, and mathematics (STEM) fields. This increase in first-generation college student enrollment has prompted an increase in enrollment in STEM education. Typically, first-generation students struggle to master STEM fields' coursework because of inadequate math preparation and an overall lack of understanding of STEM fields. Most first-generation students come from high schools, where there is little or no knowledge of technology as an academic major. When the STEM acronym is considered, the general population tends to be more familiar with traditional majors such as science, math, and engineering; however, many technology units in academia have been in existence less than 60 years. The limited presence of technology as an academic major is a source of obscurity. In tandem, the difference between studying engineering and studying technology are not fully understood; consequently, many students choose to major in engineering when technology should have been considered. In regards to the first-generation student population, there has been an increase in the number of students switching from other majors to technology. The students report experiencing academic improvement, thriving in a specific area, and ultimately leading to great careers.

Students whose learning styles are related to a more kinesthetic or tactile approach tend to thrive in the field of technology. This is a plausible reason why first-generation students routinely excel in technology rather than engineering. The aim of this study was to focus on the impact that majoring in technology has on first-generation students as well as the advancement of their careers in a STEM field. In this paper, the authors present a summary of a pilot study at one university.

Introduction

Since 2007, there has been a national increase in the enrollment of first-generation students. Documentation shows an increase from one out of five students enrolled in 2007 to one out of three students enrolled in 2012 [1]. This increase can be attributed to these students' motivation to enroll in college as a deliberate attempt to improve their social, economic, and occupational standing [2]. With this motivation in attending college might be an increase in first-generation students majoring in science, technology, engineering, and mathematics (STEM) fields, specifically in engineering, because of well-publicized salaries for engineers. A rigorous course load is standard for engineering majors and, unfortunately, most first-generation students are not prepared for this level of coursework, due to poor academic expectations [3]. Most students have not been introduced to, nor grasp, the concept of technology as being "applied engineering." From this current study, the authors believe that more first-generation students could graduate with a STEM degree if they were adequately informed about choosing technology as a major.

Who Are First-Generation Students?

There are various ways of describing a first-generation student. The one most widely accepted and used by federal TRIO programs (Upward Bound, Talent Search, and Student Support Services), and the one used for this current study, is an individual whose parents did not complete a baccalaureate degree or an individual who regularly resided with and received support from only one parent, who did not complete a baccalaureate degree [4]. A few characteristics of first-generation students are underrepresented minorities, female, non-traditional, and from low-income families [5]. This group of students usually attends college at a lower rate than other demographics, and data show a lower completion rate for them as well.

Definition of Key Terms

Key terms used in this current study:

College of Technology: an entity that centralizes the university's applied learning programs into one administrative/academic unit [6].

Major in Technology: a concentration in a field of study that focuses on technology; any tool or operating system designed to improve the efficiency, quality, and competitiveness of an organization.

STEM: science, technology, engineering, and mathematics.

Technology: "the creation of new and useful device, machines and systems to include the purposeful application of information in the design, production, and utilization of goods and services, and in the organization of human activities" [7].

Underrepresented Minority: as defined by the National Science Foundation, "three racial/ethnic minority groups (Blacks, Hispanics and American Indians) whose representation in science and engineering is smaller than their representation in the U.S. population" [8].

Background

There has been a documented increase in first-generation students attending college. This increase of first-generation students in college can be attributed to the quest for better economic standing, improved social standing, as well as an occupational viability. Many students realize that progressing into higher education is beneficial to improving their economic status. However, they also realize that university studies are not the only way to advance financially. Concurrently, students are also noticing that earning a college degree gives them an opportunity to obtain a job at a higher entry level compared to that of a person with only a high school diploma. Even though first-generation students have more motivation to attend college, they are still faced with barriers that keep them from succeeding as students whose parents attended college.

Barriers to Entry and Perceived Barriers to Completion

According to Schmidt [9], there are barriers or obstacles to completion and persistence in the STEM fields of study. Preparation, attitudes, and persistence of first-generation students in technical areas are by-products of a similar system functioning at the K-12 level of education. Groundwork in high school is critical for success in college [10]. Socioeconomic status and school district funding set the stage for early childhood education. Neighborhoods inhabited by certain populations often received limited resources for substandard educational support, based on tax revenues. Consequently, if society does not plan for certain students to attend college after high school, the plan of action is different.

The K-12 system produces college-ready applicants at a desired level in desired locations. The logic employed in this scenario was that future factory workers do not need college preparation mathematics and science courses in high school, as stated by Carnevale and Schulz [11]: "The elementary and secondary schools in America are adequate at educating the designated college bound students, but [they] are not successful at preparing the non-college bound youth." Unfortunately, these perceived non-college-bound youth are often Black or Latino and of lower socioeconomic status. That article was written in 1988; now, almost 25 years later, there is a gaping hole in the pipeline of diverse and underserved students, who are prepared for STEM majors in college and graduate school [12].

Barriers Outside of Academia

A noticeable barrier that first-generation students face is a lack of educational goals [13]. First-generation students typically do not have the same drive for success in college as do students whose parents attended college. Some might see college as intimidating, so the social aspect of college is daunting for first-generation students as well. First-generation students struggle more with seeking advice for logistical challenges of higher education, such as how to register for courses, career advice, and academic advising. Some of their initial struggles could be linked to not having much support from high school counselors [14]. Once the student arrives on campus and realizes the lack of aspiration to succeed in college compared to peers, the student's self-efficacy drops. This phenomenon becomes apparent when a student is not in a major or field of study that coincides with individual academic strengths.

Parental influence is a huge barrier that first-generation students must face and manage [15]. Parents who have never attended college usually are intimidated by not knowing or understanding the issues faced in college and usually shy away from communicating with their adult child. Some parents do not recognize the benefits of college and may knowingly or unknowingly discourage their child from succeeding. The most documented barrier to mention is the financial burden of college. Typically, first-generation students cannot afford the fees and additional expenses to attend college, based on the increasing costs of many universities [16].

The ones who do attend usually spend a significant portion of their time working to take care of any financial burdens or monetary needs. Working part-time takes away from a first-generation student's time to study. Unfortunately, the need for immediate income becomes more important, especially when compared to a student whose parents attended college and are able to provide better financing. While these three barriers do not complete the list, they represent the most documented and impactful challenges for first-generation students.

Relevance

National Focus on STEM

Nationally and locally, there is an obvious need for more people to pursue and obtain advanced degrees, especially in STEM fields [17]. The President of the United States has declared an initiative to increase the number of women and underrepresented students in STEM education as well [18]. This push for increasing participation is due to the lack of students graduating with STEM degrees combined with the need for this expertise in the new economy. The increase in first-generation students entering college has prompted an increase in first-generation students majoring in STEM fields. The decision to choose a STEM major may be driven by the same motivating factors that impacted the decision to attend college. The choice of a STEM major can also be attributed to specific career focuses. In parallel, it is publicized that STEM-field majors, especially in engineering and computer science, typically have higher paying salaries. Typically, having a STEM degree will enable an employee to have a more prominent role in a company after graduation.

The deterrents accompanying the increase in first-generation students majoring in STEM fields are the barriers these students will face. The major barrier appears be the lack of K-12 academic preparation in mathematics [19]. Higher achievement in levels and frequency of math courses is critical. For instance, students who do not master algebra by the end of eight grade are not prepared for college. Persistent students, who succeed in advanced math classes in high school, tend to have a positive sense of self-efficacy leading to college attendance. Considering the course load that a typical engineering or science major will encounter, poor math skills could possibly lead to failure at the collegiate level. In concert with the lack of self-efficacy from entering college, these students' confidence level will usually fall, causing them to be placed on academic probation, leading to a status of "academically dropped." These students who are "dropped" usually do not return to finish their degrees. Consequently, there becomes an additional risk for students and their parents in the form of loan debt without the income to service it.

This current study is significant because of the trends in population growth of domestic first-generation students as well as the rising number of students needed to complete undergraduate studies at prestigious universities in a technical field. Concurrently, the economic decline in the U.S. has created a more competitive job market for recent graduates [20]. From a broader perspective, challenges of job creation and national security are heavily dependent on the STEM fields, most notably, technology for a sustainable solution [21].

The Evolution of Technology as an Academic Major

The debate about the amount of overlap continues between professors in engineering and those in technology. There are also varying opinions of discernment between theoretical engineers and applied engineers. Land [22] contended that engineering technologists are in fact engineers and performed extensive research that was published by the American Society of Engineering Education (ASEE) to support his position. The literature review in his most recent study claimed that the industrial scope of technology has been evolving since the 1950s. Land paralleled the development and positioning of coursework at technical schools and universities to growth in industry stemming from the space race in the late 1950s. Certificate programs grew to degree granting courses of study. Two-year associate degree programs were expanded to four-year baccalaureate programs [23]. Heiner and Hendrix [23] supported Land's position by stating that people create technology to solve problems; however, technology can create new problems as well. The dawn of the information age and growth of computer technology hosted graduate degrees in technology in the early 1990s, according to the History of Programs in Knoy Hall of Technology at Purdue University.

Table 1. Starting Salaries Reported by the Career Counseling Office, Purdue University [24]

Technology	Average	Engineering	Average
Aeronautical Engineering Technology	$51,540	Aero/Astro Engineering	$55,895
Building Construction Management	$48,230	Construction Engineering	$54,625
Electrical Engineering Technology	$51,954	Electrical Engineering	$60,437
Industrial Technology	$47,171	Industrial Engineering	$56,938
Mechanical Engineering Technology	$48,437	Mechanical Engineering	$56,845
Computer Information Technology	$54,235	Computer Science	$59,090
Computer Graphics Technology	$41,474		

Research Design

Given the low completion rates in science, engineering, and math, more first-generation students could graduate with a bachelor's degree in STEM fields if they were adequately informed about choosing technology as a major. Systems theory as defined by Patton [25] in qualitative research and evaluation methods was the supporting framework for this current study. Patton explained system theory as follows: Holistic thinking is central to a system perspective. A system is a whole that is both greater than and different from its parts. Indeed, a system cannot validly be divided into independent parts as discrete entities of inquiry because the effects of the behavior of the parts on the whole depend on what is happening to the other parts. The parts are so interconnected and interdependent that any simple cause-and-effect analysis distorts more than it illuminates. Changes in one part lead to changes among all parts and the system itself. Nor can one simply add the parts in some linear fashion and get a useful sense of the whole [25].

Celebrated cultural competency consultant, Kendall [26], defined higher education as a whole, and the individual universities that comprise it as a "system." Higher education is definitely a complex system. More specifically, an individual university, such as Purdue, is viewed as a complex organization with interconnecting and multi-functioning facets. The focus of this current study was limited to domestic first-generation students in the College of Technology at Purdue University's main campus in West Lafayette, Indiana; international students were not used as subjects for the purpose of the study. Participants were assumed to have answered all questions truthfully. This sample was criterion-based, yet still convenient; all of the subjects were from the same college within one university's campus. The assumption was that the findings of the sample were representative of the population.

Population and Sample

Although this current study is not generalizable to a larger population, it is internally generalizable to the population examined [27], specifically the College of Technology at Purdue University. The population was defined as first-generation students that were also technology students or alumni of the College of Technology. The population of this pilot study was limited to Purdue University's main campus in the College of Technology. A total of 15 subjects were selected. Seven of the participants were African-American, five were Caucasian, two were Hispanic, and one was Asian. There were no Native-American participants. These 15 subjects were readily available and willing to participate. Subjects also had to meet two criteria: they had to be a first-generation college student in the College of Technology [28] and be enrolled in courses or an alum of the College of Technology.

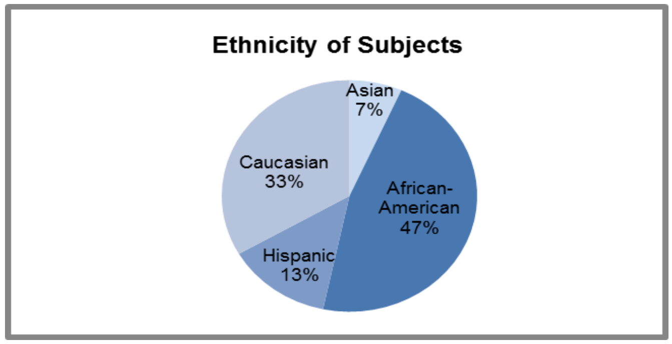


Figure 1. Ethnicity of Subjects in the Pilot Study

A survey with pointed (yes/no or when) and open-ended questions was used to gather data. For inter-rater reliability, the research team was able to clarify any ambiguities using an additional objective coder [29]. Traditional manual coding that normally accompanies qualitative research was implemented for this mixed-methods study [30]. "Key words," "key phrases," and "redundant terms" were identified for further analysis.

Results and Discussion

The data listed are the answers from the participants in the pilot study. Of the 15 study participants, five were majoring in Organizational, Leadership and Supervision (OLS), three in Computer Graphics and Technology (CGT), and two in Industrial Technology (IT). Aviation Technology (AT), Building Construction Management (BCM), Electrical Engineering Technology (EET), Manufacturing Engineering Technology (Mfg.ET), and Mechanical Engineering Technology (MET) each had one student majoring in its field. Of the 15 students, five began their freshmen careers in the College of Technology, while the other 10 switched to the College of Technology after being enrolled for at least one semester. Of the 10 students who switched into the College of Technology, four switched from the College of Science, four switched from being undecided, and two switched from engineering.

The participants were asked a series of questions pertaining to their academics, self-efficacy, and career aspirations, as they pertained to being in the College of Technology. Figure 8 shows the response ratio when the students were asked, "When you first applied to college, did you have an understanding of careers in technology?" Of the 15 students, 13 answered no, and 2 answered yes.

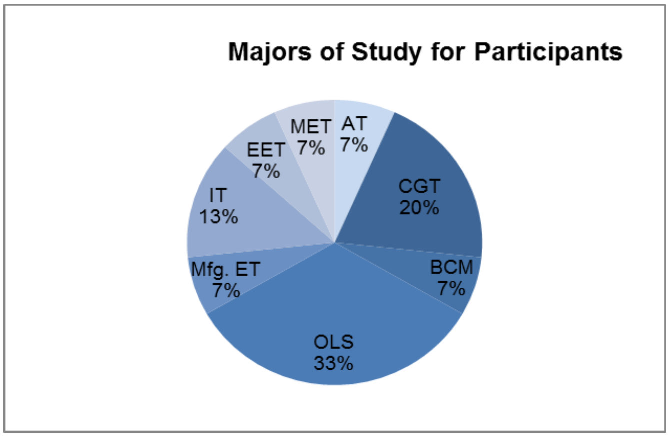


Figure 2. Participants' Majors in the College of Technology

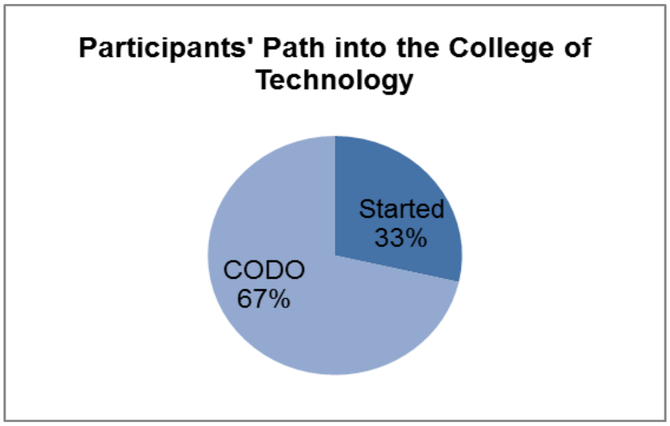


Figure 3. Participants' Pathways to Technology—Started or Transferred via CODO

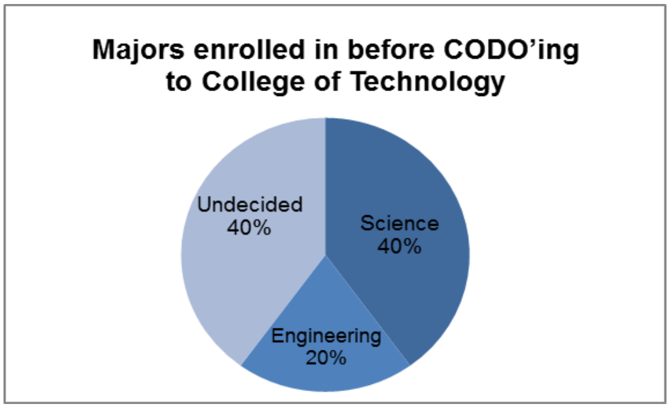


Figure 4. Participants' Academic Majors before Moving into Technology

Listed below are several questions pertaining to the student's self-efficacy majoring in technology, decisions for majoring in technology, and career aspirations once they switched to the technology field.

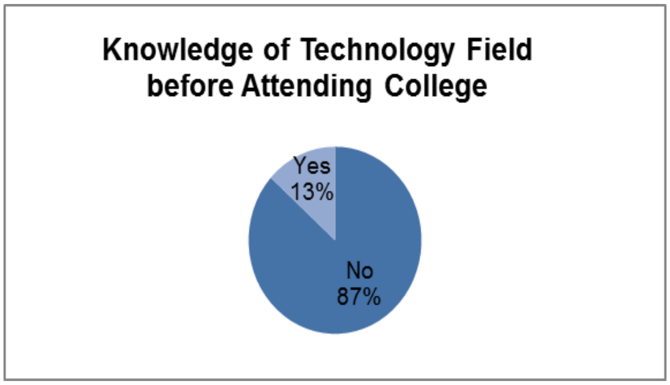


Figure 5. Subjects Reporting on Understanding of Technology before Choosing a College Major

Self-Efficacy

The following is a list of the most common responses to the question, "How would you describe your academic progress once you transferred/CODO into the College of Technology?"

- Academically I am doing the same as I was in Mechanical Engineering, though I enjoy it a lot more.
- I had a passion for what I was learning, so once I transferred my grades slowly went up.
- My grades improved and I started to enjoy class topics much more.
- I excelled and was able to successfully raise my GPA from 2.5 and graduate with a 3.34
- I would describe my academic progress as successful thus far, even though some classes are quite difficult.
- My academic progress was more successful in the classes that I enjoyed

Decision Factors

The following are paraphrased responses to the question, "Why did you choose a major in the College of Technology?" The responses are listed in order of frequency with the highest frequency as the first response:

- More career options in technology
- Stronger interest in course work within Technology fields
- Received knowledge of the departmental area
- Didn't enjoy engineering field
- Better educational environment between students and faculty

Career Aspiration

The following is a list of the most common responses to the question, “How would a greater level of understanding about the career opportunities in the fields of technology have impacted your choice in major?”

- I think I would have explored the college of technology if I had learned a little more about it before getting set in a major
- Heavily impacted me, because many of the careers are ones I would like to have.
- I would have dove into student business and entrepreneurship initiatives in technology far faster.
- I would have just gone into technology and not struggled with the classes in Engineering. My GPA would have also been higher from the start. I wish I would have been explained that they can both get the same jobs.
- I think having more of an understanding would allow students to make better choices upfront, things like which courses to take and how to network in that area, thinking about small choices such as these lead to a better outcome in the long haul; resulting in less time in college meaning less debt

Conclusions

Responses indicated that a lack of knowledge about the technology field was a factor in choosing a major for first-generation college students. The evidence from this pilot study suggests that student’s unawareness of technology as a major is a factor in initial decision making when pursuing a STEM-related college education. Students’ self-efficacy appears to be closely tied to their GPA and overall performance in the classroom. A better understanding of career placement with respect to options for training and skill preparation could lead students to major in technology. Based on the subjects’ responses, students having a more in-depth knowledge of the academic majors in technology as well as career paths in technology may lead to more first-generation college students completing a STEM degree.

Future Study

Students from peer institutions will be solicited to broaden the subject pool for greater generalizability. Both genders will be sought as participants, despite typical male dominance in traditional STEM fields of study. Female participants in the study may be listed as double minorities by stakeholders and for demographic metrics.

References

[1] Greenwald, R. (2012, November 11). Think of First Generation Students as Pioneers, Not Problems. *The Chronicle of Higher Education*, 1-3.

[2] Ayala, C., & Striplen, A. (2002). A Career Introduction Model for First-Generation College Freshmen Students. *Thriving in Challenging and Uncertain Times*, ed. Garry R. Walz, Richard Knowdell, and Chris Kirkman, 57-62

[3] Terenzini, P., Springer, L., Yaeger, P., Pascarella, E., & Nora, A. (1996). First-Generation College Students: Characteristics, Experiences, and Cognitive Development. *Research in Higher Education*, *37*, 1-22.

[4] Higher Education Act of 1965, 1998 Higher Education Act Amendments Subpart2 – Federal Early Outreach and Student Services Programs, Chapter – Federal TRIO Programs SEC. 402 A. 20 U.S.C. 1070a-11.

[5] Lohfink, M. M., & Paulsen, M. B. (2005). Comparing the Determinants of Persistence for First-generation and Continuing-Generation Students. *Journal of College Student Development, 46*(4), 409-428.

[6] College of Technology (CoT). (2012). *About Us*. Retrieved from http://www.tech. purdue.edu/ about_us

[7] DeVore, P. (1980). *Technology: An Introduction*. NewYork: Davis Publications.

[8] National Science Foundation (NSF). (2012). *Louis Stokes Alliances for Minority Participation*. Retrieved from https://www.nsf.gov/funding/ pgm_summ. jsp?pims_id=1364

[9] U.S. Department of Labor, Employment and Training Administration. (2012). *CareerOneStop*. Retrieved from http://www.careerinfonet.org/finaidadvisor/ earnings.asp

[10] Schmidt, P. (2006, April). Study Blames Obstacles, Not Lack of Interest, for Shortage of Black and Hispanic Scientists. *The Chronicle of Higher Education*.

[11] Gold, B. A. (2007). *Still Separate and Unequal; Segregation and the Future of Urban SchoolRreform*. New York: Teacher College Press.

[12] Carnavale, A., & Schultz, E. (1988, November). Technical Training in America: How Much and Who Gets It. *Training and Development Journal*, *42*(11), 18-32.

[13] Committee on Science. (2006). *Rising above the Gathering Storm; Energizing and Employing America for a Brighter Economic Future*. Washington D.C.: The National Academy of Sciences.

[14] Choy, S. (2001). *Students Whose Parents Did Not Go to College: Postsecondary Access, Persistence, and Attainment.* Washington, DC: National Center for Education Statistics.

[15] Hossler, D., Schmit, J., & Vesper, N. (1999). *Going to College: How Social, Economic, and Educational Factors Influence the Decisions Students Make.* Baltimore: The John Hopkins University Press.

[16] Berkner, L., & Chavez, L. (1997). *Access to Postsecondary Education for 1992 High School Graduates.* Washington, D.C.: National Center for Education Statistics.

[17] *President Obama Launches Educate to Innovate Campaign Focus on Excellence Science and Technology*. (2009). Retrieved from http://www.whitehouse.gov/the-press-office/president-obama-launches-educate-innovate-campaign-excellence-science-technology-en

[18] Stone, C., Van Horn, C., & Zukin, C. (2012). Chasing the American Dream: Recent College Graduates and the Great Recession. *WorkTrends; Americans Attitudes about Work, Employers and Government*. New Brunswick: Rutgers University.

[19] Horn, L., & Nunez, A (2000). *Mapping the Road to College: First-Genertation Students' Math Track, Planning Strategies, and Context of Support.* Washington, D.C.: National Center for Education Statistics.

[20] Maton, K. I., & Hrabowski, F. A. (2004). Increasing the Number of African American Ph.D.s in the Sciences and Engineering: A Strengths-Based Approach. *American Psychologist, 59*(6), 547-556.

[21] Clewell, B., de Cohen, C., Tsui, L., & Deterding, N. (2006). *Revitalizing the Nation's Talent Pool in STEM*. Washington DC: The Urban Institute.

[22] Land, R. E. (2012, Spring). Engineering Technologists Are Engineers. *Journal of Engineering Technology*, *29*(1), 32-39.

[23] Heiner, C., & Hendrix, W. (1980). *People Create Technology*. Worchester: Davis Publications, Inc.

[24] Office of Institutional Research, Purdue University (2011). *Starting Salaries by College/ School Reported by the Career Counseling to Office of Student Analytical Research*. West Lafayette: Purdue University.

[25] Patton, M. Q. (2002). *Qualitative Research and Evaluation Methods* Thousand Oaks, CA: Sage.

[26] Kendall, F. E. (2006). *Understanding White Privilege*. New York: Routledge.

[27] Navarra-Madsen, J., Bales, R. A., & Hynds, D. L. (2010). Role of scholarships in improving success rates of undergraduate science, technology, engineering and mathematics (STEM) Majors. *Procedia - Social and Behavioral Sciences, 8*, 458-464. doi: 10.1016/j.sbspro.2010.12.063.

[28] Maxwell, J. A. (1996). *Qualitative Research Design: An Interactive Approach*. Thousand Oaks, CA: Sage.

[29] Donaldson, S. (2010). *URM Graduate Students in STEM Fields of Study*. Unpublished manuscript

[30] Miles, M., & Huberman, A. (1984). *Qualitative Data Analysis; A Sourcebook on New Methods*. Newbury Park, CA: Sage.

Biographies

E. SHIRL DONALDSON earned a doctorate of philosophy in Industrial Technology from Purdue University in December 2012. Upon receiving her PhD, she completed a strategic post-doctoral appointment focused on diversity, entrepreneurship, project management, and supply chain management. In 2013, Dr. Donaldson was certified as a Project Management Professional (PMP). Dr. Donaldson was selected as an Entrepreneurial Leadership Academy (ELA) Fellow in 2015. Dr. Donaldson is an assistant professor at the University of Texas at Tyler in the College of Business and Technology. Her commitment to intellectual growth is driven by her life experience. Dr. Donaldson's research interests include project management, technology management, quality systems, entrepreneurship, and diversity in STEM fields. Dr. Donaldson may be reached at sdonaldson@uttyler.edu

RYAN N. FAVORS serves as the program specialist for Horizons Student Support Services at Purdue University. His responsibilities are instructing various courses such as study skills for freshmen as well as providing academic assistance to first-generation and/or low-income students. He provides additional support to students by organizing and managing faculty mentoring and tutoring programs. His focus is on providing the necessary assistance to help students achieve their goals academically as well as in life. Ryan earned his Bachelor of Science degree from Georgia State University and a Master of Science degree in Chemistry from Purdue University in West Lafayette. Prior to obtaining his current position with Purdue University, Ryan worked as a geochemist with the National Energy Technology Laboratory in Pittsburgh, Pennsylvania. He spent two years working with the Carbon Sequestration group. His main research area focused on monitoring the absorption of carbon dioxide onto coal seams via infrared spectroscopy. Dr. Favors may be reached at rfavors@purdue.edu

EVACUATION DATABASE MODULE: RESIDENCE INSPECTION PROCESS

Kimberly Spoa-Harty, Purdue University, Calumet; Barbara Nicolai, Purdue University, Calumet

Abstract

The purpose of this project was to outline and design an effective digital process for the inspection of residential homes defined within an evacuation module. With past disasters, many evacuation procedures required authorities to inspect homes to ensure the safety of all residents. This process can be replicated for disaster events in which the inspection occurs prior to the disaster or immediately after a disaster has affected that area. The project plan was to take information gathered in the defined evacuation area and interact with the residents and authorities to help aid in faster, more efficient home inspections. This system was designed to have the capability to be duplicated and set the standards for local, state, and federal agencies to implement and successfully use to help save lives. It would also have the capability to store data for future review of the process, which would allow continued improvements of the process as it evolved for each evacuation use.

This project presents some database modeling around the inspection process, explains system design for proper use, and incorporates security fundamentals to ensure that the updated information is valid and the most current information available. Lastly, this project will help identify the FEMA X-Codes that are used in search-and-rescue situations, allow for proper use of these codes, and turn this effort into digital, researchable, and instantly accessible information. Uses of the codes are sometimes interpreted differently, depending on the search team performing the searches and their interpretations using spray paint on the exterior of homes and cars. The system as a whole should provide the standardization that search-and-rescue teams need, and help aid in faster evacuations of areas that require pre-disaster assistance.

Introduction

If an evacuation is ordered, the processes and procedures for conducting the evacuation, reporting on successful evacuees of the identified area, and inspecting the residential home to verify or force the evacuation are all important pieces to the process of evacuating because of a disaster. There has yet to be a fully integrated digital system built to handle an evacuation, which is only part of an entire disaster management communication system (DMCS). The focus of this research and theory was on more details of the process of residential home inspections. This portion of the evacuation process can occur as a proactive measure to an impending or potential disaster as well as after a disaster has occurred. Evacuating residential homes prior to a fire, hurricane, and tsunami are examples of situations in which a proactive approach would be taken, while earthquake, chemical plant explosions, and tornadoes would be examples of reactive evacuations.

As with any system that is built from concepts and theories, a list of in-scope, out-of-scope, and system requirements must be established. The system requirements should include, but not be limited to, the following:

1. Interact with the public and workforce members.
2. Be accessible via the Internet or mobile device.
3. Be able to store data for report extraction.
4. Visibly show the progress and status of individual residential home inspection status.
5. Interact with residential evacuation status information and remove those households that report as successfully vacated.
6. Provide a report on only the homes that are necessary to inspect.
7. Provide feedback to the command center on resource needs for a specific residential address; for example, rescue equipment and materials beyond the team's onsite tools.
8. Allow rescue team interaction to update and detail the status of the residential inspection according to and utilizing standard codes such as those provided by FEMA, called X-Codes [1].

In-scope items are residential addresses. Out-of-scope items include vehicles, public and private businesses and buildings, industrial or commercial businesses, healthcare facilities and other public facilities such as schools, libraries, etc., and the documentation of evacuated pets. The sole purpose is to design a base working system that is expandable to cater to the additional needs and processes in an effort for continued improvement and overall support of the system.

Inspection Process

The residential inspection process should be initiated after the evacuation area is defined. The process should also be known as either a proactive or a reactive evacuation, and it should take into consideration those residential occupants preferring not to evacuate. Fussel [2] talks about many reasons why residents do not evacuate an area. Many may have stayed to ride out the storm, while others did not have the resources such as money, transportation, or medical supplies to support a successful evacuation. Others simply were delayed as a result of trying to unite with family and friends prior to evacuating. The process as a whole should solve many issues that Fussel discusses and raise awareness to methods of social communication and social networking through computers, phones, and other social media applications.

One proposed use of the inspection process is to allow evacuees to report on their evacuation status and allow other household members visible access to that information as well as to report their evacuation status. This information is very valuable to families as well as for the command center. The command center will be able to quickly review on a map which homes have been completely evacuated and which homes need immediate attention. Time spent inspecting a home for residents that have already vacated can be time spent on citizens who do not have the means to communicate or evacuate the area.

Designing the System

Designing the inspection portion of the evacuation system can become very complex very quickly. The approach taken was to find a logical common ground by using the base processes of the United States Search and Rescue teams along with the FEMA codes, review the issues around these procedures, and find a method by which technology can help reduce errors, provide faster response time, and yield more accurate information in a timely fashion. After all, time is critical in emergency situations.

After defining the requirements, in- and out-of-scope items, and the overall process, the next action could be to develop a prototype of the interface. What will the users see and interact with? What data are necessary to capture and store? How will the rescue teams know which houses to inspect next? And how will families know when all of the household members are reported as having been evacuated? The first step is to define the information to be collected from the residents: data such as first and last name, how many reside in the household, who is head of house, ages, any medical conditions or physical disabilities that emergency personnel may need to know, address of the residence, evacuation status of each member in the household, and possible evacuation location. The next step would be to define the information to be gathered from the search-and-rescue teams: the state the team is from, the task force team code, the team number, the time and date stamp of when the inspection started and was completed, the status of the survey, the address being surveyed, the structure status, personal hazards status, and residential status information. The display for the search-and-rescue team should have a residential status that would stay up-to-date during the inspection in the event that a resident reported successful evacuation and there is no longer a need to look for that person at the residence.

Other processes within the evacuation module would need to store and gather the information that the inspection process would utilize to report on information critical for search-and-rescue efforts. The data collected and calculated within the inspection process also need to be stored in a database for further reporting and post-disaster evaluations. These are data that are currently not easily accessible or organized to help provide crucial information in planning and preparing for disasters. Many manuals and policies are in place to instruct federal, state, and local agencies on expectations of services and responsibilities; however, that information is easily lost or inaccurately utilized due to interpretations, chaos, and lack of training and practice prior to an event. This system can bridge the gap and expand beyond this basic foundation to tailor to the needs of each agency involved, educate users about procedures to follow and data to collect, and provide more accurate information after the disaster is over on how well the response actually functioned. Improving on the process will only help aid those in need as well as proper spending and allocation of resources when correcting issues or areas in which the needs were guessed and not based on current and accurate data.

Security and Reporting

Collecting and storing the data may seem the easy portion to design, and that may be the case. However, proper thought on how to collect the data in such a way as to reduce normal human error is crucial in data collection for the system. For example, building into the design of the interface error trapping events will help force data to be much cleaner than allowing free text and selection. There are some valid areas in which free text or manual data entry would be necessary, but should be avoided if possible to reduce human error and allow the data to be easily queried for reporting and statistical purposes. Figure 1 shows a simple screen to give examples of how to collect the data. The task force team codes are already known and established by

FEMA; thus, listing just the team options will reduce the risk of mistypes and variations of upper- and lower-case letters.

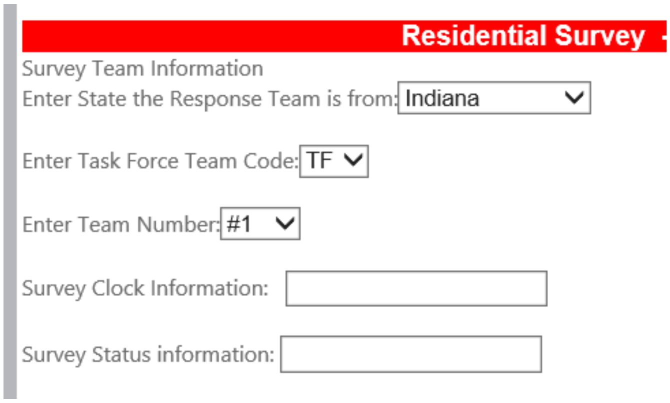


Figure 1. Sample Residential Survey Search-and-Rescue Data Collection Screen

The state in which the task force team originates is also important, as resources from many states or areas may come to help in the search-and-rescue efforts [3]. The clock information and status will be automatically populated by the system. For example, the clock information can show the current time spent on the inspection. Behind the scenes, the database has collected the start time and date of the inspection at the time the team has entered this screen to begin the inspection process for a residential address. The status information will also be automatically populated by the system; if this is the first inspection, the status could be "In Progress." If this is the second or third inspection, the status could reflect that and state "In Progress #4," indicating this is the fourth inspection on the home.

FEMA has established what is known as the X-Codes. These are generally seen on buildings, structures, cars, or anything that was inspected in the search-and-rescue process. They use spray paint or what is provided to the teams by FEMA or the command center. Figures 2 and 3 show examples of the master code and a picture of what it looks like in use.

One point of the article by Moye [4], along with viewing the pictures on Southern Spaces, is that interpretation and use of the X codes are not uniform; therefore, when visual inspections are reviewed, interpretation of the hazardous materials and task for team codes may be up for further interpretation or misinterpretation. Moving this process to a digital format and providing the taskforce teams with a digital means to store and upload information into the system can reduce or remove any misinterpretations as well as provide a format for viewing this information remotely instead of requiring onsite inspections. There may be situations in which a structure is missing or gone. Where is that information to be collected or viewed? Or how will the search-and-rescue teams know if and where a house should have resided? Through the use of Google Maps and street/aerial views, the interjection of this technology with the system can allow for immediate viewing and positional information in the area where the house should be. It can show the teams if the house was 1-story or 2-story, the color, the approximate size, and the location of neighbors. Much of the documentation created by the search-and-rescue teams is simply their own drawings in the field. Removing the drawings and providing that information digitally can only help speed up the search-and-rescue process and also provide more accurate feedback necessary for proper research and evaluation of current situations.

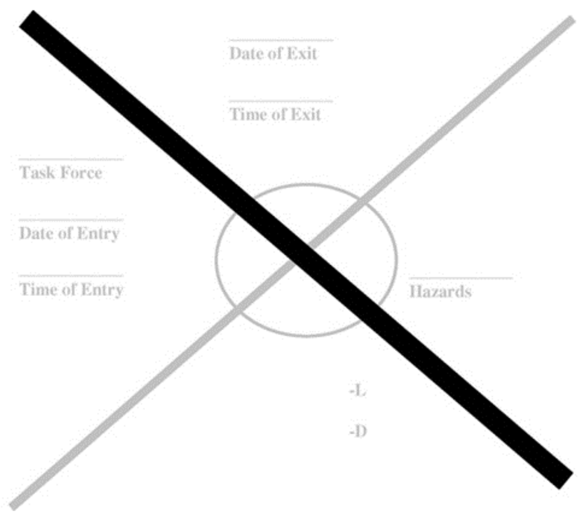


Figure 2. FEMA X-Code Master [4]

Figure 3. FEMA code on Building [4]

Additional Features

FEMA has a National Urban Search and Rescue Response System: Rescue Field Operations Guide [5] that explains the proper policies and procedures of how to conduct the inspections, along with the X-Codes and other structural codes necessary to direct teams for safe re-entry into the building. What it lacks are the definitions of hazardous material identification and codes; however, with proper review and possibly coordination with HAZMAT, a definition of the codes necessary to cover most situations seems achievable. Other features could allow search-and-rescue teams to take live pictures and insert them into the system, while providing an overlay or injection into the street view so that command centers, homeowners, and possibly insurance agencies can view the information quickly and potentially warn residents about returning to an unsafe area. It could provide immediate information to process claims and quickly start the calculations of total damages instead of inaccurately estimating the damages.

Once the process and system is tested on a base level, it will be ready for additional features and functionality. Defining the requirements and scope items will aid in proper planning of the additional features and show whether additional databases or space are necessary, and explain deliverables. It also will help in the design by showing the data necessary to collect and what outside sources or technology to incorporate into the system. Lastly, it will help design the security and error-trapping structure of the system, which fields should auto populate and which should have predefined lists, or allow for checks or decisions to be recorded.

Conclusions

After researching FEMA's field guide and reviewing how the system was used, it became more apparent that the inspection process of an evacuation system is a critical and valuable process that, if developed into a digital, accessible system, can lay the groundwork for improvements and a faster method of information delivery. Information during a response to a disaster needs to be fast. During the age of social media, smartphones, tablets, and television, the expectations of information to be provided quickly or easily accessible is becoming more of a norm. Spinning up hotspots are not in forms of backpacks, vehicles, and—as of July, 2013—Google's Loon-balloons project [6]. Smartphones, tablets, and other digital devices are very powerful tools, and the use of the Internet as a means of communication and connection to systems provides a very powerful catalyst to support the necessary requirements of responding to or preparing for an evacuation. Being able to see a picture of the home as a result of a hurricane or impending fire without traveling back into a hazardous area is priceless for the homeowner. The trapped resident, who may have been found and rescued in days, may now be rescued in a matter of hours because the team can bypass the homes that have a status of successful evacuation. Also, the command center can gather statistics on the number of homes to search and request the appropriate number of resources, deploy or assign streets or homes to teams, and watch the progress of the inspections as they occur. This is invaluable information and can provide a glimpse not yet seen to help in more efficient evacuations. Future plans are to take this database design and implement a working prototype to build and mature for use in helping the public, the government, and the response teams.

References

[1] Department of Homeland Security, & Federal Emergency Management Agency. (2006). *National Urban Search & Rescue (US&R) Response System: Rescue Field Operations Guide.* (US&R-23-FG). Retrieved from http://www.fema.gov/pdf/ emergency/ usr/ usr_23_20080205_rog.pdf

[2] Fussell, E. (2006, June 11). *Leaving New Orleans: Social Stratification, Networks, and Hurricane Evacuation.* Understanding Katrina: Perspectives from the Social Sciences. Retrieved from http:// forums.ssrc.org/ understandingkatrina/leaving-new-orleans-social-stratification-networks-and-hurricane-evacuation/

[3] U.S. Army Corps of Engineers Readiness Support Center. (2009). *Urban Search & Rescue: Structures Specialist Field Operations Guide (FOG)*. (6th ed.). Retrieved from http://www.disasterengineer.org/ LinkClick.aspx?fileticket=YZy4Fh%2BBzS8% 3D&tabid=57&mid=394

[4] Moye, D. (2010, August 26). *Katrina + 5: An X-Code Exhibition.* Southern Spaces. Retrieved from http://www.southernspaces.org/2010/katrina-5-x-code-exhibition

[5] Federal Emergency Management Agency. (2011). *Emergency Support Function #9 - Search and Rescue Annex.* (ESF #9-10).

[6] Fitchard, K. (2013, October 21). *With Project Loon, Google Is Engineering a Mobile Network in Reverse.* Retrieved from http://gigaom.com/2013/10/21/with-project-loon-google-is-engineering-a-mobile-network -in-reverse/

Biographies

KIMBERLY SPOA-HARTY is currently a graduate student at Purdue University, Calumet. She is currently working towards her Master of Science degree in the School of Technology with a focus on computer information technologies, while achieving a database certification and holding a 4.0 GPA. Kim is also a system engineer/technical architect on an enterprise healthcare organization client computing team and has been a professional in her field for the past 11 years. Kimberly Spoa-Harty may be reached at kspoahar@purduecal.edu

BARBARA J. NICOLAI is currently an associate professor of Computer Information Technology at Purdue University, Calumet. She earned her B.A. in organization management (1990) at the Calumet College of St. Joseph; post-baccalaureate certificate in computer information systems (1990) from Purdue University, Calumet; and, M.S. in education, instructional design (1999) from Purdue University, Calumet, with an emphasis in technology in software engineering at DePaul University. Her interests include developing and enhancing a complete and universal disaster communication management system. Professor Nicolai may be reached at bnicolai@purduecal.edu

Development of Casual 2D Game Laboratory Exercises for Computer Graphics Programming

Ge Jin, Purdue University Calumet; Magesh Chandramouli, Purdue University Calumet

Abstract

An introductory programming course is an important foundational course in computer science, information technology, computer graphics technology, and other computing-related disciplines. However, it is a challenging task for an instructor to stimulate and maintain student interest in programming in a freshman-level programming course. The difficulty of sustaining student interest in programming has resulted in high dropout rates in computing-related majors in higher education institutions worldwide. In this study, a series of hands-on laboratory exercises were developed focusing on casual 2D games to increase student interest in an introductory computer graphics programming course. A Pong game laboratory exercise was developed to teach conditional statements and keyboard/mouse interaction. Tic-Tac-Toe and Tetris game laboratory exercises were designed to reinforce the usage of array data structure and boundary checking. A Maze game laboratory exercise was developed to convey the knowledge of recursive programming. In addition, an “Angry Baby” game laboratory exercise was designed to teach programming using open source libraries. Students showed great interest in the aforementioned casual game laboratory exercises and provided positive feedback in the end-of-semester course evaluations.

Introduction

Teaching a foundational programming course is a challenging task. The difficulty of passing a programming course at the freshman level has resulted in high dropout rates in computer science, information technology, computer graphics technology (CGT), and other computing-related majors in higher education worldwide [1]. Computing educators have stated that learning programming languages and acquiring problem-solving skills are time-consuming and difficult tasks [2, 3]. One important reason is that current programming languages are mainly designed for industrial use and, hence, are way too complicated for teaching programming foundations. Jenkins [4] indicated that the programming language for introductory courses should be chosen for educational purposes rather than its popularity in industry.

The role of motivation in student performance and eventual success has been emphasized by numerous authors [5, 6]. Talton and Fitzpatrick [7] noted that “A long-standing difficulty in the development of introductory courses in computer graphics is balancing the educational necessity of ensuring mastery of fundamental graphics concepts with the highly desirable goal of exciting and inspiring students to further study by enabling them to produce visually interesting programming projects.” The use of non-traditional methods of instruction such as active learning [8], problem solving [9] [10], and project-based learning [11, 12] have had a positive impact on student learning. Within the context of introductory programming instruction [13] and other technology-based learning [14, 15], such innovative instructional methods seem to facilitate the transfer of skills from the classroom and applying them to the workplace. The use of game-based approaches for facilitating programming instruction has been attempted by other researchers as well. A 2D Game Engine (GameMaker) [16] was developed in order to introduce basic programming concepts to freshmen students. Several researchers [17-19] have supported the role of interactive digital frameworks in facilitating effective instructing computational thinking and programming instruction. The effectiveness of digital games in the learning process and in motivating students was demonstrated by Papastergiou [20]. Nevertheless, research has also cautioned against the undue use of such dynamic media because of the cognitive overload that they may cause [21].

With due consideration to the advantages and disadvantages from overuse, as discussed above, this study focused on the development of casual 2D game exercises that could facilitate the programming component, especially from a computer graphics perspective. At Purdue University Calumet, owing to the lack of sufficient programming courses at the freshman and sophomore levels, the authors of this current study employed this game-driven approach for teaching programing concepts. CGT students had to rely on Java/C++ programming courses offered by other departments, which were discipline-specific and did not directly cater to the needs of the CGT curriculum. Hence, the proposed game-based approach was developed with the specific purpose of teaching programming notions (from a CGT perspective). The approach also was based on the focus of the CGT program on areas such as multimedia design, web design and development, computer animation, game development, and graphic design. The CGT curriculum involves various courses pertaining to game design, web development, imaging, and modeling, all of which have a significant visual component. As CGT students tend to be visually oriented, it is advantageous to capitalize on this visual learning capability and use it as a means to deliver programming concepts in the form of visual game-based exercises. The 2D casual game laboratory exercises were developed with the dual objectives of enhancing general programming concepts and instructing computer graphics game development skills.

A firm grasp of the basic principles of programming and graphic programming, in particular, should help CGT students in many of the future courses involving other computer graphics areas such as modeling, animation, rendering, and various other production and post-production processes. Programming knowledge was also considered to be an important skill by many employers. Hence, strengthening basic programing skills and enhancing computational thinking capabilities help build a strong foundation to help CGT students succeed both in academia and industry. To this end, the authors of this current study proposed the use of casual 2D game laboratory exercises to promote student interest in an introductory programming course. Four casual 2D games: Pong, Tetris, Maze, and Angry Baby were chosen to reinforce the conditional statement, array, recursion, and API programming concepts, respectively. Visual programming exercises can quickly communicate programming concepts, especially for students with visual learning style preferences [22-24]. Overall, the results evinced that the visual and casual 2D game laboratory helped students learn complex concepts. An open source programming environment called Processing© was chosen in the design and implementation of the aforementioned laboratory exercises in an introductory graphics programming course.

Methods

Some programming concepts are generic and different programming languages use the same foundational logic, albeit with different syntax. These include: data, variables, scope, functions, loops, iteration, conditionals, recursion, etc. Illustrations can quickly communicate programming concepts, especially for students with visual learning style preferences [24]. Besides the aforementioned basic programming elements, students need to know the very important programming paradigm called object-oriented programming (OOP). Extremely successful programming languages like Java and C++ are based on the notion of OOP. The developed casual game laboratory exercises would focus on one or more fundamental programming concepts.

Development of the Pong Game Laboratory Exercise

A conditional statement is an example of a fundamental concept in programming wherein a specific sequence (or logic) is executed when a specific condition (or criteria) is satisfied. Graphics examples may help students to transcend the abstract level and take the learning process to a more concrete level. This is because, when using visual examples, the students can actually see the results of conditional statements via the graphic output window. Pong is one of the first arcade games that was created in 1970s. In this game, the "ball" will reflect back from the side walls until either the player or the opponent scores a point.

The logic behind the ball bouncing off the sidewalls is essentially a conditional statement. If the vertical position of the ball is less than 0 (the upper boundary of screen) or higher than the screen height (the lower boundary of screen), the ball will change its speed along the vertical axis. Without the conditional statement, the ball will disappear from the upper or the lower boundary of the screen. In this way, the students can immediately interpret the result of a conditional statement in a visual fashion, as depicted in Figure 1. The logic of conditional statements and the corresponding processing code are illustrated in Figure 2. Similar logic for conditional statements is applied to the collision between the ball, the player's paddle, and the opponent's paddle.

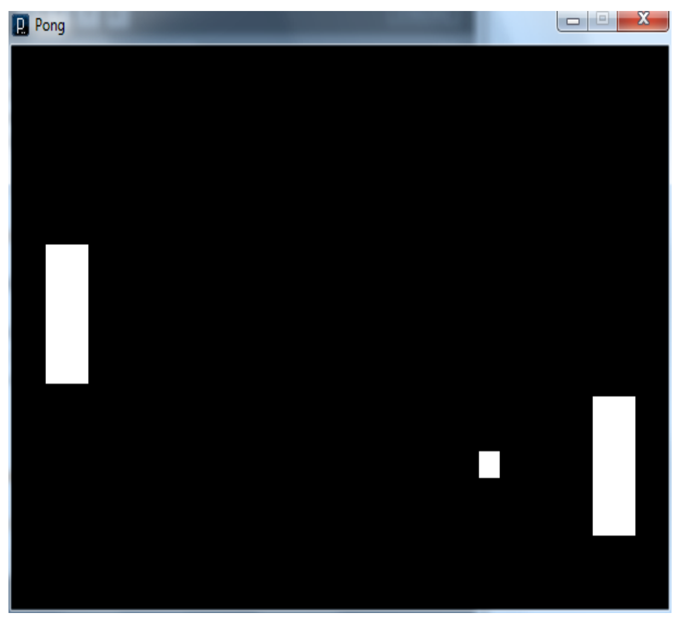


Figure 1. Screenshot of the Pong Game Laboratory Exercise for a Conditional Statement

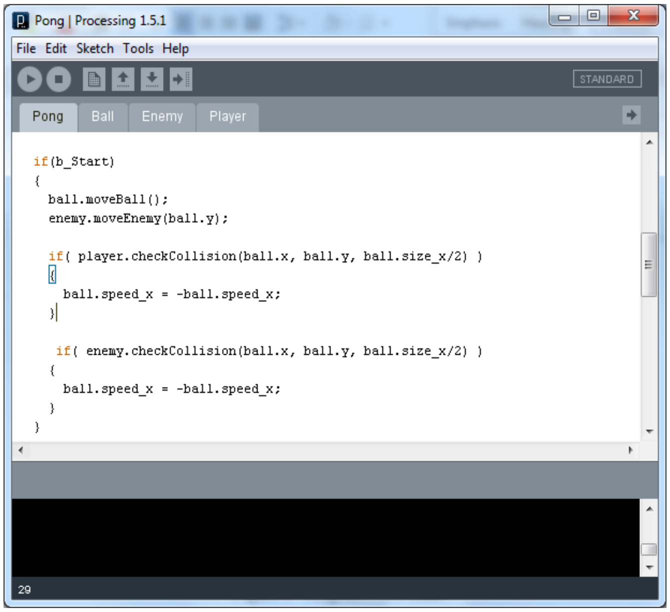


Figure 2. Processing a Conditional Code Statement of the Pong Game

Development of Tic-Tac-Toe and Tetris Game Laboratory Exercises

The concept of a variable is a major bottleneck for a freshman programing course. Simply stated, a variable is a data-holder or a computer memory used to hold information. Just as in the real-world example, different containers are used to hold different types of materials, and different variables are used to store different types of data. A more advanced data concept for an introductory programming course is an array. There are several issues when students start to use array data structures. The first issue is to use an invalid array index, where the valid array index ranges from 0 to an array size of minus 1. The second issue is mapping real-world problems to an array data structure.

The first example that has been used to map real-world problems to an array data structure is the simple Tic-Tac-Toe game. In this demo example, a 3x3 integer array was created to represent a Tic-Tac-Toe map, as shown in Figure 3. The Tic-Tac-Toe example demonstrates that a traditional board game can be represented by a simple array structure. This example also illustrates the importance of separating the underlying data structure (3x3 integer array) from the graphical displays. The Tic-Tac-Toe game requires the student to apply graphical drawing functions, mouse input functions, object-oriented design, and array data structures to solve the problem. Here are several important tasks that students need to complete:

1. A class is designed to represent the Tic-Tac-Toe map. A data member of a 3x3 integer array will represent the map. The array is initialized with a value of 0.
2. In the main function, a 3x3 grid is drawn on the display screen. For each grid, the function checks the value of the Tic-Tac-Toe array. If the array element value is 0, nothing is drawn. If it is 1, a circle is displayed. If it is -1, an “X” symbol is drawn.
3. If the player clicks on the display screen, the mouse click position will be mapped to the array index and the Tic-Tac-Toe array element value will be set to 1.
4. The computer will check the remaining array elements and choose the best place and set the array element value to -1.
5. Whenever a player or computer sets an array element value, an evaluation routine will check the three consecutive values along horizontal, vertical, and diagonal directions to determine the winner.

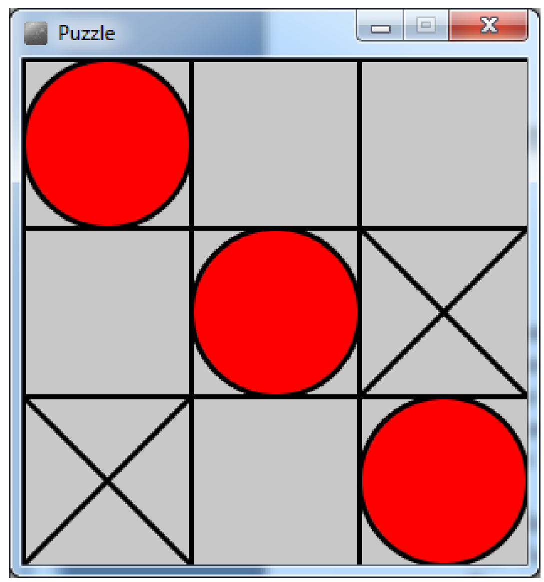


Figure 3. Tic-Tac-Toe Game for an Array Concept

A more advanced laboratory exercise is the Tetris game. Tetris is a famous 2D game that was developed by two Russian programmers. After completing the simple Tic-Tac-Toe game, students are able to map the Tetris game to an array data structure. The display screen is mapped to a 10x20 integer array. The Tetris block is mapped to a 4-element integer array. The Tetris block moves inside the 10x20 map to see if the block touches the lower boundary of the map or any block previously occupied the map grid. The rotation of the block is essentially changing the 4-element array value of the Tetris block object. Here are several important tasks that students need to complete:

1. A Tetris map class is designed to represent the display screen of the Tetris game. A data member of a 10x20 integer array is used to represent the map. The array is initialized with a value of 0.
2. A Tetris block class is designed to represent the block of the Tetris game. A data member of the 4x2 integer array represents the shape of the Tetris block. The initial value of the shape array is determined by the type of the block.
3. In the main function, a 10x20 grid is drawn on the display screen. For each grid, the function checks the value of the Tetris map array. If the array element value is 0, nothing is drawn. If it is 1, a solid rectangle is drawn on the grid location indicating that a block has occupied that grid.
4. At any time, there is an active block continuously moving down; if the player presses the left or right arrow key, the block moves left or right. If the player presses the up or down key, the block rotates clockwise or counterclockwise to change the shape.
5. After each movement of the block, the computer checks whether the block touches the lower boundary of the map or any block previously occupied the map grid. If a collision is detected, the computer will check if there is any horizontal line that is completely occupied by blocks. If so, that grid line is removed from the map array.
6. Next, a new block object is created and game play is repeated if the block occupied the top grid line, the game ends.

Development of the Maze Game Laboratory Exercise

One important concept in programming is recursion. Solving a maze game requires the knowledge of array data structures and recursive programming skills. In the Maze game laboratory exercise, the maze is represented by a 2D integer array. A value of 1 in the array element indicates the wall, and a value of 0 indicates the path. A recursive function is created to find out if one of the maze paths goes from the entrance to the exit. The recursive function works as follows:

1. If the current location is an exit point, the recursive function returns with success (true), which means the recursive function has found a solution.
2. If the current location is not an exit point, the current location is marked as a visited location by using a value of 2. After that, the values of four neighboring array elements are inspected. If any neighboring array element has a value of 0, a recursive function will be called at this location.
3. If no valid path exists, the current location is marked as a dead end by using a value of -1, and the recursive function returns with failure (false).
4. Once the recursive function returns with success (true), the path from the entrance to the exit will be displayed by marking all of the array elements with a value of 2 (see Figure 4).

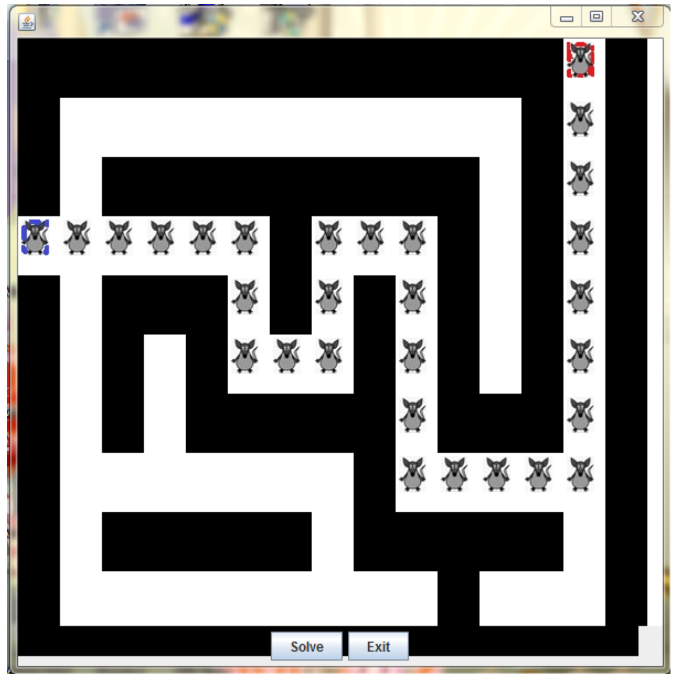


Figure 4. Maze Game Laboratory Exercise for Recursion

Development of the "Angry Baby" Game Laboratory Exercise

At the final project period of the introductory programming course, the students learned how to use open source libraries to create prototype games similar to Angry Bird. The Fisica library for the processing, a wrapper for JBox2D java library, was adopted for teaching programming using a third-party library. In this Angry Baby game, both the Angry Baby class and the Pig class were extended from the FCircle class of the Fisica library. The bricks extend the FBox class. The actual shape of the Angry Baby, pigs, and bricks were represented using images. The Pigs and Bricks were set as passive dynamic objects, and the Angry Baby object was set as an active dynamic object. In addition, the Angry Baby class had methods to deal with the mouse input. Once the user selected the Angry Baby object and dragged it into a shooting position, the initial force and direction were calculated and applied to the Baby object, as shown in Figure 5. The Baby then flies to the bricks and pigs in order to interact with them.

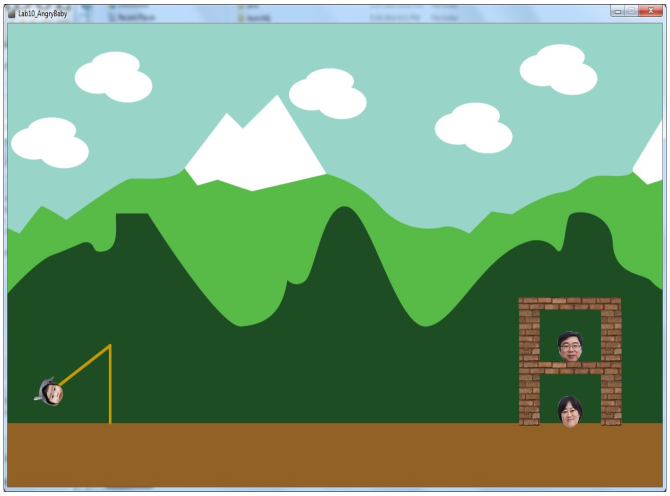


Figure 5. "Angry Baby" Game Laboratory Exercise for Open Source Library

Results and Discussion

The 2D game laboratory exercises explained thus far were designed to cover essential programming concepts as well as advanced topics such as array, recursion, and open source library. During the spring 2015 semester, 23 freshman students took the introductory computer graphics programming course with casual 2D game laboratory exercises. The exams/quizzes and labs/projects were designed to evaluate the students' learning outcome. The midterm and final exams consisted of 100 questions that tested the students' understanding of the graphics programming concepts. Table 1 shows the number of questions in each sub-category, and the students' performance in corresponding sub-categories. The exam results indicated that, at the beginning of the semester, students had struggled in understanding the basic programming concepts such as variables, conditional statements, and loops. One of the reasons was that the freshman students had never taken any programming courses before at the high school or the college. After introducing the 2D game laboratory exercises, the students' performance improved drastically in graphics transformation, object-oriented programming, user interaction, and image and text topics. Overall, the results evinced that the 2D causal game laboratory exercises helped the students in learning computer graphics programming concepts.

The IDEA (Individual Development and Educational Assessment) end-of-semester course survey was conducted to evaluate the course learning outcomes and teaching effectiveness. The students' evaluations, with regards to the course learning outcomes and the effectiveness of instruction, are presented in Table 2. In order to further confirm these positive results, the following question was included in the final teaching evaluation: "My instructor stimulated interest in the course". Eighty percent of the students replied 'Strongly Agree' and 20% selected 'Agree'. This confirmed that the students were receptive to the idea of learning computer graphics programing concepts using casual 2D game laboratory exercises.

Table 1. Question Distribution and Student Success Rates in Midterm and Final Exams

	Midterm and Final Questions	
	Question Number	Success Rate
Variable	7	67.70%
Processing Specific Functions	10	69.13%
Conditional Statement	10	71.74%
Loop	5	75%
Array	6	76.09%
Functions	17	76.98%
Graphics Transformation	12	89.06%
Object-Oriented Programming	13	86.81%
User Interaction (Keyboard/Mouse)	12	91.67%
Images/Text	8	86.31%
Total	100	80.10%

Conclusions

In this paper, the authors presented a series of 2D casual game laboratory exercises for first-year undergraduate programming course. The associated study explored the feasibility of attracting students to the programming laboratory tasks with 2D game topics. With the casual game laboratory exercises, students could create their own simple games with fundamental programming concepts such as conditional statements, array, recursion, and open source library. In the study, a series of hands-on laboratory exercises were developed focusing on casual 2D games for purposes of increasing student interest in an introductory computer graphics programming course. A Pong game laboratory exercise was developed to teach conditional statements and keyboard/mouse interaction. A Tetris game laboratory exercise was designed to reinforce the use of array data structure and boundary checking. A Maze game laboratory exercise was developed to convey the knowledge of recursive programming. In addition, an Angry Bird game laboratory exercise was designed to teach programming using open source libraries. In this paper, the authors addressed the issue of reducing cognitive overload by minimizing perplexing jargon or complex programming terminology, and using graphic illustrations, which served as effective means for communicating programming notions. With casual game laboratory exercises, the students were able to actually see the visual results via the graphic output window, which facilitated the understanding of important programming concepts. Students showed great interest in the aforementioned casual game laboratory exercises and provided positive feedback in the end-of-semester course evaluation.

Acknowledgements

The authors would like to thank Mr. Ricard Marxer for his open source Fisica library for Processing.

References

[1] Kinnunen, P., & Malmi, L. (2006). Why Students Drop Out CS1 Course? *Proceedings of the 2006 International Workshop on Computing Education Research*, (pp. 97-108).

[2] Lahtinen, E., Ala-Mutak, K., & Jarvinen, H. (2005). A Study of the Difficulties of Novice Programmers. *ACMSIGCSE Bulletin, 37*(3), 14-18.

[3] Gomes, A., & Mendes, A. J. (2007). Learning to Program - Difficulties and Solutions. *Proceedings of the International Conference on Engineering Education*, (pp. 283-287).

[4] Jenkins, T. (2002). On the Difficulty of Learning to Program. *Proceedings of the 3rd Annual conference of the LTSN Centre for Information and Computer Sciences*, (pp. 53-38).

[5] Driscoll, M. P. (2005). *Psychology of Learning for Instruction* (3rd ed.). Needham Heights, MA: Allyn and Bacon.

[6] Keller, J. M., & Litchfield, B. C. (2002). Motivation and Performance. In R. A. Reiser & J. V. Dempsey (Eds.), *Trends and Issues in Instructional Design and Technology* (pp. 83-98). Upper Saddle River, NJ: Pearson Education.

[7] Talton, J. O., & Fitzpatrick, D. (2007). Teaching Graphics with the Opengl Shading Language. *ACM SIGCSE Bulletin, 39*(1), 259-263. doi: 10.114.

[8] Prince, M. J., & Felder, R. M. (2006). Inductive Teaching and Learning Methods: Definitions, Comparisons, and Research Bases. *Journal of Engineering Education, 95*(2), 123-138.

[9] Jonassen, D. H. (2002). Integration of Problem Solving into Instructional Design. In R. A. Reiser & J. V. Dempsey (Eds.), *Trends and Issues in Instructional Design and Technology* (pp. 107-120). Upper Saddle River, NJ: Pearson Education.

[10] Newby, T. J., Stepich, D. A., Lehman, J. D., Russell, J. D., & Leftwich, A. T. (2010). *Educational Technology for Teaching and Learning.* (4th ed.). Upper Saddle River, NJ: Pearson Education.

[11] Hadim, H. A., & Esche, S. K. (2002). Enhancing the Engineering Curriculum through Project-based Learning. *Proceedings of the 32nd ASEE/IEEE Frontiers in Education Conference*, Boston.

[12] Mills, J. E., & Treagust, D. F. (2003). Engineering Education – Is Problem-based or Project-based Learning the Answer? *Australasian Journal of Engineering Education*, 2-16. Retrieved from http://www.aaee.com.au/journal/2003/mills_treagust03.pdf.

[13] Pears, A., Seidman, S., Malmi, L., Mannila, L., Adams, E., Bennedsen, J., et al. (2007). A Survey of Literature on the Teaching on Introductory Programming. *ACM SIGCSE Bulletin, 39*(4), 204-223. doi: 10.1145/1345375.1345441.

[14] Jonassen, D. H., Howland, J., Moore, J., & Marra, R. M. (2003). *Learning to Solve Problems with Technology: A Constructivist Perspective*. (2nd ed.). Upper Saddle River, NJ: Pearson Education.

[15] Roblyer, M. D. (2004). *Integrating Educational Technology into Teaching*. (3rd ed.). Upper Saddle River, NJ: Pearson Education.

[16] Hernandez, C. C., Silva, L., Segura, R. A., Schimiguel, J., Paradela Ledón, M. F., Bezerra, L. M., et al. (2010). Teaching Programming Principles through a Game Engine. *CLEI Electronic Journal, 13* (2), 3.

[17] Kazimoglu, C., Kiernan, M., Bacon, L., & MacKinnon, L. (2012). Learning Programming at the Computational Thinking Level via Digital Game Play. *Procedia Computer Science, 9*, 522-531.

[18] Chandramouli, M., Jin, G., & Connolly, P. (2012). An Innovative Teaching Initiative using Processing© Open Source Language for Graphics in First Year Engineering and Technology Courses. *The Technology Interface International Journal, 13*(1), 52-61. ISSN: 1523-9926.

[19] Chandramouli, M., & Heffron, J. (2015, March). A Desktop VR-based HCI framework for programming instruction. *In Integrated STEM Education Conference (ISEC),* (pp. 129-134). IEEE.

[20] Papastergiou, M. (2009). Digital Game-based Learning in High School Computer Science Education: Impact on Educational Effectiveness and Student Motivation. *Computers & Education, 52*, 1-12.

[21] Holzinger, A., Kickmeier-Rust, M., & Albert D. (2008). Dynamic Media in Computer Science Education; Content Complexity and Learning Performance: Is Less More? *Educational Technology & Society, 11* (1), 279-290.

[22] Thomas, L., Ratcliffe, M., Woodbury, J., & Jarman, E. (2002). Learning Styles and Performance in the Introductory Programming Sequence. *ACMSIGCSE Bulletin, 34*(1), 33-37.

[23] Lewalter, D. (2003). Cognitive Strategies for Learning from Static and Dynamic Visuals. *Learning and Instruction, 13*, 177-189.

[24] Zualkernan, I. A., Allert, J., & Qadah, G. Z. (2006). Learning Styles of Computer Programming Students: A Middle Eastern and American comparison. *IEEE Transactions on Education, 49*(4), 443-450.

Biographies

GE JIN is currently an associate professor in the Department of Computer Information Technology and Graphics at Purdue University Calumet. He teaches computer game development, computer graphics and animation, as well as computer information technology courses at the undergraduate and graduate levels. Prior to joining Purdue University Calumet, he was a postdoctoral research scientist at George Washington University's Department of Computer Science. Professor Jin holds a B.S. in computer science from Peking University, China, and an M.S. in computer science from Seoul National University, South Korea. He earned his Doctor of Science degree in computer science with a concentration in computer graphics from George Washington University. His research spans the fields of computer graphics, virtual reality, computer animation, medical visualization, and educational game development. He is a member of ACM SIGGRAPH, ASEE, and the International Society of Virtual Rehabilitation. Dr. Jin may be reached at gejin.puc@gmail.com

MAGESH CHANDRAMOULI is an assistant professor of computer graphics technology at Purdue University Calumet. He earned his B.E. degree from Anna University, India, and M.Eng from the National University of Singapore. He earned his Master of Science degree from the University of Calgary, Canada, and Ph.D. from Purdue University. His research interests include computer graphics, 3D visualization, multi-objective optimization, genetic algorithms, virtual reality, and computer animation. He is a member of IEEE, ACM SIGGRAPH, and ASEE. Dr. Chandramouli may be reached at magesh.chandramouli@purduecal.edu

Addressing New Skills Needed for the Automotive Industry through a Motorsports Educational Pathway

Vukica M. Jovanovic, Old Dominion University; Mileta M. Tomovic, Old Dominion University;
Alok K. Verma, Old Dominion University; Nathan Luetke, Old Dominion University;
Steve Branch, Patrick Henry Community College

Abstract

The automotive industry has higher-skilled positions available that need engineers and engineering technologists qualified and capable to work in a high-paced, advanced manufacturing sector. Various educational programs across the country offer programs related to the motorsports area at the Associate of Science level. There are also various articulation agreements that enable students to continue their education to the baccalaureate level. These programs try to fill in the gap related to the skills shortage in systems and new design methods and processes. The main strength of such educational pathways is that students, who are trained to work as technicians with an associate's degree in automotive and motorsports areas and then continue onto complete their four-year undergraduate degree, have specific skills highly sought by the automotive industry. In this paper, the authors present an example of such an educational pathway, with an emphasis on motorsports.

Introduction

In the beginning, motorsport competitions started as testing venues for the performance and reliability of engines and automotive vehicles [1]. *La Petit Journal* organized the first car race in France in 1894. This was a competition in which companies, such as those of inventors Karl Benz and Gottlieb Daimler, had their vehicles competing with one another. The first race competition in the U.S. was held in Evanston, Illinois, in 1895 [2] (see Figure 1). The main goal of this race was to showcase the "horseless carriage" as "an admitted mechanical achievement, highly adapted to some of the most urgent needs of our civilization."

Various studies have shown an impact of the motorsports industry to manufacturing sectors in the U.S. and across the globe [3]. For example, in the state of Indiana, it contributes to more than 23,000 jobs directly and 421,000 jobs indirectly with annual wages around $63,000, which is well above the state average, as stated in a report by Purdue University researchers: "Race to the Future: The Statewide Impact of Motorsports Industry in Indiana" [3].

Figure 1. The First Car Race in the U.S. Held in Evanston, Illinois [2]

Few career paths for science, technology, engineering, and math (STEM) areas are as dynamic, exciting, and engaging to prospective students as motorsports [4]. The speed and color of the sport engages students in thinking about how cars are designed and made in a very different way than almost any other industry.

Skills Shortage in the Automotive Sector

Skill shortages in the automotive sector are not just related to traditional causes such as high levels of separation from the trades, low take-up of apprentices, or low levels of stock of skills in the work force [5]. They are also related to rapid changes in technology. Typical problems reported were related to recruiting skilled labor, especially maintenance engineers, electrical engineers, and production cell managers [6]. Many of the jobs in the automotive sector that require qualifications between a high school diploma and a bachelor's degree are also hard to fill, since many of the current skilled workers are close to their retirement [4, 6-8].

There is a need in the industry for skilled workers to perform multi-faceted jobs (e.g., someone with electrical and welding knowledge), and some companies report that they are facing downtime in their production systems in part because of the skills shortage [7]. Expensive CNC machines can be idle in manufacturing systems due to the lack of skilled operators. Various initiatives across the country are focused on addressing these skill shortages. Some of them are focused on a development of new certificate programs, such as the Career Pathways initiative in Oregon, which created 300 flexible certificate programs [8]. Such certificates led to a job placement of 44.5% of participants, many of whom earned more than $15 per hour. Another initiative in Virginia established a Board of Workforce Development to facilitate collaboration between relevant agencies in order to address the skills shortage.

Automotive Technology Skills

The National Automotive Technical Education Foundation has identified a set of needed industry-driven skills related to automotive technology [9]. These standards are divided into the following groups: engine repair, automatic transmission, manual drivetrain and axles, suspension and steering, brakes, electrical/electronic systems, heating and air conditioning, engine performance, and alternative fuels and vehicles. These skills are then assessed by the National Institute for Automotive Service Excellence. The other section is related to the employability and possible transferability of acquired skills because of the nature of the current industrial environment, where many people are switching from one job to another [10].

Motorsports Technology Skills

Various universities around the world are offering courses related to motorsports technology, some even offering degrees in Automotive Performance Engineering and Motorsports Technology [11-12]. Others are using motorsports themes for their senior design projects [12].

Technical Skills: Motorsports programs and student competitions allow students to stay current with the technology and develop skills needed for the workforce of the future through various courses in an engineering curriculum. Motorsports projects engage students in problem-based learning with many different multidisciplinary challenges.

Project and Team Skills: Students involved in motorsports projects learn engineering concepts through hands-on experience and teamwork, leadership, and critical thinking skills that are applicable to real-life situations [7]. Another engineering management skill that might be beneficial is related to the mechanics and production crews engaging in planning, setting up, and running a motorsports event, such as a monster truck show [9].

Re-Profiling of Skills in the Automotive Sector

The automotive sector includes technologies transferable to other industries, such as defense, aerospace, energy, and transport [10]. Innovation is a key asset of a successful motorsport team. One such skill is welding, which can be transferred to a wide array of industrial jobs in various sectors [11]. Race teams spend a significant amount of time in the research and development of high-end engineering systems, while adopting new technologies under strict deadlines. Examples of new technology developed for motorsports applications, which are transferred over to the defense sector, include the development of more efficient engine-cooling systems, radiators, and filter systems for armored vehicles that need to work in very hot and dusty conditions in Afghanistan [10]. Aside from these systems, other transferable skills include aerodynamics, lightweight structures, electronics, embedded systems, and general onboard car systems.

The design of vehicles for motorsports includes engineering design principles and the use of computer-aided design. Various material options and alternatives can be analyzed in a digital model so that engineering decisions could be made as early as the design stage, before the realization phase begins. In this way, successful collaboration with people not located in one company is enabled, and skills gained during work in virtual teams could be used in any other industry.

Educational Pathway for Automotive Sector

The first bachelor's degree in Motorsports Engineering and Motorsports Engineering Technology in the U.S. was offered at Indiana University-Purdue University Indianapolis [12]. In addition, various summer camps and pre-engineering curriculum modules were developed to enable the pipeline to this educational pathway. Examples of such modules are related to concepts of a working modern racecar. Examples of educational materials related to motorsports are safety design concepts such as safety structure design and investigations of previous crashes and the development of design improvements based on them. These materials have had a positive effect on high school students and their teachers. In Great Britain, similar initiatives are taking place to engage the younger populations in activities related to motorsports to spark their interests in STEM careers, including four-day intensive courses in motorsports. For example, the Formula Student initiative focuses on teamwork, management, and marketing skills to bring more students into the motorsports educational pipeline [13]. Another example is the study of engineering concepts through an analysis of monster truck competitions [9].

Students' motorsports education continues at the university through their participation in Formula SAE teams and use of the ODU facility, the Virginia Institute for Performance Engineering and Research (VIPER) lab, which is a facility for teaching and hands-on experience, as well as a commercial race facility. Old Dominion University in Norfolk, NASA Langley Research Center in Hampton, and Virginia Tech in Blacksburg collaborated to offer a graduate degree in motorsports engineering and consulting services to automakers and racecar teams [14].

Old Dominion University (ODU), Norfolk, Virginia, and Patrick Henry Community College (PHCC), Martinsville, Virginia, have undergraduate motorsports pathway programs (see Figure 2). In these programs, they are providing educational training for future technicians, engineering technologists, and engineers interested in this technical area. The programs are designed as Associate of Applied Sciences programs that build into a Bachelor of Science degree. As a first step, students enroll in the motorsports program at PHCC. Those students wanting to continue working towards their bachelor's degree have to complete one year at the community college or at a university to take all the necessary requirements for transfer. After that, they enroll in the Mechanical Engineering Technology (MET) program at ODU. The MET program has an option for them to choose Motorsports as their minor. ODU and the New College Institute have partnered to offer Motorsports Engineering Education in Martinsville for students, professionals, and companies involved in motorsports [15].

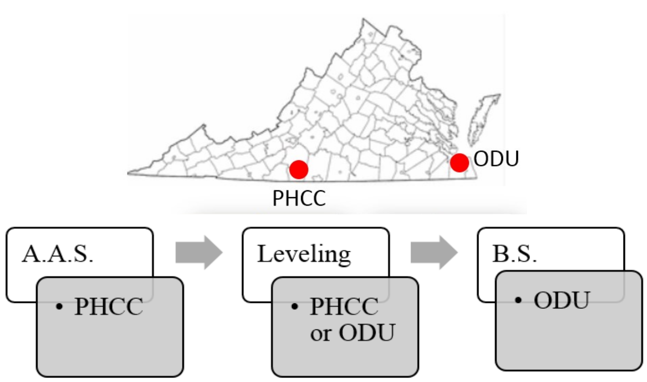


Figure 2. Locations of Two Institutions and Motorsports Educational Pathways

ODU offers a minor in motorsports engineering for mechanical engineering and engineering technology students [15]. Students are introduced to important engineering concepts related to aerodynamics, chassis dynamics, piston engines, and racecar performance. These areas are important for working with high-performance racecars. Graduates with this minor are qualified to work in entry-level positions in motorsports or the automobile sector. A motorsports minor is available to ODU students who have completed lower-division credit requirements in education and a group of technical-based credits that stress subjects related to motorsports. Students may complete general education credits at a local community college, but not many programs can provide technical courses directly related to motorsports.

Table 1 lists courses for the motorsports minor that are available to ODU students in Mechanical Engineering Technology or Mechanical and Aerospace Engineering programs. Students must take four of these courses to satisfy requirements for the minor.

Table 1. Motorsports Minor Courses Available at ODU

Code	Course Name	Credits
MAE 407	Ground Vehicle Aerodynamics	3
MAE 457	Motorsports Vehicle Dynamics	3
MAE 467	Racecar Performance	3
MET 480 / MAE 477	High Performance Piston Engines	3
MET 427 / MAE 427	Mechatronics System Design	3

High Performance Piston Engines is one example of the available courses. This course uses the motorsports lab, which includes a Briggs and Stratton animal racing engine connected to a land and sea dyno and a flow bench to study the air intake process. The students study the ideal internal combustion four-stroke cycle and work their way up through the complete fuel-air cycle. Students study chemical reactions and combustion. After a thorough study of the thermodynamics of the cycle, they complete this part of the course with comparisons to the actual cycles and spend time in the lab running the animal engine on the dyno (see Figure 3).

The next major portion of the course involves air, fuel, and exhaust flow. Topics for discussion include valves, valve timing, intake, and exhaust flow modeling (followed by flow bench experiments). Students then spend course time discussing the tuning of the manifold using CFD, Helmholtz resonators, and a simple acoustic method, as well as turbocharging and supercharging. Students also study the thermodynamic and mechanical aspects of engine design and learn how to read compressor and turbine performance maps to understand how they are created and how to use them. After this, friction and heat transfer is discussed. Many of the students in the course are also involved in the Formula or Baja motorsports teams, so they can apply what they learn right away. The following experiments are conducted during this class: torque calibration; manual dynamometer test with water brake dynamometer; sweep test for different throttle positions; air flow, air/fuel ratio, and fuel flow measurement; exhaust gas analysis; and, injector versus carburetor.

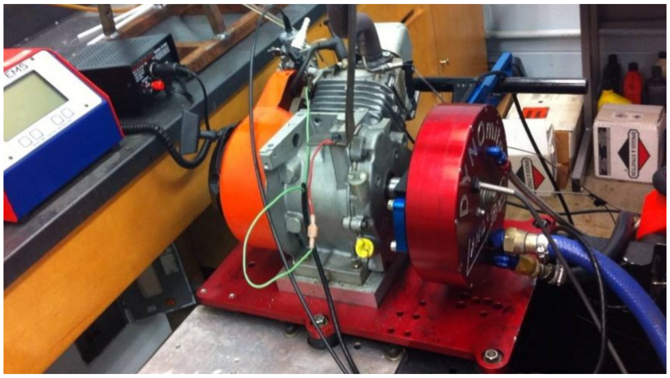


Figure 3. Motorsports Engine Testing Lab at ODU

Facilities Used in the Motorsports Program

VIPER Lab: This facility is located at PHCC, a 12,000-square-foot building next to the Virginia International Raceway, where teams can bring their racecars and simulate track conditions on a seven-post "shaker" rig [14]. The facility is designed to support hands-on teaching of undergraduate and graduate motorsports engineering courses at ODU and the New College Institute, along with PHCC. It is also used to conduct engine and drivetrain research, while operating as a commercial entity. This program was established through support from NASA, Virginia Tech, and the Virginia Tobacco Commission. The engine and drivetrain lab has three main areas of commercial concentration that complement research and teaching aspects: engine diagnosis and performance testing, engine performance optimization (tuning), and vehicle data acquisition and analysis [15].

The engine and drivetrain lab serves commercial applications during race events. Maintenance crews measure horsepower output, and various other measurements related to the race vehicle's drive and chassis. Aside from the weekend events, the lab is used by students for learning [16]. Its main applications are engine diagnostics, performance testing, performance optimization, and data acquisition and analysis. The VIPER vehicle has a 250 HP, 1.4 liter Suzuki motorcycle engine, heavily modified to produce 250 HP. The vehicle's chassis is a lightweight carbon fiber body [17].

Various other facilities are available to students in this minor at ODU: wind tunnel, engine dynamometers, and labs at Virginia International Raceway, which include a modified Formula Mazda and advanced data acquisition system. All junior- and senior-level courses in the motorsports minor are delivered both on campus and through the distance learning program. Motorsports courses are delivered by ODU at the New College Institute in Martinsville, Virginia. Facilities at PHCC include a driving simulator, vehicle dynamics rig, and chassis dynamometer. In addition, students have access to the engine instrumentation lab and Virginia International Raceway.

Motorsports Student Senior Design Teams at ODU

ODU has participated in the Formula Society of Automotive Engineers (SAE) competitions since 1998. Each year, the team has requirements to design, build the vehicle, and participate in the competition with a formula-style racecar (see Figure 4). In addition to the design and build requirements, the team has to be involved in project management tasks to plan, coordinate, and verify the robust design of all car components, subassemblies, and assemblies. Main subassemblies are chassis, drivetrain, engine, suspensions, aerodynamic components, and controls. Components are designed to the manufacturing specifications, built, assembled, and integrated. Before the race, they are tested for durability and reliability [18].

Figure 4. ODU Motorsports Fleet

Conclusions

Automotive and motorsports industries have faced rapid expansion in recent years. Various car manufacturers are participating in motorsport competitions to research and develop various innovations related to vehicle design and performance. In addition, modern high-performance vehicles are now redesigned to run on more environmentally friendly fuels such as electric, ethanol, and diesel, or in a hybrid mode. Working on their design, testing, and maintenance requires very specific skills, many of which can be translated to the automotive sector. The motorsports minor at ODU complements mechanical engineering/technology and aerospace programs. It adds a more specialized focus to prepare students for various jobs. Through work on automotive/motorsports-based themes in the stream of courses, students receive problem-based, lab-oriented, in-depth knowledge of complex engineering principles.

References

[1] Lopez, G. (2008). Brief History of Motorsports. Retrieved from http://ww2.odu.edu/~glopez/MTS/About/About_Motorpsorts.html

[2] The Henry Ford. (1999). The Chicago Times-Herald Race of 1895. Retrieved from: http://www.thehenryford.org/exhibits/showroom/1896d/race.html

[3] Fiorini, P. (2012) Purdue-led study highlights motorsport industry's significant impact across Indiana, worldwide, Retrieved from http://www.purdue.edu/newsroom/releases/2012/Q4/purdue-led-study-highlights-motorsport-industrys-significant-impact-across-indiana,-worldwide.html

[4] Hylton, P. (2010). Using Motorsports Design Concepts to Further STEM Education, *Journal of Technology Studies*, *36*, 12-15.

[5] Borthwick, J., John, D., & Werner, M. (2000). *Evidence of Skill Shortages in the Automotive Repairs and Service Trades*. National Centre for Vocational Education Research, Leabrook, South Australia, Australia.

[6] Duval, S. (2013). Automotive industry faces labour shortages, *Automotive Manufacturing Solutions*, *14*, 16-17.

[7] Thomas, I. (2008). Revving Up Students' Skills with Motorsports, *Techniques: Connecting Education & Careers*, *83*(5), 28-31.

[8] Community Colleges and Workforce Development Worksource Orregon (2013). Pathways in Oregon: A Descriptive Study of the Statewide Initiative & Initial Cohort of Completers, Retrieved from http://www.oregon.gov/ccwd/pdf/pathways/pathwaysdescriptivestudy.pdf

[9] Burgin, S., & Ritz, J. (2013). Monster Trucks: Innovations in Motorsports, *Technology & Engineering Teacher*, *72*, 26-31.

[10] Hibbert, L. (2013). Racing into new markets, *Professional Engineering, 26*(1).

[11] Bilski, C. J. (2009). Youth Education through Motorsports*, World of Welding*, 27.

[12] IUPUI. (2015). Motorsports Engineering, Indiana University – Purdue University Indianapolis, Indiana, Retrieved from: http://www.engr.iupui.edu/departments/ent/undergrad/mste/index.php

[13] Bolton, J. (2012). Winning Workshop – How to get a fast track to understanding a race car's engine. *Motor Sport News: The Voice of British Motorsport, 31*.

[14] Connolly, A. (2005). ODU to Offer Motorsports Degree with High-Tech Emphasis. *The Virginian-Pilot,* September 11.

[15] Seaber, V. (2015). Motorsports, Old Dominion University, Retrieved from: https://www.odu.edu/engtech/curricula/met/motorsports

[16] ODU. (2008). VIPER to Open Motorsports Engineering Lab at Virginia, Old Dominion University, Norfolk, Virginia, U.S.A., Retrieved from http://ww2.odu.edu/ao/news/index.php?todo=details&id=9907

[17] ODU. (2013, July). Victor Seaber of ODU's VIPER Lab Bests Professional Driver at VIR's Ultimate Track Car Challenge, Old Dominion University, Norfolk, Virginia, U.S.A., Retrieved from http://www.odu.edu/news/ 2013/7/viper_lab#sthash.gZ3w9Jhw.dpuf

[18] ODU. (2010). ODU Formula SAE 2010, Old Dominion University, Norfolk, Virginia, U.S.A., Retrieved from http://orgs.odu.edu/sae/ projects/formula/index.html

Biographies

VUKICA M. JOVANOVIC is currently an assistant professor in the Department of Engineering Technology at Old Dominion University. Her research focuses on mechatronics, product identification, product lifecycle management, assembly systems, energy efficiency, and engineering education. She has had internships in engineering services, aerospace, and power generation industries. Dr. Jovanovic received her master's in engineering (dipl.ing) degree from the University of Novi Sad, Serbia, in robotics, mechatronics and automation, and Master of Science (Magistar) degree in production systems design, both in the Department of Industrial Engineering. She received her Ph.D. in mechanical engineering technology from Purdue University. She is Chair of the Student Hardware Competition, IEEE SoutheastCon 2016 in Norfolk, VA. Dr. Jovanovic may be reached at v2jovano@odu.edu

MILETA M. TOMOVIC is currently professor and director of the Advanced Manufacturing Cluster at Old Dominion University. Dr. Tomovic received his B.S. in mechanical engineering from the University of Belgrade; M.S. in mechanical engineering from MIT; and, Ph.D. in mechanical engineering from the University of Michigan. Prior to joining ODU, Dr. Tomovic had 17 years of teaching and research experience at Purdue University with an emphasis on the development and delivery of a manufacturing curriculum, conducting applied research, and engagement with Indiana industry. While at Purdue University, Dr. Tomovic served as W. C. Furnas Professor of Enterprise Excellence, University Faculty Scholar, director of the Digital Enterprise Center, and special assistant to the Dean for Advanced Manufacturing. Dr. Tomovic may be reached at mtomovic@odu.edu

ALOK K. VERMA is Ray Ferrari Professor and Chair of the Engineering Technology Department at Old Dominion University. He also serves as the director of the automated manufacturing laboratory. Dr. Verma received his B.S. in aeronautical engineering from the famed institution, IIT Kanpur; M.S. in engineering mechanics; and, Ph.D. in mechanical engineering from ODU. Professor Verma is a licensed professional engineer in the state of Virginia, a certified manufacturing engineer, and has certifications in lean manufacturing and Six Sigma. He has organized several international conferences as general chair, including ICAM-2006 and ICAM-1999, and also serves as associate editor for three international journals. He serves as the president of the International Society of Agile Manufacturing and as the chief editor of the *International Journal of Agile Manufacturing*. Dr. Verma may be reached at averma@odu.edu

NATHAN LUETKE is currently a senior lecturer in the Engineering Technology Department at Old Dominion University. Nathan Luetke received his B.S. in mechanical engineering technology from Old Dominion University, followed shortly thereafter by an M.S. in mechanical engineering. While pursuing his master's degree, Nathan spent two years at Swales Aerospace, followed by one year at Lockheed Martin contracting for the NASA Langley Research Center in Hampton, VA. Professor Luetke may be reached at nluetke@odu.edu

STEVE BRANCH is currently Dean of Science, Technology, Engineering, and Math at Patrick Henry Community College. He received his master's degree from Appalachian State University and his bachelor's from UNC Pembroke in biology with a minor in chemistry. Dean Branch may be reached at sbranch@patrickhenry.edu

Parking and Street Lighting with Hybrid Solar and Wind Energy-Powered LEDs

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

Abstract

A campus energy education and awareness program was implemented at Sam Houston State University (SHSU) to help ensure that unnecessary building lights are turned off when rooms are unoccupied, and lights that draw a lot of current are replaced with light emitting diodes (LEDs). Implementation of energy efficient lights such as LEDs will reduce energy consumption in campus parking areas and streets. In order to support this initiative, a group of students from the engineering technology program were involved in a series of energy projects to help energy conservation endeavors on campus. A literature review of existing night and security lighting technologies—high-pressure sodium (HPS), high-intensity discharge (HID), mercury vapor, and induction—was conducted by the students. For this purpose, several online resources were used for the detailed information and campus energy directors were interviewed. A preliminary study was conducted to investigate campus lighting technologies currently in use for building site lighting, parking lots, and campus streets. In the study, energy inefficiency of current lighting technologies was discussed among the research group and presented to the campus energy department. After preliminary investigations, installation of several LED light fixtures was proposed and accepted on pilot campus locations that were powered by hybrid solar and wind power.

Introduction

An LED lighting initiative is a common attempt to reduce energy consumption among campuses. By installing energy-efficient LED lighting technology, campuses can lower energy consumption, decrease maintenance costs, and lessen wear and tear on heating and cooling systems. As one of the least risky sustainability practices with a rapid return on investment of less than three years in many cases, LED lighting also allows for implementation of projects in phases. LEDs have longer lifespans and lower energy consumption levels than conventional light bulbs. A major advantage of LEDs is low energy consumption and lifetime operation with little to no maintenance, when compared to traditional lighting such as HIDs, incandescent, fluorescent, etc. The cost of LED lighting may be an issue when a major retrofit is planned on campuses but the payback will be around three to five years, depending on the capacity of the LED lighting deployed. LEDs are similar to typical light bulbs, the main difference being that they do not have a filament, which is the reason why they have such long lives. Because LEDs do not use a filament, they also do not get hot and they run on less electrical power; this makes them more energy efficient.

There are a variety of energy projects targeted at reducing energy consumption on campuses. For instance, faculty members, students, and staff from Southwestern University (Georgetown, TX) developed a course that focuses on energy conservation strategies for the theater, particularly the replacement of incandescent lighting fixtures with systems that use LEDs. This project initiated an extension of projects on campus including the physical plant, which considered using LEDs for street lights and pedestrian lights [1]. Another educational project was awarded to support renovations of buildings at DuPage College. The Illinois Clean Energy Community Foundation awarded a $100,000 grant to support renovations to the Berg Instructional Center, Student Resource Center, and College Center. The funding enabled progress toward U.S. Green Building Council LEED Silver Certification that will ensure that energy-efficient features are incorporated into building design and engineering plans. LEED certification is a nationally recognized benchmark for the design, construction, and operation of high-performance green buildings.

Through a $100,000 grant from the Illinois Clean Energy Community Foundation, LEDs would be installed as primary lighting in the buildings' high-profile public areas such as student lounges, snack bars, restrooms, building entries, corridors, and reception areas. LED lighting fixtures would also be installed as supplemental accent lighting in classrooms and conference rooms. Energy savings ranging from $14,000 to $23,000 per year will be realized as the college replaces 1428 light fixtures with those containing LEDs. Recently, there have been many attempts to incorporate solar power with LED indoor and outdoor lighting, due to its low power consumption. Researchers investigated the feasibility of such projects, especially focusing on economic feasibility and site assessments [2-6].

The rapid development of efficient high-power LEDs has led to the production of a variety of lighting applications, broadening our horizons and giving us different concepts and uses of lighting design. The advantage of LEDs is that they can now compete with, even surpass, traditional illumination. Furthermore, powerful new legislation demands consideration of the environmental impact of a product over its lifecycle, from production to disposal. All of this makes LEDs the ideal candidate for an environmentally friendly light source. The worsening of the problems regarding global warming has made the development of renewable energy sources the focus of world-wide attention, one of which is solar energy-powered LEDs and their applications [7-9].

There have been many energy conservation attempts recently to incorporate LED lighting in order to decrease power consumption, increase the lifespan of lights, and to decrease the maintenance of lights. The Department of Energy has been supporting LED projects under a program called "Gateway Demonstrations" [10-11]. One of the recent statewide Gateway Demonstration projects was created for the Jordan Schnitzer Museum of Art in Eugene, Oregon, in January, 2011, entitled The Demonstration Assessment of -Emitting Diode (LED) Retrofit Lamps [12]. In this project, 90W PAR38 130V narrow flood lamps used for accent lighting were replaced with 12W LED PAR38 lamps for a special exhibition; the museum also staged a side-by-side comparison of three different LED PAR38 replacement lamps against their standard halogen lamps.

The LED system lighting the exhibition showed a lower present value lifecycle cost, using 14% of the energy and having a life 10 times longer than the halogen system. Another similar project was done under the same program called "LED Freezer Case Lighting: Albertsons Grocery" in Eugene, OR [13]. In this project, upright freezer cases were retrofitted with LED strip-lights combined with occupancy sensors and compared to standard fluorescent lighting on the opposite side of the aisle. Calculated payback periods approached five years from estimated energy and maintenance savings for a typical 5-door case. Another example of similar projects was completed at the Bonneville Power Administration headquarters in July 2011 [14]. In the building, 15W and 23W reflectorized compact fluorescent (CFL) track lights used to illuminate artwork were replaced with 12W LED lamps. Although the study did not show rapid payback on the LED installation compared to the CFL products, color quality and power quality improved with the LED lamps, and the narrower light distribution of the LED product more effectively concentrated the lumens on the artwork.

Project Planning

One of the energy conservation attempts is a Sam Houston State University technology student LED parking and street lighting project that has been active since 2011. Faculty and students in the Industrial Technology program at SHSU took the initiative to install hybrid solar and wind energy infrastructure and LED lights to join SHSU's energy initiative plan. For this plan, students collaborated with the university physical plant administration to determine problems and needs and then come up with potential solutions. Physical plant staff regularly audit the work students have been doing with faculty mentors. The initial project site was one of the satellite campuses where there are six metal buildings averaging 10,000 square feet each. In this location, buildings are illuminated by wall-mounted traditional lighting. There was insufficient illumination for the buildings, especially for the parking lighting. Most of the buildings in this location are not accessible during the evening hours, due to night classes and capstone projects. Initially, physical plant officers offered two spots in this location and provided light poles (for two LED light fixtures), old light fixtures (used for HID lamps), and service (official auditing and approvals, bucket trucks, etc.) for installation.

Project Design

Initially, students majoring in Industrial Design and Construction Management were tasked to create a 2D/3D model of the project infrastructure. Students worked with project faculty, physical plant administration, and a licensed master electrician to design the infrastructure. The design work is shown in Figures 1 and 2. The infrastructure was located near the 10,000-square-foot production laboratory. All of the production, assembly, and testing processes were accomplished in the production lab before implementation. Autodesk Inventor was used to design the complete renewable energy training infrastructure. After the design process and all of the approvals, construction management students and faculty built a power house (12' x 8' x 10') for all of the equipment. Figure 3 shows the layout of the outdoor wiring and conduits from the light poles to the power house.

Project Implementation

Students built concrete foundations for light pole footings and installed light poles in selected locations. Light poles and light fixtures were retrofitted to install LEDs, solar modules, wind turbines, and battery packs. Students also studied and reported normal operation time for lighting, local average wind speed, local average sun illumination, load capacity of light poles, and a secure location for batteries and controls. Seven light poles were installed near the industrial technology lab facility by students majoring in construction and electronics. Shading analysis for the solar energy was completed using solar path finder shading analysis tools. For the shading analysis, students were divided in groups and were provided three Solar Pathfinders™, assistive software, and laptops [15]. A short description of the equipment summary of the experiment was provided to students. A sun path calculator was used to view the solar window for a particular location for assessing shading. Other means can be used to evaluate shading, but sun path calculators are usually the quickest and easiest to use. The Solar Pathfinder™ was located at the proposed array site, leveled, and oriented to true south with the built-in compass and bubble level. After shading analysis, five poles were installed and solar modules, wind turbines, and LED light fixtures were mounted. The design work of brackets and metal frames to mount wind turbines, solar modules, and LED light fixtures to properly and securely attach the power generation components was completed by design and development students. All of the brackets and frames were built and tested in the lab facility. Figures 4-8 show pictures of the light poles with the wind turbines, solar modules, and power house.

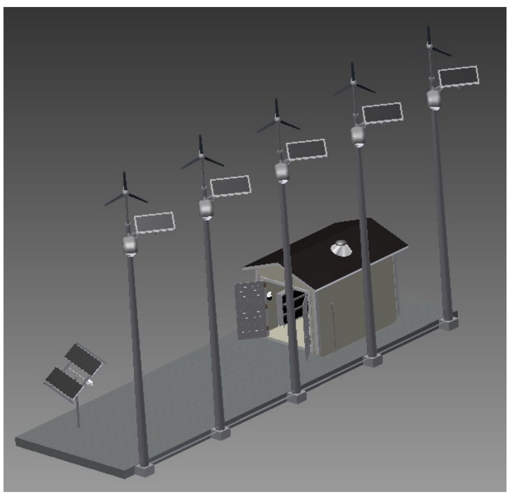


Figure 1. Complete Design Work for the LED Lighting with the Hybrid Solar-Wind Energy System

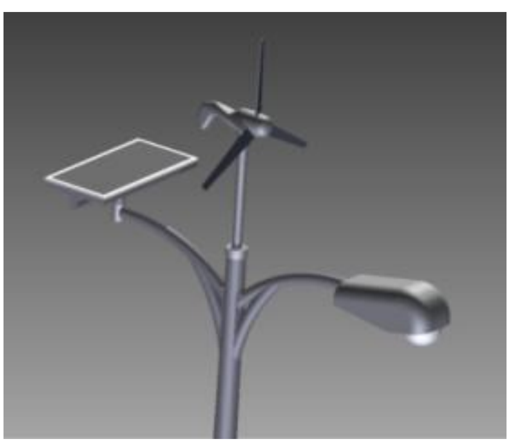


Figure 2. Design Work for the Single Light Pole with LED, Solar Panel, and Wind

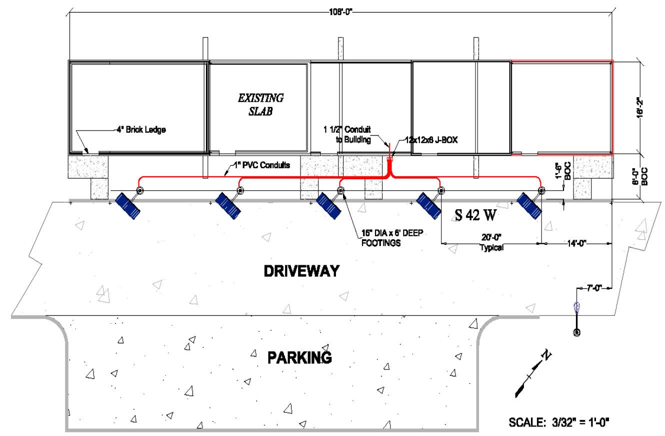


Figure 3. Layout Drawing for the Location of the Light Poles, Power House, and Conduits

Figure 4. Wireless Weather Station

Figure 5. Power/Control and Teaching House

Figure 6. Wind Power Control and Teaching Room

Figure 7. Solar Power Control and Teaching Room

Figure 8. Inspection Process

Additionally, old light fixtures were retrofitted and rebuilt to house new LEDs to be attached to the light poles. Students were able to fit two or three efficient LEDs into a single light fixture for future studies. A comparison study between various LEDs and traditional street/parking lights was conducted and reported to the university physical plant. Figures 9-14 show the LED light fixtures, control unit, installed solar panel, and light sensor.

Figure 9. Light Fixture with HID Lamp before Conversion to LED Light Fixture

Figure 10. Retrofitted LED Light Fixture–Type I

Figure 11. Retrofitted LED Light Fixture–Type II

Figure 12. Power Control Unit near the Light Pole

Figure 13. An LED Installed at a Different Location

The project team worked on the integration of the system components and wiring to complete the project. A bucket truck was provided by the SHSU physical plant to install the solar panels, LED light fixtures, wireless weather station, and to pull the wires from the light poles to the power house. Students were provided experience in various types of job duties, such as determining correct conduit sizes, installing conduits, pouring concrete slabs for the light poles, learning wire types and codes, calculation of wire gauges, balance of the components of the solar PV system, dealing with AC vs. DC electricity and conversion, sizing the batteries, using various power tools, preparing and reading electrical and construction drawings, finding correct location and tilt angles of the solar panels, etc. Following are the project steps and learning outcomes of the project:

- Brainstorming sessions
- Meetings with physical plant staff
- Site analysis
- Proposal writing for funding and permissions
- Purchasing
    - Cost analysis
    - Contacting companies/vendors
- Implementation
    - Computer aided design (2D/3D)
        - AutoCAD
        - Autodesk Inventor
        - PTC Pro Engineer
        - Microsoft Visio
        - AutoCAD Electrical
    - Construction
        - Power house
        - Running conduit and wires
        - Tower installations (light poles)
- Team working
    - Construction management, electronics, design and development, safety management
- Testing the overall system
- Publications and reports
- Potential use of the project for teaching

Figure 14. Light Sensor

In terms of student learning and satisfaction, the project was a success. With the increasing importance of energy conservation and clean energy resources in present and future energy scenarios, the ability to design and analyze renewable energy systems becomes essential for engineering and technology educators and students. All students in the project showed improvement in learning and understanding concepts of energy conservation through both the project and the complementary theory-based lecture with hands-on experiments. The ultimate goal is to increase the number of experimental projects and to cover additional renewable energy sources that complement even more of what was covered in this project. The hands-on experience from the project provided the students with the opportunity to demonstrate the knowledge that they gained in previous projects. Students learned about various aspects of energy conservation including problem identification, technical, social and environmental constraints, multidisciplinary team management, communications and documentation skills. This project also provided the students with an opportunity to view their designs from an ethical and sustainability awareness perspective, thus realizing a lifelong learning opportunity. Through practice, the students realized that the key to success for a design project is teamwork, industry interaction, and collaboration.

Technical Specifications and Costs

Technical specifications and cost estimates of the main components, such as solar module, wind turbine, LEDs, charge controller, and battery, are summarized in Table 1.

Conclusions

This undergraduate research project was one of the campus-wide efforts to promote energy conservation and use of clean renewable energy resources. This project was mainly accomplished by students and was very supportive of campus-wide efforts to promote energy conservation and use of clean renewable energy resources. The university physical plant decided to hire two of the students involved in the renewable energy project to do campus-wide energy assessment. This and similar projects have been done on campus to demonstrate the viability of renewable energy for reducing the amount of money the university pays to the utility company, as well as reduce greenhouse gas emissions which speed up global warming. Student feedback was very positive in terms of learning outcomes gained from this project. Students asked to be involved in more campus-wide projects and asked to extend this project to the local community for energy assessments. Two of the students requested small grants to prepare and mail brochures/flyers about LED lighting and energy conservation.

Table 1. Technical Specifications and Costs

Component	Brand	Voltage (V)	Current (A)	Power (W)	Cost ($)
Solar Panel (BP 4175)	BP Solar	36	4.9	175	Donation
Inverter (RD1824)	Magnum	24V	95	1800	1200
Solar Charge Controller (TS45)	Morningstar TRISTAR	45-125	45		350
Battery (Ub121350) for Solar Photovoltaic	Universal	12V	135		300
Wind Turbine	Primus	12	15	200	550
Circuit Breaker	Primus	12	20		NA
Analog Amp Meter	Primus	12	309		NA
Battery Meter	Midnight Solar	12-48			60
Analog Voltmeter	Blue Sea System	8-16			NA
Inverter for Wind Power (PST)	Samlex	12		350	150
Battery of Wind	MK	12	73		210

References

[1] Davis, E. (2010). Energy and the Arts. Southwestern University. Retrieved November, 26, 2015 from http://www.southwestern.edu/newsroom/story.php?id=296

[2] McLaren, P. (2011).A Beacon to Savings, Campus to Replace Lights for More Energy Efficiency by Pamela McLaren. Retrieved December, 8, 2015 from http://calstate.fullerton.edu/inside/2011sp/Lighting-Retrofit.as

[3] Pode, R. (2010). Solution to enhance the acceptability of solar-powered LED lighting technology. *Renewable and Sustainable Energy Reviews*, *14*(3), 1096–1103.

[4] Wu, M. S., Huang, H. H., Huang, B. J., Tang, C. W., & Cheng, C. W. (2009). Economic feasibility of solar

-powered led roadway lighting. *Renewable Energy*, *34*, 1934-1938.
[5] Huang, B. J., Wu, M. S., Hsu, P. C., Chen, J. W., & Chen, K. Y. (2010). Development of high-performance solar LED lighting system. *Energy Conversion and Management, 51*, 1669-1675.
[6] Hill, R. L., & Curtin, K. M. (2011). Solar powered light emitting diode distribution in developing countries: An assessment of potential distribution sites in rural Cambodia using network analyses. *Socio-Economic Planning Sciences, 45*(1), 48-57.
[7] Devonshire, R. (2008). The Competitive Technology Environment for LED Lighting. *Journal of Light Visual Environ*, *32*(275), 287.
[8] Zheludev, N. (2007). The life and times of the LED-a 100-year history. *Nature Photonics, 1*(189), 192.
[9] Tsuei, C. H., Sun, W. S., & Kuo, C. C. (2010). Hybrid sunlight/LED illumination and renewable solar energy saving concepts for indoor lighting. *Optics Express* A640, Optical Society of America, *18* (S4).
[10] Solid-State Lighting GATEWAY Demonstrations. (n.d.). U.S. Department of Energy, Energy Efficiency & Renewable Energy. Retrieved December, 20, 2015 from http://www1.eere.energy.gov/buildings/ssl/gatewaydemos.htm
[11] Solid-State Lighting GATEWAY Demonstration Results. (n.d.). U.S. Department of Energy – Energy Efficiency & Renewable Energy. Retrieved December, 20, 2015 from http://www1.eere.energy.gov/buildings/ssl/gatewaydemos_results.htm
[12] Demonstration Assessment of Light-Emitting Diode (LED) Retrofit Lamps (2011). Jordan Schnitzer Museum of Art, Eugene, OR. U.S. Department of Energy – Energy Efficiency & Renewable Energy. Retrieved December, 20, 2015. http://apps1.eere.energy.gov/buildings/publications/pdfs/ssl/2011_gateway_schnitzer.pd
[13] Demonstration Assessment of Light-Emitting Diode (LED) Freezer Case Lighting (2011). Albertsons Grocery, Eugene, OR. U.S. DOE Solid-State Lighting Technology Demonstration Gateway. Retrieved November 19, 2015 from http://apps1.eere.energy.gov/buildings/publications/pdfs/ssl/gateway_freezer-case.pd
[14] Demonstration Assessment of Light-Emitting Diode (LED) Retrofit Lamps (2011). Bonneville Power Administration, Portland, OR. Final Report. U.S. DOE Solid-State Lighting Technology Demonstration Gateway Program. Retrieved December 20, 2015 from http://apps1.eere.energy.gov/buildings/publications/pdfs/ssl/2011_gateway_bpa.pd
[15] Solar Pathfinder. (n.d). Retrieved December, 20, 2015 from http://www.solarpathfinder.com/P

Biographies

FARUK YILDIZ is currently an assistant professor of industrial technology at Sam Houston State University. His primary teaching areas are electronics, computer aided design, and alternative energy technologies. Research interests include low-power energy harvesting and renewable energy technologies. Dr. Yildiz may be reached at fxy001@shsu.edu

KEITH L. COOGLER is an instructor of engineering technology at Sam Houston State University. He received a B.S. in design and development and holds an M.A. in industrial education and an Ed.D. in higher education from Texas A&M University-Commerce. His primary teaching area is construction management. Research interests include automation, electronics, alternative energy, and green construction. Dr. Coogler may be reached at ith_klc@shsu.edu

The Pinhole Project: A Study in the Pedagogical Use of Technology

Alex Johnson, University of North Dakota; Cindy English, University of North Dakota; Logan Tong, University of North Dakota

Abstract

When, how, and what technologies to use in academic settings is an issue that needs to be further explored if both student retention rates and quality of educational programs are to be improved. The following case study describes a project utilizing pinhole cameras, incorporating aspects of meaningful learning, and "technogogy" that was integrated into a fundamental technology course. Information provided in this case study should allow the activity to be utilized in a variety of engineering curricula or adapted for use in other subject areas.

Introduction

Kevin Kelly, the founding executive editor of *Wired* magazine, recently made the statement that most of the problems that we face today are technogenic or, in other words, were created by technologies of the past [1]. Kelly goes on to state that he believes that in the future most of the problems will be rooted in technologies that we are creating today. Kelly's assertion of the potential problems of technology is troubling on many levels, perhaps more so due to the lessons that we have learned from history that seem to support the validity of Kelly's technogenic theory, and perhaps nowhere would the effects of Kelly's theory be felt as keenly as in the engineering education sector, which prepares our future generations.

Technogogy, as defined by Idrus [2], is "the convergence of technology, pedagogy and content in the transformative use of technology to foster learning." In a society that has become inundated with the latest technologies, it should not be surprising that these technologies have made their way into the broad educational sector. In fact, it is a rare institution that has not been impacted by the myriad technologies on the market, ranging from smartphones to iPads. Walking through an educationally focused trade show or flipping through a few pages of educational magazines such as *Tech Directions* makes it easy to find numerous technologies that are being developed specifically for education, particularly in the engineering/technology fields. Manufacturers are all too willing to supply high-cost technology teaching modules that are intended to teach subjects ranging from hydraulics to lasers and practically everything in between. Most of these modules are available with ready-to-use teaching curricula, making it easier for faculty with limited time or, unfortunately, all too often, limited knowledge to implement these modules into their classes. With the vast array of technologies available on the market, it might be easy to feel that engineering/technology students cannot be taught effectively without the use of these modules but, in this technology-rich age, it is perhaps more important than ever to realize that even the best of these technological tools cannot make up for poor teaching practices.

Avoiding the Technology Crutch

In his book, *What Technology Wants*, author Kevin Kelly coins the term technium, which he defines as the "global, massively interconnected system of technology vibrating around us" [3]. As Kelly states, technology has infiltrated our lives and has followed us throughout history, leaving its mark in almost every imaginable way. Arthur [4], author of *The Nature of Technology: What It Is and How It Evolves*, goes even further by stating that the link between technology, science, and the economy are symbiotic in nature, or co-evolving, with technology taking the leading role. With this symbiotic relationship with technology, it can oftentimes be difficult to control the manner in which we use technology and ultimately the question becomes whether we control the technology or does the technology control us. According to Wulf [5], former director of the National Academy of Engineering, it is the use of tools, or technology, which define humans. Whether humans control technology or vice versa is perhaps a less important question to ask. Rather, we should be examining how we work with technology in our own lives now that "it has been let out of the bottle" [6]. Finding this balance is the key to being a user of technology rather than being used by it. The use of PowerPoint presentations has been a hotly debated topic in academic circles for a number of years, with the debate focusing on the appropriateness of PowerPoint. Those who have been involved with academia as students or teachers have likely seen the negative side of this technology in the form of long presentations filled with seemingly endless slides containing gimmicky graphics and special effects. And while the misuse of this technology is widespread, it should not be assumed that it is impossible to use PowerPoint effectively in the classroom because many educators are effectively using it; but, as with any technology, it is wise to assess not only its usefulness in educational settings but also examine whether using the technology is an effective use of time.

The question of time is particularly important, since most educators find they have little of it to spare, and while a specific technology might prove applicable, it is worth asking the question whether a simpler, less time-consuming method might be used with equally effective results.

Technology as a Propellant for Learning

Engineering education has come under scrutiny in recent years, due to concerns about the low retention rates of engineering students. Though many have attributed these occurrences to the academic rigor of engineering programs and intensive math and science classes that many see as "weeding" classes [7], studies have shown that only a small portion of engineering students leave these programs due to academic problems. Instead, research has shown that students are leaving these programs for a variety of other reasons that can be linked to poor pedagogical practices which result in an educational climate that is ineffective for students. Some of the areas that have been mentioned involve poor instructor availability, insufficient connections being made between core concepts and real-world applications, or simply teaching that is described as uninspiring [8]. And while these problems do continue at many institutions, many more are taking action by revising curricula in ways that place more emphasis on creating the all-important connections between theoretical principles and real-world applications [9], moving to more hands-on approaches to learning involving creative learning activities that create meaningful learning environments [10]. With the shift towards hands-on approaches to learning, many institutions are looking at technologies that can be incorporated into the curricula; and while the vendors mentioned earlier almost certainly have a module for most every situation, institutions need to be careful to ensure that the technologies that they are bringing into the classroom are being chosen with concern for their educational value.

Dr. Dave Yearwood [11], a professor at the University of North Dakota, states that "success with using classroom technologies can be realized but only when instructors are careful to use such tools in a pedagogically responsible manner." Yearwood's assertion is supported by a recent article in Education World where Johnson [12] makes the statement that while there are many examples of the bad use of technology in education, there are many cases of brilliant uses of technology. Great teachers do not see technology as a crutch, but rather as a propellant. Johnson goes on to say that those teachers who master the use of technology in their curricula are those who have developed the assessment strategies that are necessary to truly evaluate the performance of their technology-enhanced projects. These teachers have developed the necessary skill sets to use technology for their own goals, rather than using technology as a crutch to make up for poor pedagogical practices.

Progressing Beyond Base Knowledge

On an April day in 1838, photographer Louis Daguerre captured a photograph of the Boulevard du Temple, in Paris, and in the process captured what is likely the first photograph of a human subject [13]. Though Daguerre's photograph (see Figure 1) provides a rare glimpse of a seldom-seen period of history, it is perhaps what is not shown in the photograph that is the most fascinating. Photography today has become almost entirely digital, and society has grown increasingly accustomed to digital cameras. A 2013 study showed that about 42% of all mobile users in the U.S. were using smartphones equipped with cameras [14]. A modern-day photographer, who is only familiar with basic point-and-shoot digital cameras, might easily assume that the scene Daguerre captured lacked human life, save for the two shadowy figures present on a sidewalk. Indeed, to a modern photographer only familiar with modern technology, this analysis makes perfect sense and one might wrongly conclude that Paris wasn't nearly so popular in 1838 as it is today.

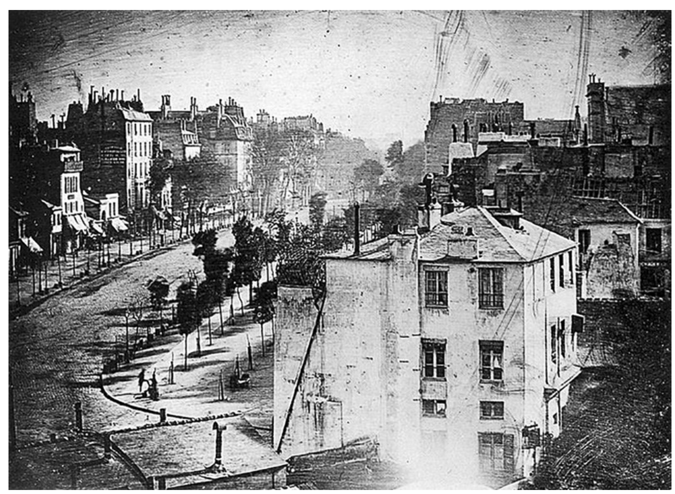


Figure 1. Daguerre's Boulevard du Temple

What many today do not understand is that in Daguerre's time, camera exposures were not measured in thousandths of a second, or even seconds, but rather in minutes. The increased time necessary for exposure was due to the relative insensitivity of the silver iodide plates used by Daguerre in his early photos [15]. Given the length of time necessary to achieve a good exposure, subjects would have had to remain very still for lengthy periods of time for the image to show up during the developing process. This explains why the only two human subjects in Daguerre's photo were individuals who were involved in a process which required holding a position for a sustained length of time, such as having one's boots polished. Though the city street around them was likely bustling with activity, the people and animals that moved through the streets simply moved too fast to be recorded in this historic image [13]. The lesson that can be learned from this historic photograph is relevant in education because all too often technologies are employed in classroom settings that obscure, rather than illustrate, essential fundamental concepts.

Blooms Taxonomy of Educational Objectives, which was named for its originator, Benjamin Bloom, in the 1950s, breaks down educational objectives by ranking them in a hierarchical order, with lower levels such as knowledge at the base and the highest order, evaluation, at the top [16]. The case study described here, involving the use of pinhole cameras, illustrates one approach that has proven effective in moving students beyond the baseline of knowledge into the higher levels of understanding that is essential when teaching critical-thinking skills.

Pinhole Case Study

Explanation of Pinhole Photography

Pinhole photography is all about controlling light. By constructing a light-proof enclosure with a single pin-sized hole of precise size, shape, and proximity to the opposing surface of the enclosure, an image of the outside world can be captured through the hole. Light traveling into the enclosure through that all-important pinhole contacts a photosensitive material located at a carefully calculated position opposite the hole. The material captures a flipped impression of the scene outside the box from the perspective of the pinhole, which is illustrated in Figure 2. Because light travels in a straight line when unobstructed, the pinhole is all the space needed for light to travel through in order to capture a perfectly detailed photograph.

Pinhole photography has been studied for centuries. The great Leonardo da Vinci mentions his use of pinholes as a tool for art and science in his manuscripts [17]. The ability of the pinhole to control just the right amount of light has been useful to many in the fields of science and engineering. In 2005, Webster Cash of the Center for Astrophysics and Space Astronomy at CU-Boulder presented a concept that would essentially become a large pinhole camera in space, used to locate far away and potentially habitable planets. The "starshade," as it was called, would block excess light of surrounding stars and focus only on light coming from distant planets up to 100 light-years away, with enough detail to determine the potential for that planet to harbor life as we know it [18]. The National Aeronautics and Space Administration (NASA) also uses pinhole principles to capture gamma and x-ray signals [19]. Pinhole apertures have and will continue to serve many purposes when controlling the flow of light and other forms of radiation.

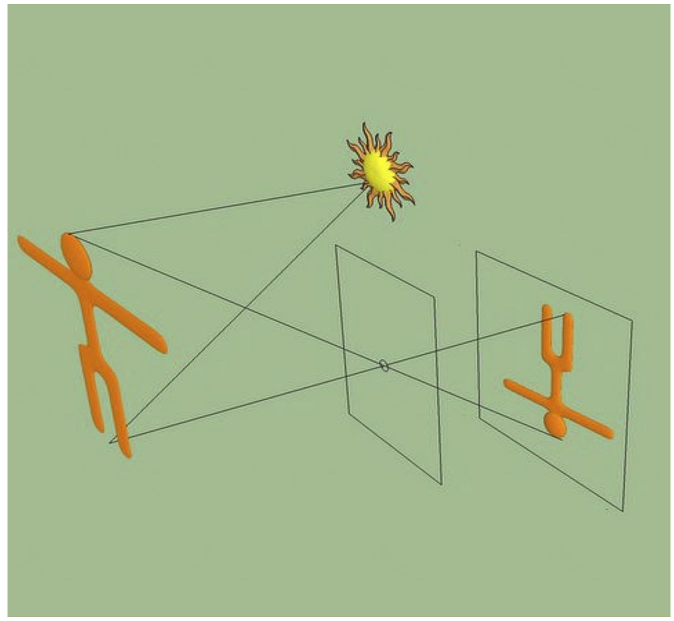


Figure 2. Light Path through Pinhole

Design Considerations

There are several factors involved in creating a successful pinhole photograph including calculations of light intensity and wavelength, exposure time, material sensitivity, distance between the aperture and the photosensitive material, and size of the hole itself. The person generally credited with the discovery of a reliable formula to calculate these factors was Lord Rayleigh, John William Strutt. Sir Rayleigh published his formula in an issue of the *Nature Journal* in 1891 [20]. This formula, shown in Equation (1), states:

$$r = \sqrt{(f\gamma)} \tag{1}$$

where, r is the radius of the aperture; f is the focal length, or distance from the hole to the photo-sensitive surface; and, γ is the wavelength of light.

Since then, many have come up with their own modified formulas, while others swear by Rayleigh's calculations. Whatever method is used, a sharp round hole of the correct size will result in a detailed image when the photo-sensitive material is exposed for the right amount of time, depending on lighting conditions and material sensitivity [20]. Lord Rayleigh's original formula, shown here in Equation (2), has been revised and adapted numerous times over the years, but most modifications follow the format from Lambrecht and Woodhouse [21]:

$$d = k * \sqrt{\gamma} * f \qquad (2)$$

where, d is the aperture diameter; k is a constant; γ is the wavelength of light; and, f is the focal length.

Renner [17], author of *Pinhole Photography: From Historic Technique to Digital Application,* recommends a constant decimal fraction between *-12* and *1*. Depending on the level, or application of the class, the mathematical concepts can be either briefly discussed or can be explored in much greater detail. There are also several published charts available that provide proper aperture sizes and also online pinhole calculators that may be appropriate in some instances, though care should be taken when using these as the underlying principles of pinhole cameras are easily obscured [22].

Explanation of the Student Project

Pinhole cameras have been used successfully in the past to teach engineering-related concepts and are quite suitable for this application due to the ease with which the activity can be scaled up or down to suit the needs of the class. The case study described here was modified from one that was provided by the Integrated Teaching and Learning Program in the College of Engineering at the University of Colorado Boulder. The learning objectives of that study fit perfectly into the curriculum of an undergraduate technology fundamentals course that was the basis of this project [23]. The activity was delivered in six, 50-minute activities over a period of three weeks. The objectives included:

1. Understand the theoretical principles related to light rays and how they apply to the creation of photographic images.
2. Apply the theoretical principles of light rays to create physical prototypes in the form of a pinhole camera and photographic images.
3. Use oral and visual communication to explain the operation of a pinhole camera.

One component of this introductory class, that covers a wide range of topics, was to teach undergraduate technology students about the path of light, its effect on photo-sensitive material, and how those things have evolved into modern technology. A pinhole camera was chosen as having the right balance of simple-to-understand components, potential to engage students, and feasibility, given factors affecting classroom projects. To develop a manageable learning activity, the authors had to consider things like material cost, setup time, level of assembly difficulty, and how to best manage the activity, while allowing students to participate in a genuine hands-on learning experience. During the planning and preparation stages, learning objectives, and how the cameras were to be constructed, were discussed. The authors built prototype pinhole cameras with matt-board, duct tape, and thin brass shim material (see Figure 4), although aluminum beverage cans would have worked as well. A vector template was created to be used with an on-site laser-cutter/engraver. In this capacity, it was determined that using the laser was a good approach. First, it expedited the laborious and time-consuming task of cutting the properly measured shapes into the matt-board (see Figure 3). The precision of the laser allowed for exact copies, thus eliminating variables in hand cutting, which would have resulted in an unnecessary waste of materials and time.

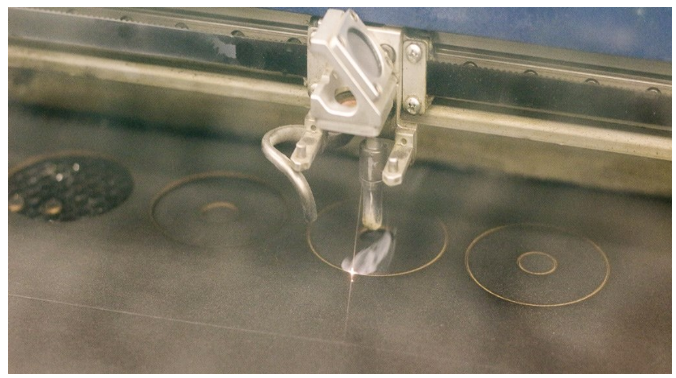


Figure 3. Laser Cutting Matt-Board

The laser was also a demonstration of how controlling light through properly calibrated optics contributes to an advanced technology. Finally, the laser has proven to be safer than other methods that have traditionally been used to produce these cameras and avoided much of the risk associated with razors and power tools. In addition, use of the laser was leveraged into a teachable moment where some principles of the pinhole project could be contextualized through demonstrating how the laser cut the box material, another example of the manipulation of light. As the box material was not uniform in color, and could not allow the reflection of any light that entered it through the pinhole without risking the quality of the image, the matt-board was pre-painted flat black. To illustrate the difference that this made in the finished products, students were shown examples of images that had been exposed in cameras that were not given this particular treatment. At this point, the preparation was complete and the pieces were ready to be assembled. While this was being done, the authors introduced the pertinent topics to students in order to build a foundation of understanding before the cameras were to be constructed and used.

Student Preparation for the Activity

The agreed-upon strategy for student preparation was a combination of pre-assigned on-line resource tutorial videos, followed by the use of class discussion. Pre-recorded video usage, as stated by Ronchetti [24], “allows a much higher level of interactivity among students and teacher, and doubles the time students spend with the teacher (half of this time being virtualized by videos).” Ronchetti believes the efforts of the instructor should be concentrated on being more interactively involved with students via the flipped classroom approach promoting a more interesting role the students will play in their experiential learning experience. This approach has also proven to be desirable with the reduced contact hours that many programs are beginning to experience.

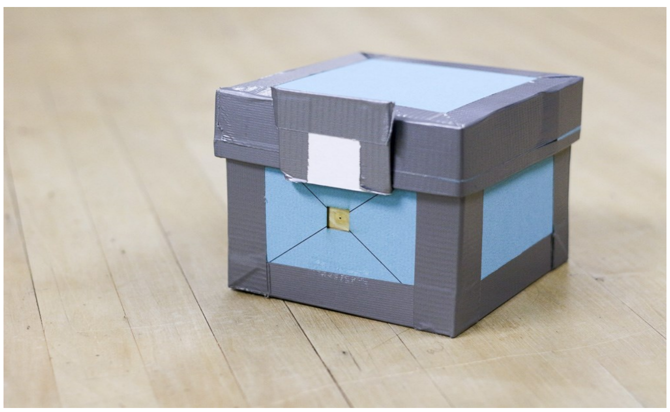


Figure 4. Prototype Pinhole Camera

Camera Assembly and Use Activity

With all of the required parts at hand, students constructed their own pinhole camera boxes using the same matt-board material as the prototype (see Figures 5-8). They were supplied with duct tape and shown how they needed to fold the flat material along lines laser-etched into them. An emphasis was placed on neatness and precision, as to avoid potential light-leaks.

Figure 5. Students with Assembled Matt-Board Boxes

Figure 6. Students Creating Pinhole in Brass Shim

Figure 7. Pinhole Material and Tools

Figure 8. Student Pair Assembling Matt-Board Box

Students were then given pre-cut brass shims, one square inch by 0.005 inches thick. With that, they were supplied with a number-two pencil that had a sewing needle inserted backwards into the pencil's eraser, leaving about one half of an inch of exposed needle point (see Figure 5). While pressing down with even pressure into the center of the brass shim with the needle-end of the pencil, the students employed a drilling motion to slowly work into the material. Once the backside of the brass dimpled slightly, they used fine-grit sandpaper on the dimpled area so as to thin the brass only where the needle was beginning to penetrate. The process took a steady hand and careful eye, as they knew the quality and size of the hole was required for a successful photograph.

To check their work, students inserted their pinhole shims into the film carrier of a photographic enlarger and focused the light shining down through the pinhole. The light took the shape of the hole and exposed any asymmetry or jagged edges. Once they verified the integrity of their pinholes, they secured them into their boxes with dark tape and fashioned small flaps to cover the pinholes from the outside so that they could control exposure time. They were then free to load the cameras with a four-by-eight sheet of photo-sensitive paper and venture outside to find a subject to photograph. The photo paper used required a wet-process darkroom to develop, but could have been done with instant-type film, or even digital cameras. Students demonstrated enthusiasm for the process, as evidenced by how quickly they went about their tests during the short class period. This was encouraging as it demonstrated that a good level of engagement with the students had been achieved.

While there was success in capturing photos with the matt-board pinhole cameras, they lacked durability and required excessive amounts of tape to keep them light-proof. Another material was needed to improve strength and light-blocking properties. A supply of quarter-inch plywood was chosen to meet those needs. Not only was it strong and light, but the laser cutter could easily cut through it. A finger-jointed pattern was used at the edges of the box that met, and students used wood glue to assemble the pieces (see Figures 9 and 10). They placed vertical strips of the material at the inside corners in an attempt to block any light coming through the glued joints. Some pieces had warped slightly, or simply did not fit together tightly enough to completely block light from entering, so laser-cut felt swatches were glued in place for a final layer of light protection.

The same type of brass shims were used to fashion new pinholes and again secured with dark tape to the inside of the box behind a pre-cut porthole. Students took far more pride in constructing these wooden pinhole cameras than they did with the matt-board versions, which is an important aspect of meaningful learning [10]. Photo-sensitive paper was again loaded into the boxes under darkroom conditions and then taken outside with the pinhole covered while they set up their shots (see Figure 11).

Figure 9. Students Assembling Plywood Boxes

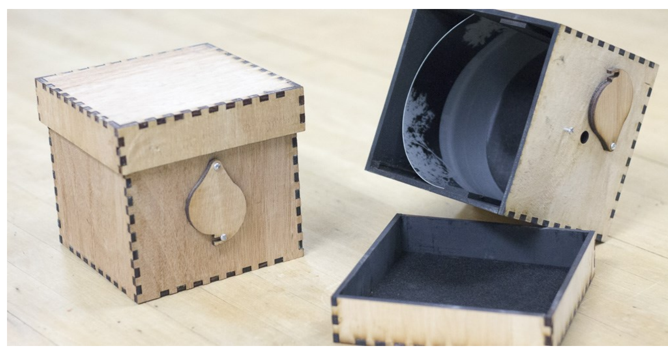


Figure 10. Finished Plywood Pinhole Cameras

Figure 11. Students Preparing to Shoot with Their Cameras

All of the students were able to get some kind of recognizable photograph out of their cameras. Most students took several tries to get the timing right in order to expose their photographs properly (see Figures 12-14). Some photographs were of much higher quality than the rest, likely due to the precision of the pinhole and quality of camera construction. Indirect observations from the faculty members conducting the lab were used to partially assess the activity; these observations suggested that the students all generally seemed to enjoy the results of their work.

Figure 12. Student Photo 1

Figure 13. Student Photo 2

Figure 14. Student Photo 3

Safety Consideration

The pinhole camera project conducted did require certain considerations for the safety of everyone involved; however, the use of the laser greatly mitigated the safety issues inherent in earlier projects of this type involving conventional power tools such as the table saw. For safety, as well as clarity, students gathered in small groups to watch demonstrations of the laser cutter at work. As is standard procedure in the manufacturing lab where this activity took place, all students wore safety glasses and were warned to be aware of their surroundings while in the lab. The laser used had specific safety controls including a safety cut-off switch to interrupt power to the laser if the glass lid is opened while in operation. Proper ventilation proved to be a necessity when working with these materials as many were flammable and created fumes that needed to be vented to the outside.

Conclusions

Though there are many technologies that can be successfully employed in engineering curricula, not all are appropriate for every stage of the learning process. Just as in Blooms Taxonomy, learning should start at the lower levels and gradually be increased in complexity [16]. Many technologies hide their inner workings and, in the process, make it more difficult for some students to grasp fundamental concepts. It is this lack of connection with the material that studies have shown result in students leaving engineering programs; but, by incorporating simpler, perhaps older, technologies like the pinhole camera discussed above into the classroom, students are given the opportunity to develop a better understanding of these fundamental concepts and, as a result, may be more likely to remain in engineering programs. The activity lends itself to being easily scaled up or down to accommodate different levels of learning; but, even at the most basic level, this activity provides an exceptional hands-on learning experience where students can absorb the principles of photography. At more advanced levels, students can be taught important scientific and mathematical concepts, and the pinhole provides an excellent platform for testing multiple variables. Since many programs do not contain darkroom facilities, it may be desirable to experiment with the use of digital pinhole photography. This was experimented with other parts of this current program with excellent results and could prove to be a good medium for a more advanced study of the topic. For digital applications, most digital single-lens reflex cameras (DSLR) should prove suitable for a pinhole conversion and the camera can be easily returned to its original configuration following the experiment.

The modifications necessary for this conversion are only applied to the body cap, which can be purchased inexpensively from a variety of sources and the formulas mentioned earlier, or modified versions of these can be used to determine the ideal aperture size for the cap, based on the specific focal length of the camera. The convenience of the digital platform makes it easy to experiment with different ISOs, exposure times as well as aperture sizes (see Figure 15 and 16).

Figure 15. Testing DSLR Pinhole Cap

Figure 16. Photograph from DSLR Pinhole Cap

We have all heard the old proverb that starts out as “Give a man a fish” and yet oftentimes in education we ignore that ancient bit of advice by misusing technology when we allow it to do too much, essentially starving our students by depriving them of the opportunity for a rich learning experience. By approaching technology education from a more simplistic angle using approaches that illustrate as well as reinforce basic principles and concepts, instead of simply giving them away, we are not depriving our students, nor are we becoming luddites, we are instead essentially “teaching them to fish.”

References

[1] Brockman, J. (2015). The technium: A conversation with Kevin Kelly. Retrieved February 20, 2015, from Edge: https://edge.org/conversation/the-technium

[2] Idrus, R. M. (2008). *Transforming engineering learning via technogogy*. 5th IASME International Conference on Engineering Education, 33-38.

[3] Kelly, K. (2011). *What technology wants*. New York: Viking.

[4] Arthur, B. W. (2009). *The nature of technology: What it is and how it evolves*. London: Clays Ltd, St Ives.

[5] Wolf, W. (1999, November-December 19-2). *The academical village in the internet age*. (A. Bromley, Interviewer)

[6] Lightman, A., Sarewitz, D., & Desser, C. (2003). *Living with the genie: Essays on technology and the quest for human mastery*. Washington DC: Island Press.

[7] Koebler, J. (2012, April 19). Experts: 'weed out' classes are killing STEM achievement. Retrieved February 20, 2015, from U.S. News: http://www.usnews.com/news/blogs/stem-education/2012/04/19/experts-weed-out-classes-are-killing-stem-achievement

[8] Knight, D. W., Carlson, L. E., & Sullivan, J. F. (2007). Improving engineering student retention through hands-on, team based, first-year design projects. *31st International Conference on Research in Engineering Education*, (pp. 1-13). Honolulu.

[9] Loftus, M. (2013, September 30). College engineering programs focus on hands-on learning. Retrieved February 19, 2015, from U.S. News: http://www.usnews.com/education/best-colleges/articles/2013/09/30/college-engineering-programs-focus-on-hands-on-learning

[10] Johnson, A., & Yearwood, D. (2014). The metallurgical challenge: A meaningful learning activity. *Technology Interface International Journal*, *14*(2), 54-62.

[11] Yearwood, D. N. (2005). Is your selection of content delivery vehicles closely aligned with your pedagogical goals? *Essays in Education*, *14*.

[12] Johnson, D. (2015). *Seven brilliant things teachers do with technology*. Education World .

[13] Weingus, L. (2014). *Picture of guy getting his shoes shined is thought to be the first photograph of a human being*. Huffington Post Arts & Culture.

[14] Sarwar, M., & Soomro, T. R. (2013). Impact of smartphone's on society. *European Journal of Scientific Research*, *98*(2), 216-226.

[15] Daniel, M. (2004). *Daguerre (1787-1851) and the*

invention of photography. Retrieved February 20, 2015, from The Metropolitan Museum of Art: http://www.metmuseum.org/toah/hd/dagu/hd_dagu.htm
[16] Bloom, B. S., Engelhart, M. D., Furst, E. J., Hill, W. H., & Krathwohl, D. R. (1956). *Taxonomy of educational objectives: The classification of educational goals handbook 1 cognitive domain*. New York: Longman.
[17] Renner, R. (2008). *Pinhole photography : from historic technique to digital application* (4th ed.). Amsterdam: Focal Press.
[18] Dunbar, B. (2005, March 10). Alien planets to pose for giant pinhole camera in space. Retrieved February 20, 2015, from NASA: http://www.nasa.gov/vision/universe/newworlds/new_worlds_imager.html
[19] NASA/Marshall Astronomy: MIXE2 instrument. (n.d.). Retrieved February 20, 2015, from NASA Science News: http://science.nasa.gov/science-news/science-at-nasa/balloon/mixe2/
[20] Lord Rayleigh, S. (1891). Some applications of photography. *Nature*, *44*(1133), 249-254.
[21] Lambrecht, R., & Woodhouse, C. (2013). *Way beyond monochrome: Advanced techniques for traditional black & white hybrid printing*. Amsterdam: Focal Press.
[22] Pinhole photography and camera design calculators. (n.d.). Retrieved February 18, 2015, from Mr. Pinhole: http://www.mrpinhole.com/index.php
[23] Hands-on activity: Create a pinhole camera. (n.d.). Retrieved February 20, 2015, from Teach Engineering: https://www.teachengineering.org/view_activity.php?url=collection/cub_/activities/cub_soundandlight/cub_soundandlight_lesson8_activity1.xml
[24] Ronchetti, M. (2010). Using video lectures to make teaching more interactive. *International Journal of Emerging Technologies in Learning*, *5*(2), 45-48.

Biographies

ALEX JOHNSON is an assistant professor in the Department of Technology at the University of North Dakota. He earned his B.S., M.S. (Industrial Technology, 2001), and Ph.D. (Teaching and Learning, 2010) from the University of North Dakota. Dr. Johnson's research interests include engineering and technology education, manufacturing processes, and small wind turbine technology. Dr. Johnson may be reached at ajohnson@business.und.edu

CINDY L.W. ENGLISH is an instructor for the School of Entrepreneurship at the University of North Dakota. Cindy earned her B.S. from Bemidji State University (Technical Illustration / Graphic Design, 1988) and her MFA degree from Marywood University (Art Direction and Design, 1999). She has also worked a combined 25 years in manufacturing in a variety of engineering capacities. Her current scholarship interests focus on the integration of graphic and packaging design applications in the industrial setting. Ms. English may be reached at cindy.english@business.und.edu

LOGAN TONG is a graduate student at the University of North Dakota working on his M.S. degree in Industrial Technology. Tong earned his B.S. (Graphic Design Technology, with a Certificate of Entrepreneurial Studies, 2012) from the University of North Dakota. Mr. Tong's research interests involve technology-integrated learning and smartphones. A native of Grand Forks, ND, Mr. Tong plans to go on to work towards a Ph.D. in teaching and learning, and would eventually like to teach at a research university. Mr. Tong may be reached logan.tong@my.und.edu

A Systematic Weighted Factor Approach for Curriculum Design in Engineering and Technical Degree Programs

Kevin M. Hubbard, Missouri State University; Martin P. Jones, Missouri State University

Abstract

Curriculum revision and new program design efforts are typically started partly as a result of constituent input, such as that from industrial advisory boards, potential employers of graduates, recent employers of graduates, and alumni. This process is often performed on an ad-hoc basis with various constituents who express conflicting opinions. In this study, the authors developed a more formalized approach to the decision-making process and applied it to curriculum revision by using a weighted-factor index method in order to remove much of the subjectivity. A practical example of this method, based upon the redesign of an academic program at Missouri State University, is presented here. A sensitivity analysis was performed on the decision-making process in order to determine the extent to which changes in weight assignment affected the final conclusion. It was found that by using this methodology, subjectivity may be minimized and rational decisions may be made during the conflict resolution phase of curriculum design or redesign.

Introduction

Many higher education programs perform curricular revisions on a regular or semi-regular basis. In addition, new programs are created and launched, although typically less frequently. Curriculum revision and new program design efforts are typically undertaken, at least in part as a result of constituent input. Constituents include industrial advisory boards, potential employers of graduates, recent employers of graduates, and alumni. Often, however, the design of a curricular revision or the creation of an entire new educational program is performed on an ad-hoc basis. Even when significant constituent input exists, various constituents often express conflicting opinions.

When conflicting opinions exist, it falls to the faculty of the program in question to make the ultimate decision as to which of those conflicting opinions prevails. It is this decision-making process that may be performed using a very informal, ad-hoc approach. One study of Canadian institutions of higher education classified the decision-making processes employed in curriculum review and design efforts as either an "administrative fiat," authority delegated to a committee of faculty members; a "democratic process"; or, a "full faculty involvement" [1]. None of the decision-making processes employed, however, incorporated a formal, mathematical or semi-mathematical, non-subjective approach.

In this study, a more formalized approach to the decision-making process was developed. The weighted factor index method has long been employed as a decision support tool to remove much of the subjectivity associated with decision making [2]. This method removes much of the subjectivity involved in competing opinion resolution and results in much more objective decisions. In addition, a set of examples based upon the design of a new Mechanical Engineering Technology program at Missouri State University is presented here.

Factors Influencing Curricular Design

Most curricular design efforts, particularly in engineering and technical degree programs, begin with the identification at some level of the desirable attributes of a graduate of the program [3]. Having identified these attributes, a number of factors may be formulated, which may have an influence on the design of the program's curriculum. These may include (but are not limited to):

- Industrial Relevance: How relevant is the planned educational experience and the content of the educational program to the needs of industry? Industrial relevance is typically one of the primary objectives of technical and engineering programs [4].
- Emulation of the Industrial Experience: How closely will the educational experience emulate the industrial experience? This question is particularly relevant in the design of laboratory content. It is typically desirable to ensure that laboratory experiences, particularly for students in engineering and technical degree programs, resemble the experiences which the graduate is expected to encounter in an industrial setting. Fur-

thermore, industrial experience among engineering technology faculty is desired [5].

- Mathematical Rigor: At what level should the rigor of the mathematical content of the degree program be set? Mathematics courses often serve as gateways, ensuring that only high-quality students matriculate to upper-division courses. Some educators see mathematical rigor as the dividing line between engineering programs and engineering technology programs [6]. It is possible, however, to incorporate mathematical content to the extent that the industrial relevance of the degree program experiences a negative impact, due to limitations on the number of credit hours which may be required.
- Employer Demand: What is the demand among potential employers for graduates of the new or newly revised degree program? Employers may be incorrectly seeking skills and knowledge from engineering graduates that are more aligned with those skills and knowledge acquired by engineering technology graduates [7].
- Competition from Degree Programs with Similar Content: Do programs, which are similar to the degree program being designed or contemplated, exist? If so, what is the level of market saturation for graduates of the new or newly redesigned program?
- Academic Relevance: Are graduates prepared for research or graduate school? The academic relevance and industrial relevance factors are often in competition with one another, as noted in the 1954 Grinter report commissioned by the American Society for Engineering Education [8]. Over a period of decades, the trend in engineering and technical education often has been to emphasize theoretical knowledge and to de-emphasize, at least to some extent, hands-on learning. Industrial constituents, however, increasingly value hands-on knowledge, as well as theory-based knowledge [9]. Prospective students value experiential learning as well [10]. The value placed on experiential learning by prospective students is gender independent [11].
- Resources: What resources are required to deliver the new and/or modified program content? Resources may include physical resources (laboratories, equipment, classrooms, computing hardware, and others) or intellectual resources (faculty, software, library resources, and others). This can be an ongoing concern for engineering technology degree programs requiring a high ratio of hands-on versus lecture-based delivery [5].
- Institutional/Cultural Compatibility: Are the vision and mission associated with the new or newly redesigned program consistent and compatible with the vision and mission of the academic unit in which the program will be housed and with those of the college or university?
- Laboratory/Lecture Mix: What are the proportions of lecture/theory-based work and laboratory-based work? For engineering technology programs, hands-on experience is seen as an integral part of the educational strategy [12].
- Delivery Mode: Will the program be delivered in a traditional in-person mode, an online mode, blended mode, or some other mode? Increasingly, this question has gained in importance. Limitations with regard to physical space, as well as limited budgets for physical expansion, have focused the attention of many programs in higher education on online education, as a means to meet demand without requiring expensive building projects [13]. Many students value the convenience and flexibility of online courses. Research indicates that students' overall experience with online courses is very positive. Students also indicate, however, that the quality of interaction and feedback, lengthy reading assignments, and issues with technology are problems that can limit the value of online education [14]. An institutional approach to online learning that includes training, support services, and proper planning and coordination of programs is necessary for a successful online or blended strategy [15].
- Size of the Target Audience: What is the student demand for a program of the nature of the one being designed or re-designed?
- Accreditation Factors: What is the desirability of the contemplated change from an accreditation perspective?
- Program Robustness: What is the level of flexibility of the curriculum? Are sufficient electives or concentration areas incorporated in the plan of study [16]?

While this list of factors is not exhaustive, it does provide some insight into the types of issues that may inform decisions with regard to curriculum design. Often, these factors are in conflict with one another. For example, industrial relevance may be viewed as a highly positive (desirable) factor. However, in order to increase industrial relevance, it may be necessary to incorporate a close emulation of the industrial experience in the curriculum. This requirement may, in turn, be associated with a large requirement for new laboratory and equipment resources. In situations where budgets are limited, these requirements may constitute a negative factor. Many conflicts of this type may arise, leading to the need for a decision support tool to assist in the conflict resolution phase of curriculum design. Formal methods of the type described here bring structure to the process and add value both from the perspective of the administration and from the perspective of the faculty and constituents [17].

A Systematic Weighted Factor Approach for Curriculum Design Decisions

As a general decision-making framework, the weighted factor index method is proposed here [2]. The factors to be employed in curriculum design decisions are often of differing orders of magnitude and expressed in differing units. Industrial relevance may be expressed using, for example, a one-to-five Likert scale, or as the average of the result from a question on a survey deployed to industrial constituents, while the need for new or additional laboratory resources may be expressed in units of tens or hundreds of thousands of dollars. For purposes of comparison, these values must be normalized so that their magnitudes are of the same order and rendered dimensionless. This is accomplished through the use of Equation (1) or Equation (2):

$$\beta_{ij} = \frac{\text{value of factor i for candidate j}}{\text{largest candidate factor value under consideration}} \quad (1)$$

$$\beta_{ij} = \frac{\text{smallest candidate factor value under consideration}}{\text{value of factor i for candidate j}} \quad (2)$$

where, β_{ij} is scaled factor i for candidate option j.

Equation (1) is employed when large factor values are desirable and Equation (2) is employed when small values of the factor being considered are desirable. Once factors have been selected and scaled using either Equation (1) or Equation (2), Equation (3) is employed to combine all scaled factors to arrive at a weighted factor index:

$$\gamma_j = \sum_{i=1}^{n} W_i \beta_{ij} \quad (3)$$

where,

γ_j = performance index (also known as the weighted factor index) for alternative j;

W_i = weighting factor for scaled factor i (a measure of the importance associated with the factor);

n = the number of factors upon which the decision is to be based.

If Equations (1) and (2) are applied correctly, then decision alternatives (options) with large γ_j values are superior to those with small γ_j values. For the purposes of weighting factor assignment, it is good practice to employ Equation (4):

$$\sum_{i=1}^{n} W_i = 1 \quad (4)$$

Using this approach, all factors to be employed in making the decision are scaled to lie in the range $0 \le \beta_{ij} \le 1$. In this fashion, differences in relative magnitude from one factor type to another, which are typically due to unit considerations, are normalized to the same scale. As a result, scaling is performed only by the weighting factor (relative importance) applied to the factor or characteristic under consideration. Once a weighted factor index γ_j has been calculated for each curricular design option under consideration, that option exhibiting the largest γ_j value, may be concluded to be the superior choice.

An Example of the Weighted Factor Index Method in Curriculum Design

The Technology and Construction Management Department at Missouri State University initiated a curriculum review and revision process for its Bachelor of Science program in Technology Management beginning in August, 2013. The program, as it existed at that time, was heavily weighted toward "enterprise skills," including:

- Personnel Management and Supervision
- Production Management
- Financial Management
- Project Management
- Safety Management
- Accounting

These topics comprised approximately 24% of the credit hours required to complete the existing degree. The mathematical rigor and technical content of the degree program had been reduced over a period of more than a decade. A series of discussions was held with regional representatives from industry with the objectives of determining the characteristics of successful program graduates, the employment potential for graduates of the existing program, and the employment potential for graduates of a redesigned degree program. A consensus developed regarding the following curriculum criteria:

- There was a need for increased mathematical rigor in the degree program.
- The enterprise skills component of the program should not be completely eliminated.
- The technical content of the program should be significantly increased, particularly with regard to engineering design content and content in the area of automation, sensing, and control.

Based on these discussions, as well as an analysis of existing, similar programs in the state and each of its eight neighboring states, the existing Technology Management B.S. degree program was transformed into a newly revised program leading to the Bachelor of Science in Mechanical Engineering Technology. Numerous curriculum design decisions were made in light of the recommended curriculum criteria from industry as above stated. One such decision dealt with the amount of enterprise skill content which should remain in the newly redesigned curriculum. In this example, the following factors were employed:

- Industrial Relevance (evaluated using a 1-5 Likert scale)
- Academic Relevance (evaluated using a 1-5 Likert scale)
- Intellectual Resources (evaluated using an estimated required dollar amount)
- Institutional/Cultural Compatibility (evaluated using a 1-5 Likert scale)
- Accreditation Factors (evaluated using a 1-5 Likert scale)

At this stage of analysis, it was unclear whether the inclusion/exclusion of enterprise content in the revised program would require additional intellectual resources. The options evaluated were:

- Option 1: Include no enterprise content in the newly redesigned curriculum.
- Option 2: Include enterprise content comprising approximately 5% of the degree program.
- Option 3: Include enterprise content comprising approximately 10% of the degree program.
- Option 4: Include enterprise content comprising approximately 15% of the degree program.

The following variables were employed:

IR_j = the value of industrial relevance for option j
AR_j = the value of academic relevance for option j
ICC_j = the value of institutional/cultural compatibility for option j
ACR_j = the value of desirability (from an accreditation perspective) for option j
β_{IRj} = scaled factor of industrial relevance for option j
β_{ARj} = scaled factor of academic relevance for option j
β_{ICCj} = scaled factor of institutional/cultural compatibility for option j
β_{ACRj} = scaled factor of accreditation desirability for option j
W_{IR} = weight (importance) assigned to industrial relevance
W_{AR} = weight (importance) assigned to academic relevance
W_{ICC} = weight (importance) assigned to institutional/cultural compatibility
W_{ACR} = weight assigned to accreditation desirability

Before beginning the analysis, departmental faculty members were consulted and the following weights were assigned:

W_{IR} = 0.30
W_{AR} = 0.25
W_{ICC} = 0.15
W_{ACR} = 0.30

Under this scenario (Scenario 1), industrial relevance and the desirability (from an accreditation perspective) of any curricular changes were weighted most heavily, followed by academic relevance and institutional/cultural compatibility of the contemplated changes. At this stage of the analysis, additional intellectual resources were not considered. For those factors enumerated using a Likert scale, a value of 5 was defined as high; a value of 4 was defined as relatively high; a value of 3 was defined as moderate; a value of 2 was defined as relatively low; and, a value of 1 was defined as low. Table 1 details the Likert scale values assigned to each factor.

Table 1. Likert Scale Values by Option and Factor

Option	IR	AR	ICC	ACR
1	2	4	2	3
2	3	3	3	3
3	4	3	3	3
4	4	2	4	2

Table 2 details the scaled factor values calculated for each option and factor. Note that since a high value for each factor was desirable, Equation (1) was employed in the calculation of each value presented in Table 2.

Table 2. Scaled Factor Values by Option

Option	β_{IR}	β_{AR}	β_{ICC}	β_{ACR}
1	0.50	1	0.5	0.75
2	0.75	0.75	0.75	0.75
3	1.0	0.75	0.75	0.75
4	1.0	0.5	1	0.5

The β_{IR} value for Option 1 is presented as an example. A larger value of industrial relevance was desirable and, as a result, Equation (1) was employed. The largest industrial relevance value, as presented in Table 1, was 4, and the industrial relevance value for Option 1 was 2. Then:

$$\beta_{IR\,1} = \frac{2}{4} = 0.50$$

The weighted factor index for Option 1 could then be calculated:

$$\gamma_1 = 0.30(0.50) + 0.25(1) + 0.15(0.50) + 0.30(0.75) = 0.70$$

Table 3 presents the weighted factor index values calculated for each option. The options, in order of superiority, were Option 3 (10% enterprise content), Option 2 (5% enterprise content), Option 4 (15% enterprise content), and Option 1 (no enterprise content). The assignment of different weights may change the result of the calculation. Suppose the weighting employed were changed to:

$W_{IR} = 0.20$
$W_{AR} = 0.50$
$W_{ICC} = 0.15$
$W_{ACR} = 0.15$

Table 3. Weighted Factor Index Values

Option	γ_j
1	0.70
2	0.75
3	0.83
4	0.73

Then the results presented in Table 4 could be reached. Here, a much greater emphasis was placed on academic relevance, while the importance associated with each of the other factors was reduced. Under this scenario (Scenario 2), the options, in order of superiority, were Option 3 (10% enterprise content), Option 1 (no enterprise content), Option 2 (5% enterprise content), and Option 4 (15% enterprise content). Note that under both Scenario 1 and Scenario 2, the pursuit of Option 3 was indicated. As a result, it may be concluded that the sensitivity of this decision with regard to changes in the relative weights of industrial relevance and academic relevance is relatively small.

A third scenario was evaluated. In this scenario (Scenario 3), it was assumed that additional intellectual resources in the form of adjunct faculty would be required to accommodate additional sections of out-of-department enterprise skills-related courses. If Option 1 were pursued, then it would be possible that an annual additional expenditure of approximately $15,000 would be incurred for adjunct faculty to serve as instructors for in-department courses, since additional courses (not enterprise skills courses) would be offered by the department. If Option 2 were pursued, no additional funds would be required for in-department adjunct faculty, but funding at a level of approximately $7,500 would be required to provide out-of-department adjunct faculty for additional sections of enterprise skills-related courses. If Option 3 were pursued, $15,000 of out-of-department adjunct faculty funding would be required. If Option 4 were pursued, out-of-department adjunct faculty requirements were estimated at $22,500. Table 5 details additional intellectual resource (adjunct faculty) funding as well as the scaled factor values associated with additional intellectual resources under each option. Note that the subscript AF was used to denote adjunct faculty funding.

Table 4. Weighted Factor Index Values with a Modified Weighting Scheme

Option	γ_j
1	0.79
2	0.75
3	0.80
4	0.68

Table 5. Intellectual Resource Funding Estimates and Scaled Factor Values

Option	Intellectual Resource Funding	β_{AF}
1	$15,000	0.50
2	$7,500	1.0
3	$15,000	0.50
4	$22,500	0.33

Since a smaller expenditure of funds was desirable, the scaled factor values delineated in Table 5 were calculated using Equation (2). The calculation of β_{AF1} for Option 1 is presented as an example. The smallest required funding amount presented in Table 5 is $7,500 (on an annual basis), while the funding required for Option 1 is $15,000. As a result:

$$\beta_{AF1} = \frac{\$7{,}500}{\$15{,}000} = 0.50$$

Table 6 presents the weighted factor index values calculated under Scenario 3. Under this scenario (Scenario 3), the options, in order of superiority, were Option 2 (5% enterprise content), Option 3 (10% enterprise content), with Option 4 (5% enterprise content), and Option 1 (no enterprise content) being equally undesirable. Under this scenario, the inclusion of monetary considerations associated with the potential need for additional adjunct faculty resulted in the emergence of Option 2 as the most desirable option. Since Option 3 was most desirable under Scenarios 1 and 2, and was ranked as second most desirable under Scenario 3, the selection of this option was indicated for inclusion in the newly redesigned Mechanical Engineering Technology curriculum at Missouri State University.

Table 6. Weighted Factor Index Values Including Intellectual Resource Funding Estimates

Option	γ_j
1	0.63
2	0.83
3	0.74
4	0.63

Conclusion

In this paper, the use of the weighted factor index method as a decision support tool for curriculum design choices was presented and discussed. Using this methodology, subjectivity may be minimized and rational decisions may be made during the conflict resolution phase of curriculum design or redesign. This methodology is easily customized to include factors and considerations on a situation-specific basis. In addition, a practical example taken from the redesign of an academic program at Missouri State University was presented. The effects of inclusion/exclusion of various factors in the decision-making process, as well as changes in the relative importance associated with each factor, were illustrated. It should be noted that subjectivity was present in the method described here during the weight-assignment phase of the analysis. It is recommended that at least an informal sensitivity analysis, such as that presented in this paper, be employed to determine the extent to which changes in weight assignment affect the final conclusion of the analysis. In addition, it should be noted that while the method presented here is useful with regard to setting general directions for curriculum design, it is not easily employed to make specific curriculum choices with regard to the selection of one course over another or the detailed content of a particular course.

No discussion was presented in this paper regarding the implementation of the curricular changes determined using the systematic weighted factor approach. The transition phase of new program implementation, during which an old degree program may be phased out as a new program is phased in, may present complex challenges. Further work may be merited in order to formulate rational approaches to this problem as well.

References

[1] Cole, A. (2000). Toward a Preliminary Understanding of Teacher Education Reform in Anglophone Canada. *McGill Journal of Education, 35*(2), 139-155.

[2] Dieter, G. E., & Schmidt, L. C. (2012). *Engineering Design* (5th ed.). New York, NY: McGraw-Hill.

[3] DeLyser, R. R., Rosa, A. J., Mirth, J., & Kim, J. (1996). Undergraduate Engineering Curricula Revision at the University of Denver. *Proceedings of Frontiers in Education*, (pp. 891-894). Salt Lake City, UT.

[4] Cecil, J., (2004). Innovation in Information Based Manufacturing Engineering Education. *Proceedings of the 2004 American Society for Engineering Education Annual Conference & Exposition*.

[5] Barbieri, E., & Fitzgibbon, W. (2008). Transformational Paradigm for Engineering and Engineering technology education. *Proceedings of the 2008 IAJC-NAIT-IJME International Conference*, Paper #023, (pp. 17-19). Nashville, TN.

[6] Williams, P. J. (2010). Technology Education to Engineering: A Good Move?. *Journal of Technology Studies, 36*(2).

[7] Smith, R. R., Jones, M. P., & Callahan, R. N. (2008). Manufacturing Engineer Manufacturing Technologist: Exploring the Similarities and Differences. *Technology Interface International Journal, 9*(1).

[8] Ungrodt, R. J. (1987). Engineering technology, the early years. *ASEE Annual Conference Proceedings*. Washington, D.C.

[9] Metcalf-Turner, P., & Fischetti, J. (1996). Professional Development Schools: Persisting Questions and Lessons Learned. *Journal of Teacher Education, 47* (4).

[10] Esmaeili, M., & Eydgahi, A. (2014). The Effects of Undergraduate Project-Based Courses on Student Attitudes Toward STEM Classes. *International Journal of Engineering Research and Innovation, 6*(2), 66 -72.

[11] Michaeli, J. G., Jovanovic, V., Popescu, O., Ana Djuric, A., & Yaprak, E. (2014). An Initial Look at Robotics-Based Initiatives to Engage Girls in Engineering. *Technology Interface International Journal, 14*(2), 12-18.

[12] Sergeyev, A., & Alaraje, N. (2013). Traditional, Blended, and Online Teaching of an Electrical Machinery Course in an Electrical Engineering Technology Program. *Technology Interface International Journal, 13*(2), 31-38.
[13] Karber, D. J. (2001). Comparisons and Contrasts in Traditional Versus On-Line Teaching in Management. *Higher Education in Europe, 26*(4), 533-536.
[14] Walker, E. C., & Kelly, E. (2007). Online instruction: Student Satisfaction, Kudos, and Pet Peeves. *The Quarterly Review of Distance Education, 8*(4), 309-319.
[15] Callahan, N., Jones, M., & Bruce, R. (2012). Best Practices and Success Factors in On-Line Education: A Comparison with Current Practice in Technology-Based Programs. *Technology Interface International Journal, 13*(1), 36-44.
[16] Chen, J. C., & Zhang, J. Z. (2010). Case Study: Applying QFD in a Graduate Curriculum Design for an Industrial Engineering Technology Program. Try Academics!. *Technology Interface International Journal, 11*(1), 66-70.
[17] Ahmed, M. S. (2012). Value of Formal Project Management to Automotive Employees. *International Journal of Modern Engineering, 13*(1), 27-35.

Biographies

KEVIN M. HUBBARD is an Assistant Professor of Technology and Construction Management at Missouri State University. He earned his B.S. degree (Aerospace Engineering, 1991) from the University of Missouri – Rolla, M.S. (Engineering Management, 1993) from the University of Missouri – Rolla, and Ph.D. from the University of Missouri – Rolla (Engineering Management, 1996). Dr. Hubbard is currently teaching at Missouri State University. His interests include automation and device control, manufacturing systems, device design, and process optimization. Dr. Hubbard may be reached at KHubbard@MissouriState.edu

MARTIN P. JONES is an Associate Professor of Technology and Construction Management at Missouri State University. He earned his B.S. degree (Physics, 1981) from the University of Maryland Baltimore County, M.S. (Materials Science & Engineering, 1984) from the Johns Hopkins University, and Ph.D. (Materials Science and Engineering, 1987) from the Johns Hopkins University. Dr. Jones is currently teaching at Missouri State University. His interests include scanner technology, nondestructive evaluation, manufacturing processes, and quality assurance. Dr. Jones may be reached at MartinJones@MissouriState.edu

Perceptions toward STEM Careers: A Gender Study in the Electrical Engineering Department at Qatar University

Nasser Alaraje, Michigan Technological University; Aleksandr Sergeyev, Michigan Technological University;
Mohammed Sayer Elaraj, Alaqsa University

Abstract

Investing in education, especially at early ages, plays a crucial role in the future of the Qatar economy. Given the current shortage of Qatari student interest in STEM education, and the undersupply of a trained STEM workforce, increasing attention has been paid to developing innovative tools for improved teaching of STEM education to attract both genders to STEM education.

While female students in STEM education are considered underrepresented and are outnumbered by male students in the U.S., the case is different in the State of Qatar. According to the latest edition of the Ministry of Development, Planning, and Statistics, released in March of 2014, the number of female students attending colleges represented 65% of the total students enrolled at universities during the 2011-2012 academic year. Additionally, 60% of the total graduates were female. This current study was done at a public university in Qatar, where female students represented 70% of the student population. In the electrical engineering department, female students made up approximately 42% of the student population. A group of 30 female students and 15 male students were surveyed on their motivations for considering engineering as a career. In this paper, the authors discuss the reasons, challenges, and motivations for considering engineering as a career among both male and female electrical engineering students, and how this will help us better understand the experiences of female engineering students in the electrical engineering department at Qatar University. Also in this paper, the authors propose thoughts that may help balance the gender gap in STEM fields and increase the representation of female students, mainly in engineering majors in the U.S., based on the lessons learned from this current study.

Introduction

According to the Bureau of Labor Statistics (BLS), the replacement rate in science, technology, engineering, and mathematics (STEM) occupations over the decade 2008-2018 is projected to be very demanding [1]. For instance, the projected replacement rate in mathematical science is 29.5%, in physics is 28.5%, in mechanical engineering is 26%, and in electrical engineering is 23%. According to data from the Current Population Survey [2], the share of the population aged 16 and over having college degrees roughly doubled over the past three decades, as did the share of those with some college education. Over the same period, the share of those attaining a high school diploma or less declined. Employment of college graduates is projected to grow faster than average from 2006 to 2016 [2]. Increasing demand for technological advances means more jobs for STEM workers. More STEM workers also will be needed to replace those leaving these occupations. Many highly skilled workers will retire, change careers, or move to management positions over the next decade.

Employers are expected to hire about 2.5 million STEM workers entering their occupations for the first time [3, 4]. Along with near-future high demand for a well-educated workforce, there is a growing concern that the U.S. is not preparing enough of the workforce in STEM areas, including students, teachers, and professionals [5-8]. In a recent international assessment of 15-year-old students, the U.S. ranks 28th in math literacy and 24th in science literacy. Moreover, in a study identifying the proportion of 24-year-olds earning degrees in natural science or engineering, the U.S. ranked 20th among all nations [5]. In the National Academy of Sciences (NAS) report "Rising above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future," as well as in the Administration's American Competitiveness Initiative [9], five distinguished recommendations targeted at improving STEM education were made. These five recommendations seek to increase the supply of new STEM teachers, improve the skills of current STEM teachers, enlarge the pre-collegiate pipeline, increase postsecondary degree attainment, and enhance support for graduate and early-career research [5].

Female STEM Engineering Education in the U.S. and Qatar

In the U.S., women in STEM education are considered underrepresented and are outnumbered by men. While women represented more than 50% of U.S. residents in

2010 [10], only 20% of bachelor's degrees in STEM fields are earned by women [11]. On the other hand, recent studies showed that more women than men attain a bachelor's degree, but the degrees are not in STEM fields. The number of women attaining a STEM degree is far less than men. Studies showed that the highest participation field of study for women from 1991-2010 was psychology, with more than 60% of psychology degrees are attained by women [10]. On the other hand, female participation in science and engineering remains below 30% during the same period. Representation of women in STEM education and careers does not reflect their percentage in the U.S. population; thus, it is the role of educators to provide thoughts that might offset the gender balance in STEM education and careers.

While the low participation rate of women in STEM education and careers is a national problem in the U.S., the case is different in the state of Qatar. According to the Ministry of Development Planning and Statistics, in their second comprehensive social statistical report during the period of 2003-2012, female students represented 65% of the total students enrolled at universities during the 2011-2012 academic year [12], and the percentage rate of female graduates with college degrees was 60% of the total degrees attained [12]. When looking at the female participation in STEM education in the state of Qatar, 66% of the students enrolled in STEM education are female students [12].

Qatar University

Qatar University was the first national College of Education established in 1973, following a decree by the Emir of Qatar in his vision to place education as a priority in the state's growth and expansion. In its first year, the college admitted a total of 150 students, including 57 male and 93 female students. Now, Qatar University is the only national university in the state of Qatar, located in Doha, the state capital [13]. In the fall of 2014, the total enrollment was over 16,000 students. Arabic is the language of instruction in education, arts, and social sciences courses, while English is the language of instruction in natural sciences, engineering, and business courses.

The university currently has seven colleges—Arts and Sciences, Business and Economics, Education, Engineering, Law, Sharia and Islamic Studies, and a College of Pharmacy—and a student-teacher ratio of 13:1. When students are first admitted, they are enrolled in a "Foundation Program," which ensures that the attainment of skills such as math, English, and computer technology are met. After completing the Foundation Program, students are ready to enroll in their respective majors [13]. Qatar University has a very diverse environment; the student body represents 52 nationalities, 65% of which are Qatari nationals. About 35% are children of expats [4]. Over 70% of Qatar University students are female and are provided their own set of facilities and classrooms [13]. In 1980, the college of engineering (CENG) at Qatar University was established with four undergraduate engineering programs and a total of 50 enrolled students. Currently, the college has grown to become the flagship for engineering education in the state of Qatar with eight undergraduate engineering programs, four master's programs, and one Ph.D. program, with a total of 1400 enrolled students [14].

The College of Engineering hosts seven academic departments: Architecture and Urban Planning (female only), Chemical Engineering (both genders), Civil Engineering (male only), Computer Science and Engineering (both genders), Electrical Engineering (both genders), and Mechanical (male only) and Industrial Systems Engineering (female only). The College of Engineering's first engineering majors to open to women were industrial and computer engineering in 2001, followed by chemical engineering in 2004 and, later, the electrical engineering [14].

The Electrical Engineering Department

The electrical engineering department (EED) offers a bachelor's degree in Electrical Engineering with two focus areas: power systems and telecommunications. The department has a graduate program offering both master's and Ph.D. degree programs. The EED opened its doors to female students in the fall of 2008; since then, the number of female students enrolled in the program experienced massive growth, going from only 28 students in 2009 to 159 students in 2013 [15]. Table 1 shows the enrollment statistics of both male and female students between 2009 and 2014 [15]. The 2013-2014 academic year enrollments showed 159 female students and 221 male students, for a total of 380 students [15]. Table 2 shows the EED graduates, both male and female, during the same period [15]. The EED had its first female graduates in 2011-2012 with a total of 13 graduating [15].

One of the authors in this study spent his sabbatical at Qatar University teaching 30 female students in the electrical engineering department, which represented almost 42% of the students in the electrical engineering department [15]. It was surprising and encouraging to see this large percentage of female students considering electrical engineering as a career, while it is a struggle in the U.S. to motivate minorities, especially female, to consider engineering as a career. The growth in enrollment was driven by the huge demand for engineers driven by the economic boom, which transformed the country into the wealthiest country in the world.

Table 1. EED Enrollments

Academic year	Male	Female	Total
2009 -2010	93	28	121
2010 -2011	115	40	155
2011 -2012	127	77	204
2012 -2013	136	98	234
2013-2014	221	159	380

Table 2. EED Graduates

Academic year	Male	Female	Total
2008 -2009	9	0	9
2009 -2010	13	0	13
2010 -2011	15	0	15
2011 -2012	28	13	41
2012 -2013	17	7	24
2013-2014	27	8	35

Background

Human development through increased opportunities and academic support for Qatari women is one of the four pillars of the Qatar National Vision (QNV) 2030 [16]. QNV 2030 defines the country's long-term objectives for transforming the state of Qatar into an advanced country by 2030, with plans for the development of a highly skilled, technologically competent, motivated workforce to prepare Qatar for a successful transition to a knowledge-based, digital-age future. According to a Rand Foundation study, the number of women enrolling in post-secondary education is twice that of men. Additionally, female participation in college education continues to increase [16].

Investing in education, especially at early ages, plays a crucial role in the future of Qatar's economy. Given the current shortage of Qatari student interest in STEM education, and the undersupply of a trained STEM workforce, increasing attention has been paid to developing innovative tools for improved teaching of STEM education. Qatar is one of the most socially advanced and politically stable countries in the region; Qatar has placed a great emphasis on education and is currently considered a hub for science, engineering, and technology education in the Middle East and gulf region. Through the support of the Qatar Foundation [17], a number of leading U.S. universities have branch campuses in Qatar Education City. Examples of universities in the education city include Weill Cornell Medical School, Texas A&M University, Georgetown University, and Carnegie Mellon University. Additionally, with the establishment of the Qatar Science and Technology Park (QSTP) in 2004 [18], Qatar has the first (and only one in the region) science park that links academia with industry, facilitating and promoting technology-based industries. QSTP is considered an international hub for applied research, innovation, and entrepreneurship.

In this paper, the authors discuss the reasons, challenges, and motivations for considering engineering as a career among both male and female electrical engineering students, and how these can help us better understand the experiences of female engineering students in the electrical engineering department at Qatar University. Also in this paper, the authors propose thoughts that may help balance the gender gap in STEM fields and increase the representation of female students, mainly in engineering majors in the U.S., based on the lessons learned from this current study.

Study Methodology and Results

With the goal of understanding how Qatari female students have developed (and will continue) their STEM career interest, mainly engineering, the authors will try to answers questions related to how Qatari female students perceive electrical engineering as a career. Students participating in this study were a group of 30 female students and 15 male students in the electrical engineering department at Qatar University. This survey, conducted in the spring of 2014, was voluntary and anonymous. The students were surveyed on their motivations for considering engineering as a career. The objective of the survey was to collect student (both male and female) responses relating to the reasons, challenges, and motivations for considering engineering as career. A set of questions was developed to measure and identify reasons for student interest toward STEM, mainly electrical engineering, as a career.

The first part of the survey consisted of three questions on the quality of K-12 education in the state of Qatar in preparing students for STEM careers. Students were asked to rank their viewpoints, based on a scale of 1 to 5, with 5 representing Strongly Agree and 1 Strongly Disagree. Tables 3 and 4 reflect student feedback, both male and female, on survey questions of part 1. The second part of the survey was a set of questions for determining why female and male students in Qatar were interested in STEM careers. The research goals were to identify how male and female students in the electrical engineering department viewed STEM as a career and possibly utilize the data in helping bridge the gender gap at home. Students were asked to identify the reasons they considered choosing engineering as a career.

Students were given the following set of possible reasons and were asked to select all that applied. Table 5 reflects student feedback, both male and female, from the survey questions of part 2.

Table 3. Female Student Responses – Part 1

Survey Questions	Overall rate
1. My school did prepare me extremely well for college?	3.46
2. Preparing female students for career in STEM should be a top priority for schools in Qatar	4.65
3. Comparing to other countries, Qatar is a doing a great job in teaching STEM	3.86

Table 4. Male Student Responses – Part 1

Survey Questions	Overall rate
1. My school did prepare me extremely well for college?	3.00
2. Preparing female students for career in STEM should be a top priority for schools in Qatar	3.85
3. Comparing to other countries, Qatar is a doing a great job in teaching STEM	3.85

Discussion

Results of the survey showed both similarities and differences between male and female students' responses. Regarding similarities, both males and females equally reported that, when compared to other countries, the state of Qatar is doing a great job in teaching STEM (question 3). Additionally, both male and female students equally said that the job potential for engineer in Qatar and the region was the main reason for choosing engineering as a career (question 4). Male students were more inclined to make a difference and help building the country (question 4).

Regarding differences, male students were more definite on their career choices in their early childhood—15% decided to study engineering in early childhood (question 5). Females, on the other hand, reported 0% for early childhood, as the time when they decided to study engineering. Another difference was probably a shift in culture in Qatar: 57% of female students reported that their parents had the most influence on their decision to study engineering, compared with only 23% of male students, who felt the same (question 6). Parents are now more open and enthusiastic to motivating their daughters to seek degrees (and jobs) in engineering fields.

Table 5. Male/Female Student Responses - Part 2

Survey Questions	Male	Female
4. What are the reasons you considered when you decided on Engineering as a career?		
a) It is my passion	46%	54%
b) The job potential in Qatar and regional	46%	46%
c) The starting salary for fresh engineer is attractive	23%	25%
d) Qatar is in need of Electrical Engineering graduates	38%	43%
e) Participating in clubs focused on engineering	8%	7%
f) There is an engineer in the family (Dad, Mom, Brother, Sister)	23%	29%
g) It is a very interesting and challenging field	69%	75%
h) My High School GPA was high to get me admitted in Engineering	54%	50%
i) My parents told me I had to	8%	0.0%
j) I want to make a difference and help building my country	46%	32%
k) I was motivated by a school teacher	8%	14%
l) Others, please specify:	0.0%	17%
5. When did you decide you wanted to study engineering?		
a) After joining the college	23%	29%
b) In high school	46%	57%
c) In middle school	15%	11%
d) In elementary school	0.0%	4%
e) Early childhood	15%	0.0%
6. Who had the most influence on your decision to study engineering?		
a) My parents	23%	57%
b) My Friend	15%	14%
c) My teacher	15%	7%
d) My sibling	8%	14%
e) My grandparent	0.0%	0.0%
f) Other relative	8%	7%
g) No one	38.5%	25%
7. How important is each factor to your success?		
a) Studying hard	92%	79%
b) Supportive Parents	54%	18%
c) A good school education	38.5%	32%
d) Joining a good university	46%	57%
e) Having a role model	30%	22%

Other similarities included identifying studying hard as the most important factor to success; both male and female students highly valued the importance of studying hard in achieving success. Both groups also reported that both having a good school education and joining a good university were definite keys for success as well (question 7). Because of the historical stereotyping of engineering as a mainly male dominated field, female students believed that preparing female students for careers in STEM should be a top priority for schools in Qatar (question 2). Data also showed a difference between males and females in viewing the role of supporting parents as a factor to success. While female students were still in need of parental support, they tended to rely mainly on their hard work as a key for success, probably due to the fact that female students are generally more critical of their performance and tend to always challenge themselves.

Conclusion

While female students in STEM education are considered underrepresented and are outnumbered by male students in the U.S., the case is different in the state of Qatar. The state of Qatar is enjoying exceptional economic growth and relies heavily on increasing the opportunities and vocational support for Qatari women to meet the Qatar National Vision (QNV) 2030 of transitioning the country into a knowledge-based, digital-age future. In this paper, the authors discussed the reasons, challenges, and motivations for considering engineering as a career among both male and female electrical engineering students, with a goal to help us better understand the experiences of female engineering students in the electrical engineering department at Qatar University.

Clearly, the results presented here provide some thoughts that may help balance the gender gap in STEM fields and increase the representation of female students, mainly in engineering majors, in the U.S. Female students in Qatar reported that their parents had the most influence on their decision to study engineering. Educating parents on potential opportunities for female students in STEM education will play a considerable role in possibly offsetting the gender gap. Additionally, results showed that Qatari female students' interest in STEM careers started in high school; thus, more emphasis on teaching math and science, and working closely with high school teachers to infuse engineering exploration into their curricula, will definitely help motivate and engage female students to pursue STEM career pathways.

References

[1] Replacement needs in 2008-18. (n.d.). 2008 National Employment Matrix title and code, Bureau of Labor Statistics. Retrieved August 7, 2014 from http://www.bls.gov/emp/ep_table_110.ht

[2] Liming, D., & Wolf, M. (2006). Job Outlook by Education 2006-16. Office of Occupational Statistics and Employment Projections, BLS

[3] Terrell, N. (2007). The Office of Occupational Statistics and Employment Projections. STEM Occupations. *Occupational Outlook Quarterly*, BLS.

[4] Occupational Outlook Handbook. (n.d.). Retrieved August 7, 2014 from http:// www.bls.gov/oc.

[5] Kuenzi, J., Matthew, C., & Mangan, B. (2006). *Science, Technology, Engineering, and Mathematics (STEM) Education Issues and Legislative Options*. CRS Report for Congress.

[6] Bonvillian, W. B. (2002). Science at a crossroads. *The Federation of American Societies for Experimental Biology Journal, 16*, 915–921.

[7] Gonzales, P., Guzmán, J. C., Partelow, L., Pahlke, E., Jocelyn, L., Kastberg, D., et al. (2003). *Highlights from the Trends in International Mathematics and Science Study (TIMSS).* Washington, DC: U.S. Department of Education, National Center for Education Statistics.

[8] Lemke, M., Sen, A., Pahlke, E., Partelow, L., Miller, D., Williams, T., et al. (2004). *International outcomes of learning in mathematics literacy and problem solving: PISA 2003 results from the U.S. perspective.* Washington, DC: U.S. Department of Education, National Center for Education Statistics, 2004

[9] Office of Science and Technology Policy. (2006). Domestic Policy Council, American Competitiveness Initiative — Leading the World In Innovation.

[10] National Science Foundation (n.d.). , Retrieved August 7, 2014 from http://www.nsf.gov/statistics/2015/nsf15311/nsf15311.pdf

[11] AAAU, Why so Few (n.d.). Retrieved August 7, 2014 from http://www.aauw.org/research/why-so-few/

[12] Ministry of Development Planning and Statistics, Qatar. (n.d.). Retrieved August 7, 2014 from http://www.gsdp.gov.qa/portal/page/portal/gsdp_en/about_gsdp/top_management

[13] Qatar University. (n.d.). Retrieved August 7, 2014 from http://www.qu.edu.qa

[14] Qatar University College of Engineering, Retrieved August 7, 2014 from http://www.qu.edu.qa/engineering

[15] Qatar University, Electrical Engineering Department. (n.d.). Retrieved August 7, 2014 from http://www.qu.edu.qa/engineering/electrical
[16] Rand Foundation Study. (n.d.). Retrieved August 7, 2014 from http://www.rand.org/content/dam/rand/pubs/monographs/2007/RAND_MG644.pd
[17] Qatar Foundation. (n.d.). Retrieved August 7, 2014 from http://www.qf.org.qa
[18] Qatar Science & Technology Park. (n.d.). Retrieved August 7, 2014 from http://www.qstp.org.qa

Biographies

NASSER ALARAJE is currently the Electrical Engineering Technology program chair as well as a faculty member at Michigan Technological University. Previously, he taught and developed courses in computer engineering technology at the University of Cincinnati and Michigan Technological University. Dr. Alaraje's research interests include processor architecture, System-on-Chip design methodology, Field-Programmable Gate Array (FPGA) architecture and design methodology, Engineering Technology Education, and hardware description language modeling. Dr. Alaraje is a 2013-2014 Fulbright scholarship recipient at Qatar University, where he taught courses on Embedded Systems. Additionally, Dr. Alaraje is the recipient of an NSF award for a digital logic design curriculum revision in collaboration with the College of Lake County in Illinois, and the NSF award in collaboration with the University of New Mexico, Drake State Technical College, and Chandler-Gilbert Community College, to focus on expanding outreach activities to increase the awareness of potential college students about career opportunities in electronics technologies. Dr. Alaraje is a member of the American Society for Engineering Education (ASEE), a member of ASEE's Electrical and Computer Engineering Division, a member of ASEE's Engineering Technology Division, a senior member of the Institute of Electrical and Electronic Engineers (IEEE), and a member of the Electrical and Computer Engineering Technology Department Heads Association (ECETDHA). Dr. Alaraje may be reached at alaraje@mtu.edu

ALEKSANDR SERGEYEV is an associate professor in the Electrical Engineering Technology program at Michigan Tech. He is a faculty advisor for the Robotics System Enterprise and a FANUC certified instructor in robotics. Dr. Sergeyev oversees all activities of the FANUC authorized certified training center at Michigan Tech. He has developed and taught courses in the areas of robotics and automation, power, electrical machinery, programmable logical controllers, digital signal processing, and optics. He has a strong record publishing in prestigious journals and conference proceedings, including Measurements Science and Technology, Adaptive Optics, Sensors and Materials, The Technology Interface International Journal, ASEE, IEEE, and SPIE. Additionally, Dr. Sergeyev is a co-PI on several NSF and DOL awards, and a PI on multiple significant industry awards. Dr. Sergeyev may be reached at avsergue@mtu.edu

MOHAMMED SAYER ELARAJ is currently a faculty member at Alaqsa University. Before joining Alaqsa University, he was the Dean of the University College of Science and Technology and the Director of Technical and Vocational Education at the Ministry of Higher Education. Dr. Elaraj's research interests include financial analysis and advancing STEM education. Dr. Elaraj may be reached at ms.aaraj@alaqsa.edu.ps

A University, Community College, and Industry Partnership: Revamping Robotics Education to Meet 21st Century Workforce Needs

Aleksandr Sergeyev, Michigan Technological University; Nasser Alaraje, Michigan Technological University;
Scott Kuhl, Michigan Technological University; Michael Meyer, Michigan Technological University;
Mark Kinney, Bay de Noc Community College; Mark Highum, Bay de Noc Community College

Abstract

Recently, educators have worked to improve STEM education at all levels, but challenges remain. Capitalizing on the appeal of robotics is one strategy proposed to increase STEM interest. The interdisciplinary nature of robots, which involve motors, sensors, and programs, makes robotics a useful STEM pedagogical tool. There is also a significant need for industrial certification programs in robotics. Robots are increasingly used across industry sectors to improve production throughput, while maintaining product quality. The benefits of robotics, however, depend on workers with up-to-date knowledge and skills to maintain and use existing robots, enhance future technologies, and educate users. It is critical that education efforts respond to the demand for robotics specialists by offering courses and professional certification in robotics and automation. In this study, the authors developed a new approach for introducing industrial robotics into electrical engineering technology (EET) programs at Michigan Tech and Bay de Noc Community College. The curriculum and software developed by this collaboration of two- and four-year institutions was intended to match industry needs and provide a replicable model for programs around the U.S.

Introduction

Robotics and industrial automation will be a major driver for global job creation over the next five years. These trends were made clear in a study conducted by the market research firm, Metra Martech, “Positive Impact of Industrial Robots on Employment” [1]. “Many repetitive, low-skilled jobs are already being supplanted by technology. However, a number of studies have found that in the aggregate, the robotics industry is creating more jobs than the number of jobs lost to robots. For example, the International Federation of Robotics (IFR) estimates that robotics directly created 4 to 6 million jobs through 2011 worldwide, with the total rising to 8 to 10 million if indirect jobs are counted. The IFR projects that 1.9 to 3.5 million jobs related to robotics will be created in the next eight years” [2]. Due to the rapid growth of robotics and automation, especially during the last few years, its current positive impact and future projections for impact on the U.S. economy are very promising. Even by conservative estimates [1], the number of robots used in industry in the U.S. has almost doubled in recent years. In the manufacturing sector, the recent growth was 41% in just three years: the number of robots per 10,000 workers employed in 2008 was 96, and 135 in 2011. The automotive sector in the U.S. relies heavily on robotics as well; China produces more cars than the U.S., but the number of robots used in vehicle manufacture in China is estimated at 40,000, compared to 65,000 in the U.S. From 2014 to 2016, robot installations are estimated to increase about 6% a year, resulting in an overall three-year increase of 18% [1]. “Likewise, industrial robot manufacturers are reporting 18-25% growth in orders and revenue year on year. While some jobs will be displaced due to the increased rollout of robots in the manufacturing sector, many will also be created as robot manufacturers recruit to meet growing demand. Furthermore, jobs that were previously sent offshore are now being brought back to developed countries due to advances in robotics. For example, Apple now manufactures the Mac Pro in America and has spent approximately $10.5 billion in assembly robotics and machinery” [3]. In March, 2012, Amazon acquired Kiva Systems, a warehouse automation robot, and in 2013 deployed 1382 Kiva robots in three Fulfillment Centers. “This initiative has not reduced the number of employees at Amazon; in fact, it added 20,000 full-time employees to its US fulfillment centers alone” [3].

Such rapid growth of robotics automation in all sectors of industry will require an enormous number of technically sound specialists with the skills in industrial robotics and automation to maintain and monitor existing robots, enhance development of future technologies, and educate users on implementation and applications. It is critical, therefore, that educational institutions adequately respond to this high demand for robotics specialists by developing and offering appropriate courses geared towards professional certification in robotics and automation. In addition, certified robotics training centers (CRTCs) will be in high demand by industry representatives and displaced workers, who need to retool their skills. This initiative between Michigan Tech and Bay de Noc Community College was intended to demonstrate and test an effective approach for teaching emerging topics of industrial robotics in EET programs at both the university and community college levels. The curriculum and software developed via this collaborative effort were intended to match current industry needs and provide a replicable model for the EET programs across the country. The project also addressed the need for CRTCs and provided curriculum and training opportunities for students from other institutions, industry representatives, and displaced workers. Resources developed via this initiative were to be disseminated through a variety of means, including workshops, conferences, and publications.

Workforce Need

In 2014, the ManpowerGroup surveyed nearly 40,000 employers across 41 countries and territories as part of its annual Talent Shortage Survey [4], and found that employers were having the most difficulty finding the right people to fill jobs in Japan, 81%; Brazil, 63%; and the U.S., 40%. In fact, two occupations in the U.S., technicians (primarily production/operations, engineering or mathematics) and engineers, topped the list of 10 jobs that employers were having difficulty filling. In addition, the American Society for Training and Development (ASTD) reported major skill gaps in the U.S. The 2013 ASTD report stated that U.S. organizations spent ~$164.2 billion on employee learning in 2012 [5]. The U.S. is facing an alarmingly high replacement need for STEM professionals [6, 7]. For instance, the projected replacement rate in mathematical science was 29.5%; in physics, 28.5%; in mechanical engineering, 26%; and, in electrical engineering, 23%. It was estimated that during this decade, employers would need to hire about 2.5 million STEM workers, drawing largely from engineering and engineering technology programs known for equipping graduates with the tools to enter the workforce, for the first time, prepared [8, 9]. This required an innovative curriculum that involved hands-on opportunities for practical problem solving.

On the one hand, the pipeline for an educated future workforce is already in place. According to data from the Current Population Survey [7], the share of the population aged 16 and over, who have college degrees, roughly doubled over the past three decades, as did the share of those with some college education. However, there is concern that the U.S. is still not preparing a sufficient number of students, teachers, and professionals in STEM areas [10-13]. "In a recent international assessment of 15-year-old students, the U.S. ranked 28th in math literacy and 24th in science literacy. Moreover, the U.S. ranks 20th among all nations in the proportion of 24-year-olds who earn degrees in natural science or engineering" [10]. In the National Academy of Sciences (NAS) report, "Rising above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future," as well as in the Administration's American Competitiveness Initiative [14], five recommendations targeted improving STEM education: 1) increase the supply of new STEM teachers, 2) improve the skills of current STEM teachers, 3) enlarge the pre-collegiate pipeline, 4) increase postsecondary degree attainment, and 5) enhance support for graduate and early career research [10]. In this paper, the authors describe an approach to address, through short- and long-term goals, each of these recommendations.

Educational Need

Robotics is an effective tool for promoting STEM fields. Educators have been making measurable progress toward improving STEM education from primary to tertiary levels of education, but challenges remain. Given the current shortage of student interest in STEM education, increased attention has been given to the appeal and attraction of robotics. The interdisciplinary construction of robots, which involves motors, sensors, and programming, makes it a useful pedagogical tool for all STEM areas. The novelty of robotics is instrumental in attracting and recruiting diverse STEM students. In the classroom, robotics can easily be used to introduce a variety of mandatory skills needed to pursue a variety of STEM career paths [15-19]. More specifically, a robotics platform advances student understanding of both scientific and mathematical principles [17, 20], develops and enhances problem-solving techniques [17, 18, 20-23], and promotes cooperative learning [17, 20, 24].

While robotics can be used as an interdisciplinary STEM learning tool, there is also a strong need for industrial certification programs in robotics automation. More and more robots are designed to perform tasks that people may not want to do, such as vacuuming, or are not able to do safely, such as dismantling bombs. They have changed the lives of Amyotrophic Lateral Sclerosis (ALS) patients by giving them the ability to speak after their vocal cords have failed and have sparked our imagination in space exploration (not to mention our fascination with characters like R2D2). As many have put it, robots do our dirty, dangerous, and/or dull work. Millions of domestic/personal robots are already on the market worldwide, from lawn mowers to entertainment robots [25]. As a result, popular interest in robots has increased significantly [16-28]. Global competition, productivity demands, advances in technology, and affordability will force companies to increase the use of robots in the foreseeable future [29-31]. While the automotive industry was the first to use robotics, aerospace, machining, and medical industries now also rely on robotics automation [32, 33]. More than ever, trained and certified specialists are needed to maintain and monitor existing robots and to develop more advanced robotics technologies [29, 34-36].

As mentioned, robotics can be used as an interdisciplinary, project-based learning vehicle to teach STEM fundamentals [37-39]. Understanding the valuable role robotics education plays in helping students understand theoretical concepts through invention and creation, many universities include components of robotics research in curricular offerings [40]. It is widely recognized that robotics is a valuable learning tool that can enhance overall STEM comprehension and critical thinking [37, 41-43]. As a result of these benefits and industry needs, new programs in robotics automation and applied mobile robots are popping up in the U.S. and abroad. Industrial help from Microsoft, FANUC Robotics America Inc., and MobileRobots Inc., is essential to the growth of these programs. The objectives behind robotic programs are clear: in the short term, robotics education "fosters student's ability to capture the following desired skills: problem solving, communication, teamwork, independence, imagination, and creativity" [44-46]; and, in the long term, robotics education plays a key role in preparing a workforce to implement 21st-century technologies.

Currently, few universities have specific robotics degrees [44-46]. For example, Worcester Polytechnic Institute (WPI) has offered a Bachelor of Science in Robotics Engineering since 2007 [47]. Universities with robotics graduate degrees include Carnegie Mellon University, MIT, UPENN, UCLA, WPI, and the South Dakota School of Mines and Technology. Michigan State University has a well-established robotics and automation laboratory, but it is utilized for graduate robotics courses and research. Very few universities across the U.S. offer a degree and/or certification specifically in robotics automation. In fact, Lake Superior State University is one of only a few universities in Michigan that specializes in robotics automation; however, it does not have a program to certify industry representatives [48]. With few focused industrial robotics programs, undergraduate industrial robotics training often occurs in electrical engineering technology programs. Training in robotics automation is especially important to Michigan's economy. A major decline in automotive manufacturing jobs has left many areas in Michigan with high rates of unemployment. Baraga County, located 15 miles south of Michigan Tech, has one of the nation's highest rates of unemployment. Yet, Michigan has an unmet need for workers in robotics jobs [26, 49]. Filling these jobs, however, requires workers trained and certified in the following skill sets: designing, testing, maintaining, and inspecting robotics components; troubleshooting robot malfunctions; using microcomputers, oscilloscopes, hydraulic test equipment, microprocessors, electronics, and mechanics; and, reading blueprints, electrical wiring diagrams, and pneumatic/hydraulic diagrams.

Driven by industry needs, the new curriculum designed in this project was intended to be adapted for both two- and four-year programs. This collaboration aimed to address the current U.S. workforce need for properly prepared STEM professionals, train current industry representatives and displaced workers in robotics automation, educate K-12 teachers with the current art of industrial robotics, and promote STEM fields among K-12 students.

Current Industry Partnership

Michigan Tech's EET Department has an established collaborative relationship with FANUC Robotics America Inc., the leading company specializing in developing and producing innovative and intelligent robotics solutions. FANUC Robotics supports Michigan Tech's School of Technology, as well as other STEM programs. FANUC has provided significant educational discounts and made possible the purchase of resources that would otherwise not be feasible. In 2010, the EET department purchased two LR Mate Training Carts MH1 & Certification Package, totaling $63,754. The company list price for the same products and services was $648,080. Thus, FANUC Robotics has already provided an educational "gift in kind" valued at $584,326. In 2013, Michigan Tech acquired two additional LR Mate Training Carts. Michigan Tech's FANUC robot is the latest electric, servo-driven mini robot, housed in a self-contained, portable enclosure. It provides multiple benefits: industry-standard components that allow teaching principles of automation, compact and portable design, affordability, safe construction, and an integrated vision system that is commonly used in industry.

Michigan Tech is a FANUC Robotics CERT-endorsed program, and the EET department is a Certified Training and Education Site for FANUC Robotics Material Handling Program Software and iR-Vision 2D. The collaboration between Michigan Tech and FANUC continues to bloom. In 2013, Michigan Tech became a FANUC Authorized Certified Training Facility. Under this agreement, Michigan Tech is a regional training center specializing in industrial automation, eligible to train and certify students from other institutions, industry representatives, and displaced workers. Michigan Tech is one of only three existing FANUC Authorized Satellite Training Programs in the U.S., and the only one in the state of Michigan [50].

Current State of Robotics Automation at Michigan Tech and Bay de Noc Community College

At Michigan Tech, the authors have been building a strong undergraduate Robotics Automation Program through the EET department. The cross-disciplinary robotics automation training program was successfully launched in 2009 [51]. The program continues to enroll Michigan Tech students from diverse STEM disciplines, industry employees who seek retooling in robotics automation skills, and students from other universities. Industrial collaboration between the EET department and FANUC Robotics is continuing to expand. The global presence of the automotive sector in Michigan, as well as the large number of companies specializing in industrial automation, generate an enormous demand for well-trained and certified in robotics automation specialists. Our ability to offer ongoing training and certification not only makes this project sustainable but also provides the authors with an extensive opportunity for continuous evaluation of the proposed educational initiatives.

The current success of the program, CERT experts, and industry collaborations make Michigan Tech the ideal partner for Bay College. Via this collaborative initiative, Bay College planned to adapt Michigan Tech's existing curriculum in robotics automation, and implement and evaluate the robotics curriculum in a two-year degree program. This partnership of two- and four-year institutions would not only serve as an exemplary model of collaboration, but would also develop a full spectrum of robotics curriculum adaptable at various levels of education. Bay College faculty would work with experts in robotics from Michigan Tech to adapt the existing curriculum for the two-year program, developing new courses in robotics automation, and creating state-of-the-art educational robotics training software. In addition, Bay College faculty would participate in the CERT program at FANUC. The goal was to become a FANUC-certified facility, which would allow Bay College to become a Certified Training and Education Site for FANUC Robotics Material Handling Program Software and iR-Vision 2D.

Collaborative Initiative 1: Robotics Automation Curriculum Development for EET Programs

Collaboration between Michigan Tech and Bay College will have a significant impact on the curriculum at both institutions. During this initiative, a broad spectrum of educational material would be developed and made available between institutions for adaptation. Figure 1 depicts the proposed models in robotics curriculum development, which would impact three different educational groups: two- and four-year institutions; students from other universities and community colleges, industry representatives, and displaced workers; and K-12 teachers and high school students. Following are the proposed curriculum changes.

The robotics curriculum at Michigan Tech was to be enhanced by adding a new course, Robotics Vision Systems, and by developing new, state-of-the-art educational robotics simulation software called RobotRun. Bay College had no robotics-related courses in its current curriculum. Through this project, Bay would add two new courses and utilize the open-source robotics training software (developed through this project) in the classroom. Working closely with Michigan Tech, Bay College would modify Michigan Tech's existing Real-Time Robotics System course for use at the community college level. During the project, faculty from both partner institutions would collaborate in the development of the new Robotics Vision course and the robotics training software. Both the new course and the software were to be adapted for use in the Bay College curriculum. Bay College was currently in the process of developing a multi-skilled technician certificate program that would serve as a broad-based entry point for students interested in careers ranging from automation to advanced manufacturing to industrial systems control and more. The robotics courses being developed as part of the partnership with Michigan Tech would fit seamlessly into this degree in order to provide students with an entry-level understanding of robotics and automation technology. Furthermore, the courses would be included as part of the articulated transfer program designed for students interested in a more intensive study of robotics. These courses would also be available to pre-engineering students, which is also an articulated transfer program to Michigan Tech. Students at Bay College would benefit from these curriculum additions in numerous ways, including expanded exposure to advanced technologies, better career preparation, and increased options for transfer to Michigan Tech.

Building upon the Strong Foundation of Michigan Tech's Existing Course: Real-Time Robotics Systems

As shown in Figure 1, the current curriculum at Michigan Tech in robotics automation includes one Real-Time Robotics Systems course (4 credit hours: 3 hours of recitation and 3 hours of weekly lab) covering all of the theoretical and practical aspects of the knowledge required for technologists involved in the robotics automation industry. The course presents the technology of mechanical manipulations and robotics systems control. A broad range of robotics topics is covered including sensors, end-effectors, and actuators. Essentially, this course is the building block for future coursework in the mechanics, control, and programming of robotics systems. Designed from a manufacturing perspective, the course addresses robots in an isolated manner, while exploring the broad topic of industrial work cells that contain a robot. This includes robotics automation and all related technology needed to integrate the robot with the work environment and with the enterprise database.

The course also addresses the major aspects of design, fabrication, and robotic-enabling systems. Design aspects involve determining specifications for a robot, configurations, and which sensors and actuators should be used. Considerable attention is currently dedicated to safety procedures of operating robotics platforms. The currently used FANUC Roboguide software package allows students to learn the programming language used in the field of robotics for off-line programming. After receiving sufficient off-line programming training and passing the safety-related test, students implement their knowledge and perform laboratory experiments that involve hands-on programming and operation of a state-of-the-art FANUC industrial robot. This course offers the foundation of an educational platform for developing and implementing an effective curriculum model in robotics automation.

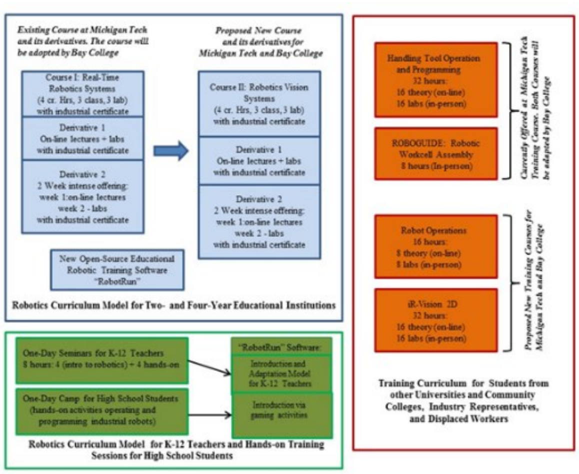


Figure 1. Proposed Robotics Automation Curriculum Development

Close collaboration with industry in the initial design of this course also helped to advance an industrial certification program that is endorsed by industry. Students who successfully complete the course get certified and issued a FANUC industrial certificate in "Handling Tool Operation and Programming." To further promote course development and make the course offering model more flexible, two derivatives of the course have been developed. The first, a hybrid version of the course, has been successfully implemented several times since 2012. In this version of the course, the theory, quizzes, and exams are delivered online, but students still have an opportunity for hands-on training during weekly three-hour labs. This model allows for more flexible scheduling of the class, which in turn helps students who work while attending school. The second course derivative involves an intensive two-week structure with the same amount of theory and hands-on practices in a condensed time period.

The first week involves an introduction to the theoretical content, culminating in the midterm exam. In the second week, students are completely immersed in the hands-on activities of operating and programming FANUC industrial robots. The second week culminates with a two-hour certification/final exam. The two-week intensive course model has proven to be very effective, and has become very popular among students at Michigan Tech in a variety of disciplines. Since 2009, a FANUC certified instructor at Michigan Tech has trained and awarded industrial certificates to more than a hundred students. Building upon the foundational course in place at Michigan Tech, Bay College will adapt and implement all of the derivatives of the Real-Time Robotics System course in order to provide Bay College students with flexible course offerings and certification options.

New Course: Robotics Vision Systems

Nearly any robot currently used in industry is equipped with a vision system. Vision systems are being used increasingly with robotics automation to perform common and sometimes complex industrial tasks such as part identification, part location, part orientation, part inspection, and tracking. The vision system provides the robot "eyes" needed to perform complex manufacturing tasks. The Robotics Vision Systems course will be designed as a four-credit-hour course (three hours of recitation and three hours of weekly lab). The course will introduce topics on 1) safety, including laser safety; 2) basics of optics and image processing; 3) setting up lightning conditions required for the successful vision error proofing and camera calibration; 4) teaching tool, application, and calibration frames; 5) performing 2D calibration and 2D single and multiview robotics processes; and, 6) performing 3D calibration and 3D single view robotics vision processes. Hands-on training is an integral part of any course developed in the School of Technology at Michigan Tech, and this course is no exception. It will include 12 laboratory exercises, totaling 36 hours, with the goal of providing students the opportunity to configure and execute real-life, industry comparable, robotics vision scenarios. The course will be similar to the existing Real-Time Robotics Systems' rigorous assessment strategy and will culminate in a two-hour certification exam. Students successfully passing the exam will receive a certificate in iR-Vision 2D issued by the FANUC certified instructors. In addition to the traditional offering, two derivatives (a hybrid and two-week intensive version) of the Robotics Vision Systems will be developed and implemented at both institutions, Bay College and Michigan Tech.

New Open-Source Robotics Training Software: RobotRun

Via this collaborative initiative, an engaging, free, and open-source robotics training software package aimed at helping students learn the basics of programming robotics arms will be developed. The software will act as a simulator, where a user can write a program and then view how that program performs when run on a virtual 3D robotic arm displayed on the screen. Although robotics plays an essential role at a variety of manufacturing facilities, there is currently no accessible and free software that can give students the opportunity to learn about using the robotics hardware without purchasing expensive, complex, proprietary software packages. This software is intended to be used alongside the other training materials developed as a part of this project, but it will also be made available online for anyone to download and use. The RobotRun software will show 3D, animated rendering of a robotic arm that can be controlled via an intuitive programming language similar to the programs used to program real robotic arms.

The programming language in the robotic arm simulator software will provide all of the basic commands that exist in real-world robotics systems so that students can easily transfer the knowledge gained from the software to real-world robotic arms. The software will allow the user to control where the end-effector should jog, the speed and type of motion termination, how many times it should repeat the movement, and other common robotics controls. Besides the option of jogging the robot and performing programming tasks, the software will be configured to present users with different scenarios that mimic real-world industrial scenarios such as pick and place, palletizing, welding, painting, etc. The program will also allow users to load and save their programs so that they can submit them to an instructor for grading. The new software will provide all options necessary to teach the required skills in robotics handling tool operation and programming. It will be simple, without features of expensive robotics simulation software packages that are designed for in-depth industrial simulations, and are not typically used in educational settings. The open-source and free nature of the developed RobotRun training software will have a significant and broad impact by 1) enabling institutions unable to obtain expensive industrial robots to adapt and teach the developed robotics courses, 2) providing K-12 teachers with the opportunity to promote STEM education to students by introducing the appealing concept of robotics via an interactive training environment, at no cost to K-12 institutions, and 3) providing displaced workers wanting to improve their robotics skills with an intuitive, interactive, and complete tool to succeed.

Initiative 2: Curriculum for Students from Any Institution, Industry, and Displaced Workers

While robots play a role in all STEM fields, robots are key components of most manufacturing industries, from health to automotive sectors. Robotics automation has been embraced as a way to stay globally competitive and to reduce reliance on manual labor to perform redundant tasks. If the U.S. does not want to outsource, it needs to automate. To provide support for industry, educational institutions need to: 1) develop a training curriculum with industrial certification available to students from institutions, where a robotics curriculum is not available—this will make those students more valuable in the job market; 2) provide effective, certified training to industry representatives, who need to retool their skills to match rapidly developing technologies, especially in the field of robotics automation; and, 3) provide displaced workers with the opportunity to enhance or acquire new skills in robotics and enter the in-demand robotics job market. Michigan Tech's existing industrial certification program will be enhanced by offering two additional FANUC certificates.

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

The course was designed to be very practical, and course topics include an overview of: the development of industrial robotics; the concepts of mechanical design and control and programming language; and the robotics in operation and various applications. Hands-on experience is an essential part of this course and will occupy 70% of course time. The lab exercises are devoted to practical aspects of programming FANUC Robotics robots. This 32-hour course was designed to be offered partially online. The first 16 hours are devoted to theoretical content delivered online. The remaining 16 hours are designated laboratory exercises conducted in the lab at Michigan Tech or Bay College manipulating and programming FANUC industrial robots. The course concludes in a certification exam designed to evaluate participants' understanding of covered in the course material. Participants successfully passing the exam will receive a certificate issued by a FANUC-certified instructor. The course can be offered on demand and conducted on weekends, during student breaks, or in the summer. This flexibility has proven successful in attracting students from other institutions, industry representatives, and displaced workers. Feedback from past participants of the Michigan Tech training sessions showed very positive results. Students indicated that the partially online delivery approach not only saved travel time and money but also allowed participants to be more focused on the hands-on part of the course, thereby providing a more effective learning environment.

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

FANUC Roboguide software is widely used in industry; therefore, there is a great need to train workers on this software. The PI has developed an eight-hour training course that provides participants with a foundation for understanding all software features. By the end of the course, students assemble a fully functional virtual robotic workcell that includes the robot, end-effector, several fixtures, and industrial parts that the robot can manipulate. Students program the robot to execute "pick and place" operation, run simulations in step-by-step and production modes, and compile a file for further transmission to the physical FANUC robot for real-time production. This one-day training can be offered on demand and in conjunction with the other existing and under-development certification courses.

Certification 3: Robot Operations (16 hours)

There is a great demand in the industrial sector for robot operators, who do not necessarily need to have in-depth programming and theoretical skills. This course is intended for the person who operates or may be required to perform basic maintenance on FANUC robots via the standard application software package. It will teach students how to safely power up, power down, jog the robot to predefined positions, and set up different frames of operation. In addition, it will cover tasks and procedures needed to recover from common program and robot faults, and teach basic programming skills. The course will not address the setup and operation of specific software features and options nor will it teach in-depth programming skills; these are covered in the 32-hour Handling Tool Operation and Programming course.

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

Nearly any robot currently used in industry is equipped with a vision system. Vision systems are being used increasingly with robotics automation to perform common and sometimes complex industrial tasks such as part identification, part location, part orientation, part inspection, and tracking. In other words, the vision system is the robot's "eyes" needed to perform complex manufacturing tasks. This new course will teach students how to set up, calibrate, teach, test, and modify iR-Vision applications using FANUC robots. The course will include detailed discussion of hardware and software setup, establishing the communication link between the robot and teaching computer, teaching single- and multi-view processes, and programming. Safety procedures will be integrated into all exercises. As an integral part of this course, a series of lab exercises will be developed to provide hands-on training to reinforce the theory the student has learned. This 32-hour course will be designed with a structure similar to the Handling Tool Operation and Programming course: 16 hours of online and 16 hours of hands-on training. The course concludes in a certification exam designed to evaluate participants' understanding of material covered in the course as well as the ability to successfully set up, calibrate, program, and utilize the FANUC robot-equipped vision system. Participants passing the exam will receive a certificate in iR-Vision 2D issued by a FANUC-certified instructor. Similar to the other certification courses, it can be offered on demand and conducted on weekends, during student breaks, or in the summer.

Initiative 3: Model of Robotics Curriculum for K-12 Teachers and Hands-on Training Sessions for High School Students

As a way of encouraging more (and more diverse) students to consider careers in robotics, faculty members from Bay College and Michigan Tech will promote robotics automation to K-12 teachers and high school students. One-day seminars for K-12 teachers will be conducted at both Michigan Tech and Bay College in Years 2 and 3 of the project. During the seminar, participants will: 1) learn concepts of industrial robotics; 2) learn the basics of programming FANUC industrial robots; 3) try the robotics software "RobotRun"; and, 4) work with faculty to consider ways the software can be integrated into the K-12 curriculum. Participating teachers will be provided with four hours of theory and four hours of hands-on operating and programming with FANUC robots and the RobotRun simulation software. To promote the field of robotics directly among the high school students, one day camp will be conducted annually at both institutions. Students will: 1) learn basic principles of industrial robots; 2) operate and program FANUC industrial robots; and, 3) utilize the gaming environment of the "RobotRun" simulation software to play embedded games and conduct basic programming tasks (in Years 2 and 3). Due to the remote location of Upper Peninsula schools, very few programs targeting STEM fields are available. The proposed camps will provide high school students with the extraordinary opportunity to learn and become engaged in STEM-related activities using the appealing nature of robotics. This early age engagement in STEM activities will help to create a clear path for the students to continue education through postsecondary institutions.

Conclusion

The primary merit of this initiative between Michigan Tech and Bay de Noc Community College is in how it reaches two- and four-year EET students with current concepts and hands-on practices in industrial robotics that meet current industry needs. There is significant demand from industry for well-prepared specialists capable of programming, maintaining, and troubleshooting modern robots. As a result, the goal was to develop a model curriculum and associated tools to address current and future industry expectations. In addition to enhancing STEM education at the college level, this collaborative project would provide a template for how other institutions can bridge the gap between academia and industry, and academia and K-12. These bridges are critical for providing new resources for recruiting and preparing a sustainable pipeline of graduates in robotics automation. Short-term outcomes include models for outreach that encourage early STEM interest, two certificates endorsed by industry, and faculty development workshops to reach other universities and colleges.

Development of an advanced, industry-driven, hands-on educational curriculum in robotics automation will improve the quality of STEM education for EET students at two- and four-year institutions. The RobotRun software will be freely available for adaptation, which will allow robotics to be taught even when the purchase of industrial robots is not feasible. Faculty development will include extensive training and industrial certification in robotics and automation. Partnership with FANUC will create an important ongoing link between academia and industry to ensure that the curriculum is regularly updated to meet emerging needs. K-12 teacher seminars will introduce advances in technology to those individuals playing a pivotal role in inspiring future generations of engineering technologists. The new robotics courses and equipment obtained via this collaboration will attract the interest of K-12 teachers and students, while simultaneously advancing undergraduate learning. Collaboration and dissemination will align university robotics automation education with industry needs. As a result of the project, engineering technologists will enter the workforce prepared to adapt to the complex and changing demands of tomorrow's high-tech workplace.

Acknowledgments

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

References

[1] International Federation of Robotics: Metra Martech Study on Robotics. (2011, February 21). Retrieved from http://www.ifr.org/uploads/media/Metra_Martech_Study_on_robots_02.pd)

[2] International Federation of Robotics. (n.d.) Retrieved from http://www.ifr.or

[3] Apple Inc. (2013, November 13). Retrieved from http://appleinsider.com/articles/13/11/13/apple-investing-record-105-billion-on-supply-chain-robots-machiner

[4] Manpower Group: Annual Talent Shortage Survey. (2014). Retrieved from http://www.manpowergroup.com/talent-shortage-explorer/#.VAnGjvmwJ8

[5] American Society for Training and Development Report. (2015). Retrieved from http://www.astd.org/Professional-Resources/State-Of-The-Industry-Repor

[6] Deek, F. P., Kimmel, H., & McHugh, J. (1998). Pedagogical changes in the delivery of the first course in computer science: Problem solving, then programming, *Journal of Engineering Education*, *87*(3), 313-320.

[7] Bureau of Labor Statistics. (2013, December 19). Replacement needs in 2008-18, 2008 National Employment Matrix Title and Code. Retrieved from http://www.bls.gov/emp/ep_table_110.ht

[8] Liming, D. & Wolf, M. (2008, fall). Job Outlook by Education 2006-16. *Occupational Outlook Quarterly*. Retrieved from http://www.bls.gov/careeroutlook/2008/fall/art01.pd

[9] Terrell, N. (2007). STEM Occupations. *Occupational Outlook Quarterly.* Retrieved from http://www.bls.gov/careeroutlook/2007/spring/art04.pd

[10] Bureau of Labor Statistics. (2013, January 8). *Occupational Outlook Handbook*. Retrieved from www.bls.gov/oc.

[11] Kuenzi, J., Matthew, C., & Mangan, B. (2006). *Science, Technology, Engineering, and Mathematics*

(STEM) Education Issues and Legislative Options. Congressional Research Report. Washington, DC: Congressional Research Service.

[12] Bonvillian, W. B. (2002). Science at a Crossroads. *The Federation of American Societies for Experimental Biology Journal*, *16*, 915-921.

[13] Gonzales, P., Guzmán, J. C., Partelow, L., Pahlke, E., Jocelyn, L., Kastberg, D., et al. (2003). *Highlights from the Trends in International Mathematics and Science Study (TIMSS)*. Washington, DC: U.S. Department of Education, National Center for Education Statistics.

[14] Lemke, M., Sen, A., Pahlke, E., Partelow, L., Miller, D., Williams, T., et al. (2004). *International Outcomes of Learning in Mathematics Literacy and Problem Solving: PISA 2003*. Results from the U.S. Perspective. Washington, DC: U.S. Department of Education, National Center for Education Statistics.

[15] Office of Science and Technology Policy. (2006, February). American Competitiveness Initiative—Leading the World In Innovation. Retrieved from http://www.innovationtaskforce.org/docs/ACI% 20booklet.pd

[16] Matariæ, M. J., Koenig, N., & Feil-Seifer, D. (2007, March). Materials for Enabling Hands-On Robotics and STEM Education. *AAAI Spring Symposium on Robots and Robot Venues: Resources for AI Education*, Palo Alto, CA.

[17] Whitman, L. E., & Witherspoon, T. L. (2003). Using Legos to Interest High School Students and Improve K12 STEM Education. *Proceedings of the 33rd Annual Frontiers in Education Conference*, *2*, F3A_6-F3A_10, 5-8.

[18] Robinson, M. (2005). Robotics-Driven Activities: Can They Improve Middle School Science Learning? *Bulletin of Science, Technology & Society*, *25*(1), 73-84.

[19] Mauch, E. (2001). Using Technological Innovation to Improve the Problem Solving Skills of Middle School Students. *The Clearing House*, *75(*4), 211-213.

[20] Barker, B., & Ansorge, J. (2007). Robotics as Means to Increase Achievement Scores in an Informal Learning Environment, *Journal of Research on Technology in Education*, *39*(3), 229-243.

[21] Beer, R. D., Chiel, H. J., & Drushel, R. (1999). Using Robotics to Teach Science and Engineering. *Communications of the ACM*, *42*(6), 85-92.

[22] Barnes, D. J. (2002). Teaching Introductory Java through Lego Mindstorms Models*, Proceedings of the 33rd SIGCSE Technical Symposium on Computer Science Education*, 147-151.

[23] Rogers, C., & Portsmore, M. (2004), Bringing Engineering to Elementary School. *Journal of STEM Education, 5*(3/4), 17-28.

[24] Nourbakhsh, I., Crowley, K., Bhave, A., Hamner, E., Hsium, T., Perez-Bergquist, A., et al. (2005). The Robotic Autonomy Mobile Robots Course: Robot Design, Curriculum Design, and Educational Assessment. *Autonomous Robots*, *18*(1), 103-127.

[25] Papert, S. (1980). *Mindstorms: Children, Computers, and Powerful Ideas*. New York: BasicBooks, Inc.

[26] Worldrobotics. (2009). Retrieved from http:// www.worldrobotics.org/ downloads/2009_First_News_of_Worldrobotics.pd

[27] Johnson, J. (2003). Children, Robotics, and Education. *7th Annual Symposium on Artificial Life and Robotics, 7*(1-2), 16-21.

[28] Fernandez, K. (2009). NASA Summer Robotics Interns Perform Simulation of Robotics Technology. *Proceedings of the ASEE Annual Conference,* AC 2009-328.

[29] Ciaraldi, M., (2009), Designing an Undergraduate Robotics Engineering Curriculum: Unified Robotics I and II. *Proceedings of the ASEE Annual Conference,* AC 2009-1161.

[30] Devine, K. (2009). Integrating Robot Simulation and Off-Line Programming into an Industrial Robotics Course. *Proceedings of the ASEE Annual Conference,* AC 2009-2159.

[31] Schneider, R. (2005). Robotic Automation Can Cut Costs. *Manufacturing Engineering, 135*(6), 65-70.

[32] Jones, T. (2006). Trends and Motivations for Robot Purchases. Retrieved from www.robotics.or

[33] Morey, B. (2007). Robotics Seeks Its Role in Aerospace. *Manufacturing Engineering*, *139(*4), 1-5.

[34] Nieves, E. (2005). Robots: More Capable, Still Flexible. *Manufacturing Engineering*, 134(5).

[35] Tolinski, R. (2006). Robots Step Up to Machining. *Manufacturing Engineering, 137*(3), 121.

[36] Devine, K. (2009). Agile Robotic Work Cells for Teaching Manufacturing Engineering. *Proceedings of the ASEE Annual Conference, AC 2009-2159.*

[37] Ciaraldi, M. (2009). Robotics Engineering: A New Discipline for a New Century. *Proceedings of the ASEE Annual Conference,* AC 2009-997.

[38] Alimisis, D. (2005). *Technical School Students Design and Develop Robotic Gear-Based Constructions for the Transmission of Motion*. In Gregorczyk G., Walat, A., & Borowiecki M. (eds.), Eurologo, Digital Tools for Lifelong Learning. Warsaw: DrukSfera, 76-86.

[39] Chang, D. (2009). Educating Generation Y in Robotics. *Proceedings of the ASEE Annual Conference*, AC 2009-750.

[40] Ren, P. (2009). Bridging Theory and Practice in a Senior-Level Robotics Course for Mechanical and Electrical Engineers. *Proceedings of the ASEE Annual Conference*, AC 2009-671.
[41] Piaget, J. (1974). *To Understand Is to Invent*. New York: Basic Books.
[42] You, Y. (2009) A Project-Oriented Approach in Teaching Robotics Application Engineering. *Proceedings of the ASEE Annual Conference*, AC 2009-2354.
[43] Michalson, W. (2009). Balancing Breadth and Depth in Engineering Education: Unified Robotics III and IV. *Proceedings of the ASEE Annual Conference*, AC 2009-1681.
[44] Liu, Y. (2009). From Handy Board to VEX: The Evolution of a Junior-Level Robotics Laboratory Course. *Proceedings of the ASEE Annual Conference,* AC 2009-1890.
[45] Karatrantou, A. (2004). Introduction in Basic Principles and Programming Structures Using the Robotic Constructions LEGO Mindstorms. *Proceedings of the 3rd National Conference, Teaching Informatics, University of Peloponnese.*
[46] Eslami, A. (2009). A Remote-Access Robotics and PLC Laboratory for Distance Learning Program. *Proceedings of the ASEE Annual Conference,* AC 2009-1410.
[47] Watson, J. B., & Rossett, A. (1999). Guiding the Independent Learner in Web-Based Training. *Educational Technology*, *39*(3), 27-36.
[48] Stienecker, A. (2008). Applied Industrial Robotics: A Paradigm Shift. *Proceedings of the ASEE Annual Conference*, AC 2008-861.
[49] Lake Superior State University. (2008). Retrieved from https://www.lssu.edu/programsofstudy/engineering-manufact
[50] FANUC Authorized Satellite Training Program (F.A.S.T). (2015). Retrieved from http://robot.fanucamerica.com/support-services/robotics-training/schools.asp
[51] MLive Michigan. (2010). Retrieved from http://www.mlive.com/michigan-jobsearch/index.ssf/2010/02/its_official_michigan_is_the_toughest_pl.htm

Biographies

ALEKSANDR SERGEYEV is associate professor in the Electrical Engineering Technology program at Michigan Tech. He is a faculty advisor for the Robotics System Enterprise and a FANUC-certified instructor in robotics. Dr. Sergeyev oversees all activities of the FANUC-authorized certified training center at Michigan Tech. He has developed and taught courses in the areas of robotics and automation, power, electrical machinery, programmable logical controllers, digital signal processing, and optics. He has a strong record publishing in prestigious journals and conference proceedings including Measurements Science and Technology, Adaptive Optics, Sensors and Materials, The *Technology Interface International Journal*, ASEE, IEEE, and SPIE. Additionally, Dr. Sergeyev is a co-PI on several NSF and DOL awards, and a PI on multiple significant industry awards. Dr. Sergeyev may be reached at avsergue@mtu.edu

NASSER ALARAJE is an associate professor and the program chair of electrical engineering technology at Michigan Tech. Prior to his faculty appointment, he was employed by Lucent Technologies as a hardware design engineer (1997-2002), and by vLogix as a chief hardware design engineer (2002-04). In 2009, Dr. Alaraje was awarded the Golden Jubilee by the College of Engineering at Assiut University, in Egypt. He has served as an ABET/IEEE-TAC evaluator for electrical engineering technology and computer engineering technology programs. Dr. Alaraje is a 2013-14 Fulbright scholarship recipient at Qatar University, where he taught courses on embedded systems. Additionally, he is the recipient of an NSF award for digital logic design curriculum revision in collaboration with the College of Lake County in Illinois, and an NSF award in collaboration with the University of New Mexico, Drake State Technical College, and Chandler-Gilbert Community College, that focused on expanding outreach to increase awareness of precollege students about career opportunities in electronics technologies. Dr. Alaraje may be reached at alaraje@mtu.edu

SCOTT KUHL is an associate professor of computer science, advisor to the Husky Game Development (HGD) Enterprise, and an adjunct faculty member in the Applied Cognitive Sciences and Human Factors program at Michigan Tech. His primary areas of research include immersive virtual reality systems, such as head-mounted displays, and human perception. He has published in the ACM *Symposium on Applied Perception* and ACM *Transactions on Applied Perception* and other venues. Dr. Kuhl has worked on NSF and Department of Labor projects and has received corporate and industry sponsorships for HGD Enterprise. Dr. Kuhl may be reached at kuhl@mtu.edu

MICHAEL MEYER is both the director of the William G. Jackson Center for Teaching and Learning and a senior lecturer in physics at Michigan Tech. His current position focuses on helping faculty improve instruction by implementing research-based pedagogy and technology. He conducts new faculty and graduate teaching assistant orientations as well as regular professional development workshops for faculty. He supervises student evaluations of instruction at Michigan Tech and provides consultation in effective teaching practices. He has participated on NSF review panels and presented on teaching innovations at regional and national conferences. Mr. Meyer may be reached at mrmeyer@mtu.edu

MARK KINNEY is dean of business and technology at Bay de Noc Community College (Bay College). Previously, he oversaw workforce development for the college and served as executive director of institutional effectiveness and research. He was also dean for computer information systems and technology at Baker College of Cadillac from 2007-09. Mark's education is in the areas of business administration and computer information systems. He is completing a dissertation that would grant him an Ed.D. from Central Michigan University. Mark has taught a variety of classes at the college level, including those relating to SQL and relational database management, intermediate spreadsheet applications, management information systems, the Internet and the World Wide Web, and a variety of Microsoft Office applications. Mark served on the development team for the AACC's Voluntary Framework of Accountability and on the advisory board for the MCCA's Center for Student Success. Mr. Kinney may be reached at kinneym@baycollege.edu

MARK HIGHUM is an instructor in the Computer Networks and Security program at Bay College. He holds certifications in information technology, including an MSCA in Windows Server (2003). Prior to teaching computer networks, Mr. Highum taught in the electronics and automation programs. He holds the Certified Electronics Technician-Senior certification from the Electronics Technicians Association. He has taught classes for credit and for industry in the fields of robotics, mechatronics, electronics, electrical machinery and controls, and programmable logic controls. He has been actively involved in the SkillsUSA Mechatronics contest since 1999. As part of that involvement, he helped train the first U.S. team to compete in mechatronics at the World Skills contest in 2003. Mr. Highum may be reached at highumm@baycollege.edu

A PROJECT IN OUTREACH AND SERVICE LEARNING: NANOTECHNOLOGY LECTURES DELIVERED BY UNDERGRADUATE STUDENTS TO A LOCAL HIGH SCHOOL

Gene L. Harding, Purdue University

Abstract

College and university students, or u-students, are often used in K-12 engagement/outreach activities. Such activities include summer camps, competitions during the academic year, workshops, internships, and evening programs. In this paper, the author describes a novel approach: taking u-students into the high school (HS) classroom to teach students about topics from the university courses.

In the spring 2012 semester, the author taught a course entitled "Introduction to Nanotechnology" for the first time at his location, which is a satellite campus over 100 miles away from the main campus. The students were required to develop a learning module and deliver it to a local high school. There were two primary goals: 1) evaluate how well his students developed and delivered the material, and 2) evaluate how well his students assessed the HS students' understanding of the material. A secondary goal was evaluating how well the HS students understood the material.

Discussed in this paper are:

- details of the project assignment;
- the approach used by each of the author's student groups to teach and assess the material;
- the demographic of each HS class taught;
- assessment results of the HS students' learning;
- the author's assessment of his u-students' performance;
- feedback from the HS teachers, HS students, and the author's students; and,
- lessons learned from the experience.

Introduction

It is fairly common to use university students, or u-students to help with activities designed to engage high school (HS) students. Such activities take a number of different forms, including:

- Having u-students help with camps, typically bringing HS students to the university campus during the summer when facilities are more available [1-3];
- Conducting competitions during some or all of the academic year involving local HS students and teachers [4, 5];
- Bringing HS students to campus for one-day workshops to learn about what college is like and/or what is involved in various technical disciplines [6-8];
- Research internships for HS students [9];
- U-students training middle school and high school educators, who in turn engage their students [10]; and,
- Periodic evening programs offered during the school year [11].

The approach described here is a little different. In this case, the author's class was divided into three-student teams that developed presentations based on material learned in that course, and each team was assigned to teach a different class at a local high school. In addition to developing the technical material and presenting it, the students were also responsible for assessing how well the HS students learned the material presented. This was a new concept for most of them.

Course Overview and Project Assignment

The author taught an introductory course in nanotechnology developed by one of his colleagues at the main campus. [12] The course is a broad, high-level overview of nanotechnology with a lab focus on scanning probe microscopy (SPM) with the following learning objectives:

- Identify the basic concepts behind nanotechnology.
- Characterize electrical material at the nano level.
- Analyze nanocomposite materials.
- Describe the tools of nanotechnology.
- Use the SPM.

A colleague set up the course with a special project requirement, 25% of the course grade, to develop a learning module that could be delivered to a primary or secondary school class. The u-students were given wide latitude to select a topic related to nanotechnology. Since the purpose of the course was to study nanotechnology, not K-12 pedagogy, the key objective of the special project was to deepen the u-students' understanding of some area of nanotechnology, not to actually teach HS students. The author used a similar approach with the special project, but decided to modify it slightly. Because there was an ongoing relationship with faculty members at several area high schools, it was decided to take the project one step further and require students to deliver it to one of the schools (i.e., turn theory into practice) and assess its effectiveness. The live presentations had both service learning [13] and outreach components: the HS staff wanted to generate interest in a nanotechnology course they were planning to offer the following year, and the author aimed to raise awareness of the university's local presence.

The project instructions included several ideas for topics, but they were suggestions only. The students were encouraged to be creative in selecting a topic and method of presentation. The project was partitioned into six phases, listed in chronological order with grade weightings in Table 1. It was assigned about halfway through the semester, late enough to have covered a good portion of the course material, but early enough to allow ample time for development of the project and delivery of the presentation. The project assignment is included in Appendix 1.

Table 1. Project Grade Weightings

Grading Phase	Points
Presentation Outline	10
Draft Learning Module	10
Final Learning Module	15
Practice Presentation	15
Final Presentation	40
Assessment	10
Total	100

Approaches Used

The university class consisted of nine students in good academic standing, all male, and all majoring in electrical engineering technology at Purdue University-South Bend. They were divided into three groups of three-student instructors for this project. All three-student instructor groups chose to use PowerPoint presentations, but two of the groups augmented their presentations. Group 2 led an interactive quiz session during which the students competed in groups against each other, while Group 3 chose to do a demo. They constructed an enlarged model of the cantilever used in an atomic force microscope (AFM), along with a feature for it to "probe" so that they could demonstrate what happens unseen as an AFM probes the topography of a surface. Group 1 set three learning objectives for their nanotechnology presentation: learn some basic terms, learn about tools and techniques, and learn some applications. They split their presentation into three sections, one for each objective, and each of them presented one section. They began the first section with a short quiz to assess the HS students' current knowledge, and concluded their presentation with a summative quiz to assess how much knowledge was gained. Their approach was well thought out, although their second objective was worded too broadly; the only tool/technique discussed in detail in the course was the AFM, but it is only one of several tools used in nanotechnology. Group 1's presentation outline is included in Appendix 2.

The second group also came up with a pretty good plan, although they got the terminology of learning objectives, presentation details, and assessments confused. They also divided their presentation into three parts, one per student: background and overview, applications in new materials, and applications in biology. They decided to follow their presentation with a fun activity to reinforce the material. The class was split into teams and quizzed on the material, with the teams competing against each other in "game show" fashion. A written quiz followed this activity to assess the HS students' learning. This group was the rowdiest of the three, in part because of the quiz activity and in part because of the personalities of the instructor students and the HS teacher. On the other hand, since they were having fun, the students were highly engaged, so the session was effective. Group 2's presentation outline is included in Appendix 3.

Group 3 decided to start with a general discussion of technology, then the scale used in nanotechnology, and finally a somewhat detailed discussion of how an AFM works, including a demo with a large model of an AFM cantilever probe. They paused several times during their presentation to review key topics and do a short group question/answer session. Initially, they planned to use a short essay from the HS students to do their assessment; but, after discovering the grading challenges associated with such an assessment, they ultimately decided to go with a multiple-choice quiz instead. Their presentation outline is included in Appendix 4. Table 2 summarizes the presentation and assessment approaches used.

Table 2. Presentation and Assessment Approaches by Group

	Group 1	Group 2	Group 3
Presentation Approach	Slides only	Slides + Game	Slides + Model
Initial Assessment Approach	Multiple Choice	Multiple Choice	Essay
Final Assessment Approach	Multiple Choice	Multiple Choice	Multiple Choice
Questions in Quiz	14	9	10
Options per Question	4	4	3

High School Student Demographics

The local high school involved was very large (3500+ students). The department head chose the classes to receive presentations: three different classes with three different teachers. The first class, which received the presentation from u-student Group 1, was a regular-level sophomore Chemistry I class of 29 students. The second class, which received the presentation from Group 2, was a freshman Honors Biology I class of 29 students. The third class, receiving the presentation from Group 3, was a sophomore Chemistry I Honors class of 26 students. [14] All three classes had a fairly even distribution of male and female students. For privacy reasons, no personally identifiable information (PII) was collected. Each HS student used the last four characters from his/her student identification card instead of his/her name. This allowed the HS teachers to track grade information while preserving the students' privacy.

Assessment of High School Student Performance

All three groups decided to use multiple-choice quizzes to do their summative assessments: 14 questions for Group 1; nine for Group 2; and ten for Group 3. The first two groups used questions with four options, while the third group used questions with only three options. As might be expected, both of the Honors classes outperformed the standard class, although they also both benefitted from augmented presentations (group quiz competition for Group 2, and demo model for Group 3). Moreover, the high scores in Group 3 may also be partially due to the use of three-option questions. The average scores for each of the classes are shown in Table 3.

The assessment analysis portion of the assignment was left very open-ended. The requirement was just to be "clear and individually quantified." Individual scoring was done using codes, based on a portion of the student ID in order to avoid the possibility of collecting personally identifiable information. All three groups reported raw scores as m of n points, but reporting approaches diverged from there. Group 1 decided to report the individual scores in a table as a raw score of m out of 14 points, and as a percentage. They additionally aggregated the scores into two histograms: one that reported the raw scores, which ranged from 8-14, and one that reported the letter grades A-F. Their assessment is included in Appendix 5. Group 2 focused on missed problems. They reported the following: individual scores as raw scores out of 18 points, specific problem(s) each student missed, and both a table and a histogram showing how many students missed each problem. This approach has the useful advantage of revealing questions with high "miss" rates, which generally indicate either a topic that needs to be reinforced or a question that was formed poorly. The Group 2 assessment is shown in Appendix 6.

Table 3. Average Quiz Scores by Class

Group	Class	Quiz Average
1	Chem I	75%
2	Honors Biology I	90%
3	Honors Chem I	96%

Group 3 chose to do a table reporting how each student did on each problem. Their table lists student numbers down the left side and quiz question numbers across the top. Although not done, it would be simple to add a row to their data table to aggregate scores by problem, and thus reveal "miss" rates. Group 3's report is shown in Appendix 7. It should be noted that the results would be skewed if any of the HS students received more than one presentation. Although no personally identifiable information was collected, a careful review of the student identification numbers revealed that all were unique, confirming that each student only saw one presentation.

Assessment of University Student Performance

The six phases of the assignment were weighted such that each phase was worth at least one letter grade. The Final Presentation was the heart of the assignment, so it was 40% of the project grade. Details of the grading rubric are shown in Appendix 8. The students performed well in this assignment. Average class grades for the individual components ranged from a low of 83% (8.3/10) for the Draft Learning Modules to a perfect 10/10 for the Assessments. The class average for the whole project was 91.1%, with a high of

Table 4. Project Grade Summary

Assignment	Outline	Draft Learning Module	Final Learning Module	Practice Presentation	Final Presentation	Assessment	Total
Point Value	10	10	15	15	40	10	100
Class Average	8.7	8.3	12.7	13.7	37.8	10.0	91.1
High	9	9	15	15	40	10	98
Low	8	7	9	11	33	10	80

98% and low of 80%. Details of the class's performance are shown in Table 4. The author graded more "gently" than usual on this project, because all of the students were engineering technology majors, not education majors. Nevertheless, the observations and the students' scores indicated a high level of success.

Feedback

Although there were no formal surveys done to collect feedback, the author did get feedback directly from the u-students and the HS teachers, and indirect feedback from the HS students via their teachers. The HS teachers all said that they enjoyed and appreciated the sessions. One of them even requested a repeat performance the following year. This particular topic turned out to be a great fit at this high school, because they were considering offering a course in nanotechnology and hoped the university presentations would spur interest. Likewise, the HS students generally seemed to appreciate the presentations. Their attentiveness, body language, and facial expressions implied a moderate to high level of engagement for most of the students. The indirect student feedback from the teachers was also positive, although it is hard to know how much negative feedback the students would give their teachers and whether the teachers would pass that on or not.

The author's own students gave mixed reviews. Most of them agreed that assembling and teaching a block of material forced them to learn it better. On the other hand, some found the assignment fun and energizing and had a great time doing presentations at the local high school. A minority of the students, although they did not say they "disliked" it, were clearly less enthused about the project. Then again, those students probably were not really "enthused" about any assignments. One interesting note: The author observed that there was not a consistent correlation between level of enthusiasm and project grade.

Lessons Learned

The two primary goals and one secondary goal of this research were met. The data indicated that:

1. The university students did a good job of creating and delivering a nanotechnology learning module for local high school students (average grade range 83 – 94%);
2. The university students assessed the high school students' learning with reasonable effectiveness (average grade 100%); and,
3. The high school students learned the material, at least in the short term (average class grades from 75 – 96%).

There are, of course, areas for possible improvement. First, the quiz format could be standardized, such as listing the same number of options for each question and using the same number of questions. Further, a core set of questions could probably be developed, so that at least part of each quiz would be directly comparable to the other quizzes. Second, it would be interesting to survey the HS teachers and students to get a more formal, standardized set of responses. This project was reviewed and approved by the university's Institutional Review Board (IRB). This process protects the subjects involved in the research, in this case the HS students. Safeguards were used to ensure no personally identifiable information was collected and that the research project clearly met the exemption standards established by federal law. [15] An application and online training were required, along with several email and phone discussions with the university's IRB representative. Although critically important, the training and paperwork involved were quite substantial and should not be underestimated.

The author observed a few benefits to the class during this project. Development and delivery of the learning module forced the students to learn the material better, reinforcing the class learning objectives. It also gave them a better idea of what is involved in creating, delivering, and assessing a teaching module. Finally, it provided an opportunity to serve the community by engaging a local high school. On the other hand, there were several costs associated with this effort. Three of the lecture periods, 10% of the semester's lectures, were dedicated for the practice presentations. This was sufficient for this class because it was small, nine students, but could be untenable for larger classes. (Perhaps there would be a way to handle it with teaching assistants, but there are none at the author's location.) Moreover, each lecture set aside for a practice presentation reduced the time that could be spent covering new material. Finally, the bureaucracy associated with human subjects research can be discouraging, and at times may seem disproportionate to the research effort and legal requirements.

Conclusions

The primary and secondary goals of developing and delivering a nanotechnology learning module, and assessing the success of both the university and high school students, were achieved. The big drawbacks were giving up lecture periods for the practice presentations and the bureaucracy associated with the human subjects research. This course has not been taught again at the author's location, and none of the other courses he teaches have room for the engagement activity discussed above, so it has not been tried since. There were both good and bad aspects to the activity, and instructors considering the costs to be an acceptable price to pay for the benefits achieved may want to consider such a project in their courses.

References

[1] Fletcher, R. (2000). Using an Alternative Energy Summer Camp for High School Students as a University Outreach Program for the Recruitment of Future Engineering Students: A Two-Year Study. *Proceedings of the 2010 ASEE Annual Conference and Expo*.

[2] Electric go-kart summer camp. Retrieved July 29, 2015 from https://polytechnic.purdue.edu/newsroom/electric-go-kart-summer-cam

[3] Operation Catapult. Retrieved July 29, 2015 from http://www.rose-hulman.edu/admissions-financial-aid/early-planning/operation-catapult.asp

[4] Rogers, J., & Cobb, S. (2007). The Regional Moonbuggy Competition: A Unique, Year-long Outreach Program to High School Students. *Proceedings of the 2007 ASEE Annual Conference and Exposition*.

[5] Harriger, A., & Harriger, B. (2015). Generating Interest in ET Through High School Competitions. *Proceedings of the 2015 ASEE Annual Conference and Exposition*.

[6] Harding, G., & Sanders, M. (2012). Project Lead the Way Conference for Recruiting: A Small-Campus Outreach to Local High School Students. *Proceedings of the 2012 ASEE Annual Conference and Exposition*.

[7] Davis, W., Villa, E., & Stafford, S. (2001). Discover Engineering Day: Collaborations in Pre-College Recruitment. *Proceedings of the 2001 ASEE Annual Conference and Exposition.*

[8] Schaffer, R., Dues, J., Cooley, T., & Sisk, D. (2008). High School Recruiting that Works: The "Day in College." *Proceedings of the 2008 ASEE Annual Conference and Exposition*.

[9] Beck, M. R., Morgan, E. A., Strand, S. S., & Woolsey, T. A. (2006). Volunteers Bring Passion to Science Outreach. *Science*, *314*, 1246-1247.

[10] Zephirin, T., Mayy, M., Cox, M. F., & David, T. S. (2012). The Development of an Outreach Activity Introducing Middle and High School Students to Nanotechnology and Carbon Nanotubes. *Proceedings of the 2012 ASEE Annual Conference and Exposition*.

[11] Long, D., Sutterer, K., & Berry, F. (2003). Explore Engineering: Rose-Hulman's Outreach to Middle and High School Students. *Proceedings of the 2003 ASEE Annual Conference and Exposition*.

[12] ECET 32100, Introduction to Nanotechnology. Retrieved July 29, 2015 from https://polytechnic.purdue.edu/courses/ecet-32

[13] Buck, J. L., Conley, S., Harris, B. G., & McInnis, E. Y. (2012). Service Learning: Bridging the Gap Between Classroom Theory and Application. *Technology Interface International Journal,* 12(2), 66-72.

[14] Penn High School course descriptions web page. Retrieved July 29, 2015 from http://penn.phmschools.org/scienc

[15] Basic HHS Policy for Protection of Human Research Subjects, Title 45 CFR 46.101, (b)(1) and (b)(2). Retrieved February 1, 2015 from http://www.hhs.gov/ohrp/humansubjects/guidance/45cfr46.html#46.10

Biography

GENE L. HARDING is an associate professor of electrical and computer engineering technology at Purdue University, where he has taught for 12+ years. He has three years' of industrial experience with Agilent Technologies, 28 years' of combined active and reserve service in the United States Air Force, holds an MSEE from Rose-Hulman Institute of Technology, and is a licensed professional engineer. Dr. Harding may be reached at glhardin@purdue.edu

Appendices

1. Project assignment
2. Group 1 presentation outline
3. Group 2 presentation outline
4. Group 3 presentation outline
5. Group 1 assessment of high school students
6. Group 2 assessment of high school students
7. Group 3 assessment of high school students
8. Project assignment grading rubric

Appendix 1: Project Assignment

ECET321 Introduction to Nanotechnology
Project Assignment

The class will be divided into groups. Each group will develop a nanotechnology project in the form of a K-12 demonstration of a nanotechnology concept. There are many ideas on the internet for these activities. You are welcome to view these for ideas, but do not replicate them.

The subject area (within nanotechnology) of your project is your choice. However, consulting the course instructor considering the subject matter is ***highly recommended***.

Progress on your project should be conveyed periodically to your instructor. The timeline is:

08 Mar: Outline due (all groups)
This should include a title, learning objectives, presentation approach, and assessment approach. Put some thought into a title that is both descriptive and interesting. Craft two or three learning objectives that are clear, achievable, and assessable (i.e., testable) in the given timeframe. Describe the basic approach to the presentation, and how you will assess its success.
20 Mar: Draft learning module due (all groups)
27 Mar: Final learning module due (all groups)
29 Mar: Group 1 class presentation
03 Apr: Group 2 class presentation
05 Apr: Group 3 class presentation
10 Apr: Presentations at Penn High School
10, 12 Apr: No class ☺

The presentation should include the following:

1. Background information about the concept and why it is important (5-10 minutes).
2. Detailed presentation of the topic (about 45 minutes). The main presentation could be an interactive activity, a problem or puzzle to solve, a PowerPoint presentation, a demonstration of some sort (live or online), or something else. Creativity is encouraged.
3. An assessment to evaluate the effectiveness of the demonstration (15-20 minutes).
4. References.

The project must include all members of the team (equal effort among team members).

A few ideas include:

Length scale
Use of the nanoHUB
Nanoparticle synthesis or assembly
Nanotechnology tools/techniques, such as scanning probe microscopy
Electrical characteristics at the nanoscale
Carbon nanotubes
Nanoelectrical measurements
Nanoelectrical devices

Appendix 2: Group 1 Presentation Outline

Title 1/2
LOs 3/3
Pres approach 3/3
Asmt " 2/2

9/10

Nanotechnology Presentation Outline
3-8-12

1. Title: Nanu Nano --> Cute, but what does it mean? -1
2. Learning Objectives
   a. Learn the meanings of "nanotechnology" and "nanoscale" ✓
   b. Learn about the tools and techniques used in nanotechnology → Too broad, narrow scope
   c. Learn some applications of nanotechnology
3. Presentation – The presentation will start with a short quiz to assess the student's current level of knowledge. The main part of the presentation will consist of three sections. Each section will consist of a powerpoint presentation, and a short activity to reinforce the powerpoint.
   a. Introduction (John)
      i. What is nanotechnology?
      ii. Nanoscale
      iii. History
      iv. Nanoscale Activity – (Worksheet to be completed in pairs)
   b. Tools and Techniques (Nathan)
      i. Atomic Force Microscope
      ii. Electron Microscope
      iii. Nanoparticle Synthesis and Assembly
      } Consider focusing on one & minimally covering the others.
      iv. Nanotechnology Tools Activity (video and/or worksheet)
   c. Applications (Dean)
      i. Electronics
      ii. Healthcare
      iii. Materials
      iv. Nanotechnology Applications Activity (video and/or worksheet)
4. Assessment – (Quiz)
   a. Results will be compared with the initial quiz to assess the success of the presentation

Well thought-out.

Remember the time restriction.

Appendix 3: Group 2 Presentation Outline

Title 2/2
LOs 2/3
Pres approach 3/3
Asmt " 2/2

9/10

ECET 321
K-12 Outline
Spring 2012

Where Biology and Technology Collide:

A Brief introduction to Nanomedical Systems

Learning objectives:

The details should go under "presentation." Each LO should be measurable so you can assess it. For example, ...

1. Define and introduce nanotechnology
   a. Problems working at the nanoscale
   b. A brief history of transistor technology
   c. Moore's Law
2. What else can we do with nanotechnology besides transistors?
   a. New materials
   b. Nanomagnets
3. Nanotechnology and Biology
   a. Nanomedicine
   b. Nanomedical systems
   c. NASA and Dr. Leary's team

Presentation Approach:

Specify what kind. I will need to get approval from Penn HS officials.

The presentation will start off by bribing their attention span with food. We will then discuss the material stated in the learning objectives. The goal is to keep the presentation lite and entertaining while keeping the new vocabulary to a minimum.

Sounds like this is really part of the presentation activit[y]

Assessment Approach:

The assessment will have two parts. The first part will divide the class into teams and quiz the class in a small group competition. The format serves a few functions. First, it will allow for an interactive environment while refocusing the students' attention. Second, it will make learning fun. Finally, it will reinforce the material. The second part of the assessment will be a written quiz.

This is the formal assessment.

LO #1 is what you will do. What do you want the students to do?
1.a. is a good start. It sounds like you may want LO #1 to be something like "Understand the meaning of nanoscale & explain some challenges when working at that [scale]." (Put into your own words.)

Appendix 4: Group 3 Presentation Outline

Title 2/2
LOs 1/3
Pres approach 3/3
Assmt " 2/2

8/10

Title: Beyond the Microscope, Nanotechnology Tools and Techniques ✓
Subject: Nanotechnology tools/techniques
Audience: Chemistry honors
Time: 12:04-1:45 p.m.
Presenters: [illegible]

Learning objectives:

1. Photo-lithography
2. AFM
3. SEM
4. Length scale

−2 These are not objectives; they are topics. It is not clear what exactly you want them to learn, which makes it impossible to know if you have succeeded.

Presentation approach:

1. 3d model blown up feature and blown up cantilever. We will use it to describe how an AFM works (contact non-contact). We will also use power point. ✓

Assessment approach:

1. Group question and answer (for correct answers we will give them candy)
2. Short essay response

This should probably be part of the presentation "activity."

You will need to develop a (grading) rubric to clarify what needs to be included in the essay.

Consider making #4 → #1 & dropping #1 & #3. You can still include SEM & lithography in the presentation, but it's probably too much to make them objectives & assessment points.

Appendix 5: Group 1 Assessments

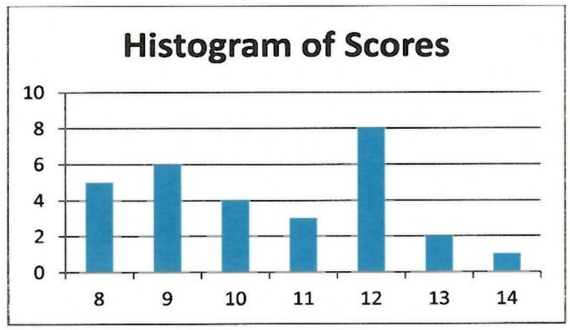
Group 1

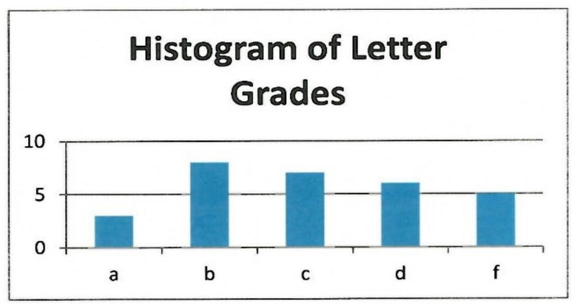
Penn H.S. Assessments

Group 1

29 students

Student #	Scores (points out of 14)	Scores (%)
A-290	12	86%
B-002	14	100%
B-375	9	64%
B-397	12	86%
B-571	10	71%
C-456	11	79%
C-718	8	57%
D-378	13	93%
G-224	10	71%
G-270	10	71%
G-386	10	71%
H-359	11	79%
H-384	12	86%
H-389	12	86%
J-372	9	64%
L-614	8	57%
M-005	11	79%
M-256	9	64%
M-428	8	57%
P-673	12	86%
S-024	9	64%
S-031	8	57%
S-151	8	57%
S-199	12	86%
S-820	9	64%
V-040	9	64%
V-808	13	93%
W-014	12	86%
W-641	12	86%
Average:	10.44828	75%





Appendix 6: Group 2 Assessments

ECET 321 Presentation Group 2

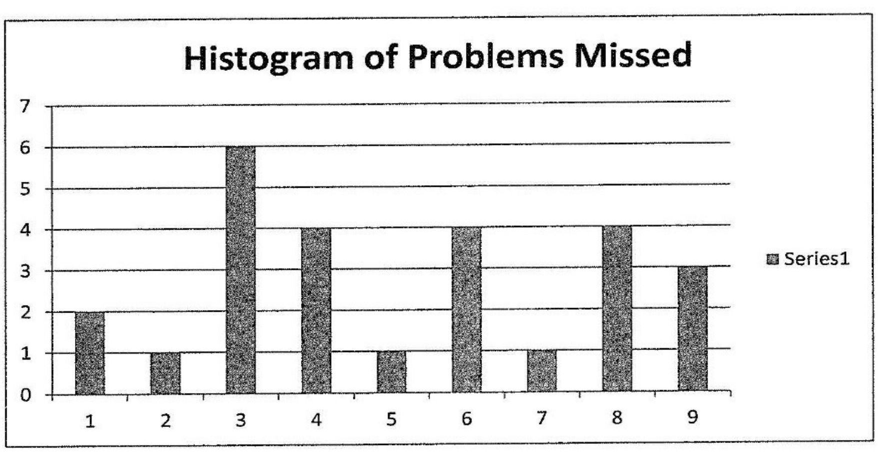
Student	Score	Problems Missed
A105	18	
B085	16	8
B093	8	3 4 6 7 9
B165	18	
B217	16	1
D295	16	2
E214	18	
G121	16	3
H101	18	
J693	18	
K065	18	
K078	18	
K118	14	6 8
K516	18	
K830	16	1
L035	18	
L215	18	
M070	8	3 5 6 8 9
M228	16	8
O514	16	3
P066	14	3 4
R023	18	
S036	18	
S227	12	4 6 9
T264	16	4
V093	16	3
W015	18	
W078	18	
W100	18	

Average	Percent
16.21	90.04

Problem Number	Occurences Missed
1	2
2	1
3	6
4	4
5	1
6	4
7	1
8	4
9	3

29 students

Group 2



Appendix 7: Group 3 Assessments

Group #3: Beyond the Microscope

Student	1	2	3	4	5	6	7	8	9	10	Total	Percentage
P 950	1	1	0	1	1	1	1	1	1	1	9	90
M 603	1	1	1	1	1	1	1	1	1	1	10	100
P 023	1	1	1	1	1	1	1	1	1	1	10	100
H 637	1	1	0	1	1	1	1	1	1	1	9	90
Cmoore 541	1	1	1	1	1	1	1	1	1	1	10	100
G 218	1	1	1	1	1	1	1	1	1	1	10	100
H 495	1	1	1	1	1	1	1	1	1	1	10	100
C 196	1	1	1	1	1	1	1	1	1	1	10	100
G 320	1	1	1	1	1	1	1	1	1	1	10	100
S 315	0	0	0	1	1	1	1	1	1	1	7	70
E 266	1	1	1	1	1	1	1	1	1	1	10	100
M 813	1	1	1	1	1	1	1	1	1	1	10	100
W 346	0	1	0	1	1	1	1	1	1	1	8	80
J 991	1	1	0	1	1	1	1	1	1	1	9	90
A 431	1	1	1	1	1	1	1	1	1	1	10	100
L 000	1	1	1	1	1	1	1	1	1	1	10	100
E 033	1	1	1	1	1	1	1	1	1	1	10	100
B 411	1	1	1	1	1	1	1	1	1	1	10	100
L 316	1	1	1	1	1	1	1	1	1	1	10	100
K 380	1	1	0	1	1	1	0	1	1	1	8	80
R 610	1	1	0	1	1	1	1	1	1	1	9	90
S 008	1	1	1	1	1	1	1	1	1	1	10	100
B 197	1	1	1	1	1	1	1	1	1	1	10	100
N 228	1	1	1	1	1	1	1	1	1	1	10	100
B 216	1	1	1	1	1	1	1	1	1	1	10	100
3409	1	1	1	1	1	1	1	1	1	1	10	100

High	100
Low	70
Average	95.77

26 students

Group 3

BEYOND BRICK AND MORTAR: A MOBILE TECHNOLOGY ECOSYSTEM AT AN HISTORICALLY BLACK COLLEGE AND UNIVERSITY

Dawn Bishop McLin, Jackson State University; Jessica L. Murphy, Jackson State University

Abstract

In this paper, the authors present the lessons learned from the implementation of a mobile technology ecosystem at Jackson State University (JSU). The Technology Advantage Scholarship Initiative (TASI) provided tablet computers (Apple iPads) to over 900 first-time, full-time freshman in the fall of 2012. Implementing the TASI required redesigning the curriculum, building a learning community for digital natives, training faculty to teach on tablets, and expansion of the classroom through the use of embedded e-textbooks. Since 1877, JSU has been providing young men and women opportunities that will empower them to succeed in an increasingly complex world. JSU is the largest Historically Black College and University (HBCU) in the state of Mississippi. JSU emphasizes public service programs designed to enhance quality of life and seeks solutions to urban problems in the physical, social, intellectual, and economic environments. This new cyber learning ecosystem community provided a vehicle for student engagement, the expansion of the classroom learning environment, student development of primary source materials, and the extension of teaching practices that move beyond the traditional brick-and-mortar lecture format.

Introduction

The face of the 21st century classroom is ever-changing. Innovations in technology are influencing how students access, learn, retain, and apply information; and they influence the educator's pedagogy in using technology as instructional aids. Mobile technologies are playing an increasingly important role in college students' academic lives. Devices such as smartphones, tablets, and e-book readers connect users to the world instantly, heightening access to information and enabling interactivity with others. Applications that run on these devices let users not only consume, but also discover and produce content. The popularity of mobile technologies among college students is increasing dramatically. It is no secret that undergraduate students bring their own digital devices to college, favoring small and portable ones such as smartphones and tablets. Nationwide, there is a shift in higher education from bound textbooks and printed research materials to mobile technology that includes electronic texts and online resources. On many four-year college campuses, 21st century students are putting the old bound textbook on the back burner. E-textbooks have moved from occasional usage to mainstream technology on college campuses [1]. E-textbooks are defined as a textbook in electronic or digital form.

There are numerous advantages of e-textbooks over printed textbooks. Researchers have found that some e-textbooks are free, or at least cheaper, and lighter than their printed counterparts, and a number of books could be carried or downloaded onto a mobile technological device such as an iPad [2]. Doering et al. [3] found that these devices are environmentally friendlier, appeal to a generation accustomed to using electronic devices, can be revised and delivered quicker, and do not result in obsolete inventories. Turner [4] noted that e-textbooks offer students an interactivity component, where they can click on any word that is not understood and be taken immediately to a definition of the word. The ability of students to download embedded assignments, pictures, videos, music and other supplementary materials; underline and highlight text; and make notes and open hyperlinks can provide for a more diverse and richer learning opportunity. E-textbooks facilitate communication between professors and students as well as among themselves. This, in turn, will form a collaborative relationship between students sharing items like class notes and building a social environment that promotes learning [3].

According to the National Academy of Engineering, the National Research Council, and the International Technology Education Association [5], technology skills are essential for all people living in the increasingly technology-driven world. "Technological Literacy is the ability to use, manage, assess and understand technology." "Technological literacy encompasses three interdependent dimensions: 1) knowledge; 2) ways of thinking and acting; and, 3) capabilities." "Technological literacy is more of a capacity to understand the broader technological world rather than an ability to work with specific pieces of it" [6]. Technologically literate persons are problem solvers, who consider technological issues from different points of view, relate them to a variety of contexts, and ask pertinent questions of themselves and others regarding the benefits and risks of technology. Technological literacy is important because technology affects almost every phase of our lives. It enables people to perform their daily tasks and supports their ability to make informed, responsible decisions that affect them as individuals, society as a whole, and the environment. Today's leaners must have a basic understanding of how technology affects their world and how they exist both within and around technology. The National Research Council and the International Technology Education Association all stress the importance of technological skills or literacy [7], and HBCUs are working diligently to promote technology innovation in the classroom.

Importance of HBCUs

Historically Black Colleges and Universities (HBCUs), have traditionally provided an education for people who might not otherwise have the opportunity or are minority serving institutions that have been proven to promote the college success of African American college students [8]. A recent report from the National Science Foundation revealed that 21 of the top 50 institutions for producing African American graduates going on to receive their doctorates in science and engineering (S&E) are HBCUs. Since 1877, Jackson State University (JSU) has been providing young men and women opportunities that will empower them to succeed in an increasingly complex world. JSU is the fourth -largest institution of higher learning in Mississippi, and is the largest HBCU in the state. JSU emphasizes public service programs designed to enhance quality of life and seeks solutions to urban problems in physical, social, intellectual, and economic environments. The vision of JSU is to be a model urban learning community for highly motivated students from diverse backgrounds, where original research and experiential learning are integrated into rigorous and internationally prominent programs in the arts, humanities, and the sciences.

For many years, HBCUs have lagged behind predominately white institutions and have had a reluctance towards implementing mobile technology and e-learning into their curricula [9]. This reluctance is often attributed to the very nature of HBCUs, which are known for their small class sizes, high levels of student support, and highly targeted instruction. Issues related to the digital divide and technological literacy may also contribute to the reluctance. The digital divide is defined here as the socioeconomic and other disparities between those people who have opportunities and skills enabling them to benefit from digital resources, especially the Internet, and those who do not have these opportunities or skills: A number of noteworthy studies have found inequalities of computer and Internet access across socioeconomic and racial lines [10, 11]. Jackson et al. [12] suggested that minority students from lower socioeconomic backgrounds were more likely to be exposed to drill-and-practice exercises, while white students from higher socio-economic backgrounds were more likely to benefit from technologies that help build, and require the use of, higher-order critical thinking skills [12].

Smartphones may be used as in integral instrument in fostering a connection in the digital divide. Smartphones serve as an easy and inexpensive method for connecting to the Internet. This might enable students to have access to information and the ability to easily communicate with others. This has been shown to provide a better classroom. Freeman (as cited in Buck et al. [13]) referred to Qualcomm's Wireless Reach Initiative, which aims to conquer the digital divide between those who can and cannot afford wireless Internet access. After smartphones were distributed to low-income students, standardized test performance drastically increased, because students could easily communicate with their peers and access information throughout the day—scores increased by 30%. This is reflective of the student-engagement factor and the applications used. Bradley (as cited in Buck et al. [13]) contended that a StudyBlue report indicated that students using the mobile app from a smartphone spend 40 minutes more studying each week compared with students relying solely on the website. Apps offer a better experience, are easier to navigate and use, and are designed for the smartphone platform [13]. With these being benefits of smartphone technology in the classroom, there are some concerns regarding possible classroom distractions and interruptions.

Smartphones in the classroom may be a distraction, due to students texting, sexting, cheating, and their use of social media during classroom instruction. Riedel [14] indicated that some educators agree that texting is a distraction, and policies should be put in place to ensure that students face consequences if caught texting in class. Consequences may include students losing individual privileges. In regards to social media, Riedel further asserted that some educators believe that the use of social media in the classroom can be better monitored if it is school-based social media only. This will help to ensure that the social media reflects the course materials and is used only for educational use purposes [14]. Concerning the smartphone use by teachers, Feeney and Freeman [15] conducted a study an ethics session at NAEYC's 2014 National Institute for Early Childhood Professional Development in Minneapolis. They queried participants to pinpoint concerns that were encountered in the classroom in lieu of educators' misuse of smartphones. The follow was revealed [15]:

- Smartphones distract teachers, who are tempted to answer calls and read and write emails or text messages when they should be focusing on children's learning, safety, and well-being.
- Adults use the cameras on their phones inappropriately. Parents and teachers take pictures of children at school and on field trips and post them on social media, without parental permission.
- Parents ask to "friend" or "follow" their children's teachers on social media, which could blur the line between professional and personal interactions.
- Teachers and family members post inappropriate or critical comments about programs and teachers on social media sites.

Given the pros and cons of smartphones and other mobile technologies (e.g., laptops, tablets, etc.), there is a growing number of educational initiatives to help promote the proper use of technology and the design of educational programs to appeal to the 21st century learner.

The TASI Program

The Technology Advantage Scholarship Initiative (TASI) was a partnership between the Mississippi e-Center, Apple, Inc., and Jackson State University. This program purchased iPads to equip more than 900 first-time, full-time JSU freshman students with the highly popular tablet computer. Implementing the TASI, or iPad initiative, involved building a learning community for digital natives, training faculty to teach on tablets, expanding the classroom through the use of embedded e-textbooks, and devising ways to learn measurement outcomes. This initiative engaged students through the process of active learning in the classroom. In this cyber learning community, mobile technology provided a vehicle for student engagement, the expansion of the classroom learning environment, student development of primary source materials, and the extension of teaching practices that move beyond the traditional lecture format. The result: a democratized platform for equal access to the latest scholarship through the latest technology, leading to an educational environment where intellectual curiosity is supported and fostered. As a result of the initiative, JSU faculty members were able to author 30 iBooks or eBooks. The iPad initiative helped students gain the skills to be lifelong learners. The students' knowledge base was expanded, which helped prepare them for the global workforce. As part of its commitment to the success of the iPad initiative, JSU created a Wi-Fi signal strictly for the iPad and initiated a million-dollar overhaul of its network to ensure that the signal could accommodate all of the students. Additionally, JSU continuously offered a slate of interactive workshops and online tutorials for both students and faculty, focused on how the Apple iPad could be used in a learning environment. Workshop topics included initial setup, educational apps, security, and content creation.

In order to determine the effect of the cyber learning initiative, and the value of the digital textbooks, a re-evaluation study began in the fall semester of 2014. The survey was provided to freshman students on the iPads they received the first week of school. The surveys were administered during the fall 2014 and spring 2015 semesters, and students were sent a web link to complete the instrument via the iPad. The survey instrument was designed to identify strengths and challenges for incoming students, as well as their reasons for entering a college or university—and for choosing JSU in particular—and their overall background and preparation for college life. The instrument contained 24 items, several of which had sub-items. Items were multiple choice, short answer, and Likert-type scales with four possible response options.

Overall, 780 students responded to all, or nearly all, of the survey questions; only eight individuals completed fewer than half of the items. The survey asked questions regarding their freshman experience and overall purpose of identifying strengths and challenges for incoming students. In terms of technology, students generally felt prepared for college, were comfortable with technology, and reported that they had used technology for learning purposes in high school. Two questions, with a total of six items, asked about students' comfort with technology and their use of technology for their JSU classes. At least 90% of the students were comfortable with mobile phones, smart phones, tablets, and laptop computers. About two-thirds reported being comfortable with iBooks or readers. The second question asked whether they used technology to help with any classes at JSU. There were seven response options—four options were positive, varying from YES, AS A REGULAR PART OF SEVERAL CLASSES (FOR EXAMPLE, PROFESSORS SHARED MATERIALS ELECTRONICALLY) to YES, BUT NOT OFTEN. The largest group of students (about 62%) chose the first response option; the next largest group (about 22%) chose the second option—YES, TO DO RESEARCH ON THE WEB FOR CLASS PAPERS AND PROJECTS. There were three negative response options, but only one was chosen by only one student (NO, PROFESSORS TOLD US TO USE THE REGULAR LIBRARY). Clearly, these students had been comfortable with technology for some time. It is surprising, then, that these students did not use technology more for academic purposes; 62% reported that they regularly used technology for class; 21% reported that they used technology for research on the web; and, 17% used technology to write papers and develop projects [16].

The initiative also helped boost student academic performance and improve JSU's retention of freshman students following their first semester. In one semester, there was a 6.5 point rise in test scores by the mid-term for all of the students that piloted the program. Several pilot studies have been conducted since the program was implemented in order to determine student perceptions toward the iPad initiative. Initial results from the pilot study indicated that mobile learning devices have the potential to enhance learning if all students have equal access to the technology. Sixty-four percent of the students reported that the class and iPad e-textbook embedded course assignments allowed them to use the iPad and other technological devices to be creative and think outside the box [17].

Lessons Learned

This cyber learning initiative distinguishes Jackson State University as an innovative institution embracing a 21st century model of teaching and learning. This program provided the institution with insight into what did and did not work in terms of faculty acceptance and student participation. First, it is important to get the right faculty members engaged and committed to the cyber learning. This requires them to learn new skills in order to effectively interact with students. In addition, JSU faculty members were required to acquire new thinking about the way they plan and teach their courses. Many welcomed this new use of technology but some seasoned faculty members had their concerns. Doering et al. [3] stated that "the way we think about teaching today has to change and focus on individual skills and abilities instead of just delivering knowledge." The faculty created a supportive technological community for students to learn. They communicated often and gave students clear expectations. They incorporated synchronous and asynchronous activities into the curriculum. Faculty had to be open and honest. They facilitated the opportunity for students to ask questions and provide opportunities for reflections and discussions. They combined learned concepts with a customized learning plan that made for a memorable closing and wrap up.

Furthermore, the JSU administration provided adequate infrastructure support and demanded reliability. An example of this was the implementation of the Innovate Center. This one-stop-shop for faculty and staff was created to assist them in creating and disseminating digital content. The center is equipped with wireless, multimedia technology including touch-screen Mondopads, podcast recording devices, and collaborative workspaces to help faculty move from concept to design to implementation in one space. Faculty members were provided guidance and instructional design. Innovate served as the new home for academic IT and distance learning. It was the location for continual faculty development and training. The center was the first phase of the library's transformation into a modern digital intellectual commons. This center invited the faculty to bring their vision to the table and allowed them to work with the instructional designer so that they could then collaborate to support their vision.

Faculty members also supported students in thinking critically and finding solutions to real-world issues. They encouraged students to think about and respond to a question in multiple ways with the iPad as a technological/instructional aid. The iPad allowed students to access a plethora of information that was literally accessible at their fingertips. The iPad engaged the students' different learning styles and encouraged them to create products that reflected their unique personalities. The initiative allowed for creativity and collaboration to be seen in real time. Students were able to make their essays and projects come alive. Students were able to share ideas and projects, and solve problems in the form of a digital story or video journal. For instance, students were able to use Dropbox, or Google Docs to share documents and collaborate on projects. Students truly were able to enhance each other's work and collaborate on a project. The use of the iPad facilitated communication across all levels, between faculty and students and among the students themselves. Students were able to create, construct, and improve critical thinking skills through the use of technology. The academic administration also made a commitment to students by establishing the Create Center. It is a space for students to complete digital projects and assignments housed in the university library. It is scheduled to open in the fall of 2014.

Finally, the findings of the pilot study have paved the way for further research in this area. The iPads seem to be the latest and the most promising educational technology tool in higher education. JSU's Technology Advantage Scholarship Initiative is just one example of how this HBCU is preparing minority students in the ever-changing landscape of higher education. The university's motto is so very true of the transformative power of this great institution. JSU is keeping pace with innovation and equipping students with the tools necessary to be able to "challenge minds, and change lives," on the fast-moving information superhighway. Historically, HBCUs have been required to think outside the box and become innovators in gaining resources in order to prepare their students for the 21st century. Like other HBCUs, JSU has done so much, with so little. The university has created classrooms without walls, and has moved beyond brick and mortar buildings to expose students to a global society that offers them endless possibilities in the 21st century.

References

[1] Reynolds, R. (2011). White paper: Digital textbooks reaching the tipping point in U.S. higher education: A revised five-year forecast.

[2] Jamali, H. R., Nicholas, D., & Rowlands, I. (2009). Results from the JISC National E-Book Observatory. *Aslib Proceeding: New Information Perspectives, 61* (1), 33-47.

[3] Doering, T., Pereura, L., & Kuechler, L. (2012). The Use of E-Textbooks in Higher Education: A Case Study. Berlin (Germany): E-Leader

[4] Turner, F. (2005). Incorporating Digital E-books into Educational Curriculum. *International Journal of Instructional Technology and Distance Learning, 2* (11), 47-52.

[5] International Technology and Engineering Education Association. (2006). Technology for All Americans: A Rational and Structure for the Study of Technology. Reston, VA: Author.

[6] International Technology and Engineering Education Association. (2003). Measuring progress: A guide to assessing students for techno-logical literacy. Reston, VA: Author.

[7] Pearson, G., & Young, A. (Eds.). (2002). *Technically speaking: Why all Americans need to know more about technology*. Washington, DC: National Academy Press.

[8] Laird, T., Bridges, B., Homes, M., Morelon, C., & Williams, J. (2004). *African American and Hispanic student engagement at minority serving and predominantly white institutions*. Paper presented at the Annual Meeting of the Association for the Study of Higher Education, Kansas City, MO.

[9] Buzzetto-More, N. (2008). Meeting the Professional Development Needs of University Faculty to Increase E-Learning Adoption. *Journal of Global Information Technology*. *3*(1), 42-52.

[10] Morgan, J., & Van Lengen, C. (2005). The digital divide and K-12 student computer usage. Issues in Informing Science and Information Technology, 2, 705-724. Retrieved from http://proceedings.informingscience.org/InSITE2005/I56f86Morg.pdf

[11] National Telecommunications and Information Administration. (2000). *Falling through the net: Towards digital inclusion*. National Telecommunications and Information Administration. U.S. Department of Commerce. Washington D.C.

[12] Jackson, L., Ervin, K., Gardner, P., & Schmitt, N. (2001). The racial digital divide: motivational, affective, and cognitive correlates of Internet use. *Journal of Applied Social Psychology*, *31*(10), 2019-2046.

[13] Buck, J. L., McInnis, E. Y., & Thomas, A. (2013). Technological Innovation for the 21st Century Learning: How Smartphone and Tablet Technology Impacts Learning. *Proceeding of the Eleventh LACCEI Latin American and Caribbean Conference for Engineering and Technology (LACCEI'2013) "Innovation in Engineering, Technology and Education for Competitiveness and Prosperity,"* Cancun, Mexico.

[14] Riedel, C. (2013). Does the smartphone have a place in the classroom? *The Journal*. Retrieved from https://thejournal.com/articles/2013/02/04/does-the-smartphone-have-a-place-in-the-classroom.asp.

[15] Feeney, S., & Freeman, N. K. (2015). Smartphones and social media. Ethical implications for educators. *YC Young Children*, *70*(1), 98.

[16] Wilde, J. (2015). *Jackson State University's Cyber Learning Initiative*. Final report-Year One Evaluation. www.Betagroupconsulting.com.

[17] McLin, D. (2013). *Teaching with Technology*. Paper presented at Cyber Learning Summit, Jackson State University. Jackson, Mississippi.

Biographies

DAWN BISHOP MCLIN is an associate professor of psychology at Jackson State University. She earned her Ph.D. from Mississippi State University and her B.S. degree from Jackson State University. Dr. McLin has been teaching with technology for over ten years and was instrumental in implementing the TASI program at Jackson State University. Her areas of research include cultural diversity, traffic safety among teens, and teaching psychology honors classes with technology. Dr. McLin may be reached at dawn.bishop@jsums.edu

JESSICA L. MURPHY is an associate professor of technology in the Department of Technology at Jackson State University. She earned her Ph.D. from Mississippi State University in technology with an emphasis on community college administration. She also has published entries for the Encyclopaedia of the Industrial Revolution. In 2010, she was elected as Vice President of the Student Division for ATMAE and President of the Student Division in 2012. On the international level, she serves as a thesis reviewer for technology education for the University of Kwa-Zulu Natal (Durban, South Africa) and the Region II Director for Epsilon Pi Tau Honor Society (covering MS, AL, GA, SC, NC, VA, the Caribbean, and South Africa). Dr. Murphy may be reached at jessica.l.murphy@jsums.edu

DEFINING THE TECHNOLOGY MANAGEMENT BODY OF KNOWLEDGE FOR ATMAE-ACCREDITED PROGRAMS

Mark Doggett, Western Kentucky University

Abstract

Using publicly available information, 84 baccalaureate and master's degree programs accredited by the Association of Technology, Management, and Applied Engineering (ATMAE) in industrial technology management, construction management, manufacturing management, or closely related degrees were compiled. The assigned textbooks for the technical management courses offered by these programs were reviewed using citation analysis. The results identified the most critical textbooks, most frequently assigned authors, and the areas of inquiry within these programs. This literature forms a basis for defining a technology management body of knowledge (TMBoK) useful to management professionals, educators, and students in the field. The research resulted in the foundation for the ATMAE Certified Technology Manager (CTM) exam.

Introduction

According to Yanez et al. [1], in order to differentiate a particular discipline, a body of knowledge that clearly outlines the field's subject matter and topics is required. Without a recognized and accepted body of knowledge for technology management, as defined by ATMAE, the discipline will continue to be confused with other technical and managerial disciplines. The development of a common body of knowledge for technology management provides the rationale for the distinguishing characteristics of ATMAE-accredited four-year and graduate programs. The American Society for Quality (ASQ), the Association for Operations Management (APICS), and the Project Management Institute (PMI) have well-recognized bodies of knowledge for their professional constituents. Each has their unique focus; i.e., quality, production/operations control, and project management. ASME standards focus on engineering competencies in specific topic areas such as flow, pressure, heat, stress, and modeling. However, ATMAE accrediting standards do not specify a core body of knowledge for technology management, only a range of required hours (12-24) and a broad list of potential subjects. This raises an interesting question. What must students learn in order to become successful entry-level technology managers?

Clarity regarding the body of literature in technology management is imperative. Establishing clear standards for a technology manager's competencies is crucial [2]. The textbooks assigned by faculty in ATMAE-accredited programs provide insight regarding a recognized body of knowledge that students must know in order to become entry-level technology managers. It is useful for the discipline to know the textbooks currently assigned in technology management programs and the body of knowledge cited within them. The following research questions were of interest in this current study:

- What textbooks are most frequently assigned by ATMAE-accredited technology management programs?
- What authors are cited most frequently within the assigned textbooks?

The purpose of this current study was to understand the current body of knowledge selected by faculty and assigned to students in ATMAE-accredited technology management programs. The goal was to create a list of the most frequently assigned textbooks sorted by program types and compare them to the technology management competencies, as described in the technology management competency model [2]. ATMAE defines technology management as "the field concerned with the supervision of personnel across the technical spectrum and a wide variety of complex technological systems. Technology Management degreed programs typically include instruction in production and operations management, project management, computer applications, quality control, safety and health issues, statistics, and general management principles" [3]. This current study was limited to technology management programs as defined by ATMAE. Definitions of technology management beyond this description were not addressed.

The ATMAE-accredited programs selected were Construction Management (CM), Manufacturing Management (MM), Industrial Technology Management (ITM), miscellaneous management, and master's degrees. The miscellaneous management programs were Safety Management/Occupational Safety and Health Management, Automotive Technology Management, Telecommunications Management, and other management-related programs. These programs were selected because they comprise the majority of the four-year technology management and master's degree programs accredited by ATMAE. The textbooks assigned for any given course depend on a variety of factors such as the publisher's level of promotion, the expertise and education of the instructor, and the availability of, or preference for, supplemental resources. For example, the perspective of a technology management instructor with a degree in mechanical engineering is different from the perspective of an instructor with a degree in industrial technology. Additionally, some instructors may prefer to develop their own materials, while others prefer the publisher's standard content. These factors do have an impact on the TMBoK. The intent of this study was not to build a comprehensive technology management database, but rather to take a snapshot of the current state within a limited population for the development of an ATMAE TMBoK. Compared to the ABET accredited-programs, the number ATMAE-accredited programs is small and they tend to focus on technology, engineering technology, and technology management rather than civil, mechanical, or electrical engineering.

The textbooks were analyzed using citation analysis to determine the most frequently cited authors. Citation analysis is the process of examining the bibliography of articles or scholarly publications. This type of analysis provides insight into the knowledge areas for a particular academic discipline. The sources cited in the selected articles or books provided information on the discipline's prominent authors and seminal works [4]. MacRoberts and MacRoberts [5], [6] stated that the number of times an article is cited shows its intellectual indebtedness. Research citations also provide readers with information on the literature that influenced authors in their works. However, authors may not cite every influential work in their bibliographies, due to space limitations and personal preferences. The overall intent of the textbook and citation analysis was to form a basis for defining an ATMAE technology management body of knowledge (TMBoK) useful to management professionals, educators, and students in the field.

Methodology

Using the Association of Technology, Management, and Applied Engineering (ATMAE) list of accredited programs, 84 technology management programs were selected as the population of interest. The course name and textbook data were collected from publicly available institutional websites. Of the 84 programs, the authors found 75 technology management-related programs with publically available textbook information. The first step of the study consisted of sorting all management courses based on program types. Table 1 shows the breakdown of the ATMAE-accredited programs studied. In the next step, all management courses of each program were sorted based on the course title. The criteria for course selection were the inclusion of the word "management" in the course title or a course description containing the word or a closely related topic. For example, the courses titled Management of Organizations and Industrial Management were some of the courses in construction management programs. Alternatively, the course titled Quality Control in Industry does not have management in the course title, but the description states that the course includes methods and procedures of measurement, prediction, and modeling, which are typically associated with industrial management. Technical skill-based courses such as computer-aided drafting and basic electricity were not included.

Table 1. Breakdown of Programs Studied

Program Type	Number
Construction Management (CM)	13
Manufacturing Management (MM)	12
Industrial Technology Management (ITM)	27
Miscellaneous Management: • Safety Management/Occupational Safety and Health Management - 6 • Automotive Technology Management - 3 • Telecommunications Management -1 • Other - 6	16
Master's programs	3

Next, all of the management courses with their corresponding required textbooks were sorted into eight management competency areas, as defined by the technology management competency model [2]. The eight competency areas were leadership/self-management, people management, operations management, process management, project management, systems management, quality management, and risk management. This step was the most challenging as it required a decision on the primary competency taught in the course and/or in the textbook. Many courses and texts cover multiple competency areas. One such example is operations management, which can be highly contextualized depending on the program or discipline. An instructor for an operations management course could choose a textbook on lean manufacturing or production control. However, a textbook on lean could also be assigned to a systems thinking or process control type course.

The final decision regarding the placement of textbooks in a particular competency area was based on the criteria shown in Table 2. It was recognized that some of the textbooks might cover more than one management competency. In those cases, the course titles and course descriptions in the context of the program provided the primary source of the information. If needed, inductive reasoning was used when placing the textbook in a management competency based on the textbook title and course name. Further reasoning was based on similar publications of the author(s).

Table 2. Criteria for Course and Textbook Placement in a Management Competency Area

Management Competency	The course and text are primarily concerned with management of:
Leadership/Self Mgmt.	Individual/professional development and/or leadership, strategy, and theory
People Mgmt.	Human resource development, behavior, and front-line supervision
Operations Mgmt.	Operations within an applied context (e.g., construction, manufacturing, etc.)
Processes Mgmt.	Universal processes that are not unique or contextualized (assessment, analysis, cost, design, technology, etc.)
Project Mgmt.	Project planning, estimating, scheduling, execution, and control
Systems Mgmt.	Development and integration of systems that cross organizational boundaries, contexts, skill-sets, or disciplines (e.g., energy, supply chain, facilities, etc.)
Quality Mgmt.	Continuous improvement, quality control, assurance, and industrial statistics
Risk Mgmt.	Occupational safety, ergonomics, industrial hygiene, environmental, legal, security, and protection

Finally, the textbooks were ranked based on the frequency of their assignment. If the textbook had multiple editions, published over several years, the specific title under the primary author was counted only once. The assumption was that changes to revised editions did not affect the TMBoK content significantly. The rankings were done by program type, (CM, MM, ITM, etc.), management competency, and program type combined with competency. The electronic bibliographic data were extracted from the textbooks most frequently assigned across the various management competency areas by contacting the publishers, if readily available. Data on 10 out of 12 books were obtained for the citation analysis.

Using Excel, the bibliographic data were ranked based on the frequency of citations by the primary or first author. Self-citations by authors were handled on a case-by-case basis in order to determine if they affected the reported results. If the citation was a textbook with multiple editions, only the number of times the title was cited under the primary author was counted. In all, 2792 bibliographic data points were collected, corresponding to 1666 authors. Secondary authors and author names appearing in book reviews were not considered. The bibliographic data were then sorted based on the competency model and the prominent authors identified by frequency of citation.

Findings: Assigned Textbooks

In this section, the authors present the findings of the most frequently assigned textbooks by program type and the most likely management competency covered. Some of the textbooks were used across program types and competencies. Of the 13 CM programs, two textbooks were assigned in four courses. *Estimating in Building Construction* by Dagostino and Feigenbaum and *Safety and Health for Engineers* by Brauer were assigned to project management and safety/risk management courses, respectively. Two other textbooks, *Construction Management* by Halpin and *Operations and Supply Chain Management* by Jacobs and Chase, were assigned three times in courses covering operations or process management. Four textbooks were assigned two times each in courses related to leadership and supervision. In the management of systems and quality, three different textbooks were each assigned once across courses. Table 3 presents a summary of the most frequently assigned textbooks for the CM programs studied.

For the 12 MM programs, *Supervision Today!* by Robbins was assigned in three courses dealing with people management. Eight different textbooks were assigned twice across the multiple competency areas of operations, processes, quality, and risk. Four different textbooks were each assigned once in the areas of leadership and project management. Table 4 presents a summary of the most frequently assigned textbooks for the MM programs studied.

In the 27 ITM programs studied, *Manufacturing Facilities Design and Material Handling* by Stephens was assigned six times for courses in systems management competencies. *Quality Improvement* by Besterfield and *Occupational Safety and Health for Technologists, Engineers, and Managers* by Goetsch were each assigned five times in the areas of quality and risk management, respectively. *Operations Management* by Stevenson was used three times for operations management courses. Five different textbooks were each assigned two times in the areas of leadership, people management, and project management. Seven different textbooks were found for the processes area. Table 5 presents a summary of the most frequently assigned textbooks for the ITM programs in the study.

Table 3. Most Frequently Assigned Textbooks by Management Competency within Construction Management Programs

Management Competency	*Textbook* (Author)	Frequency of Use
Leadership/ Self Mgmt.	*Essentials of Management* (Dubrin) *Basic Construction Management* (Rogers)	2 2
People Mgmt.	*Personality I.D.* (Life Pathways) *Supervision Today!* (Robbins)	2 2
Operations Mgmt.	*Construction Management* (Halpin)	3
Processes Mgmt.	*Operations and Supply Chain Management* (Jacobs & Chase)	3
Project Mgmt.	*Estimating in Building Construction* (Dagostino & Feigenbaum)	4
Systems Mgmt.	Three different textbooks assigned once	1
Quality Mgmt.	Three different textbooks assigned once	1
Risk Mgmt.	*Safety and Health for Engineers* (Brauer)	4

Sixteen miscellaneous industrial management programs were studied, which consisted of Safety Management/ Occupational Safety and Health Management (6), Automotive Technology Management (3), Telecommunications Management (1) and six other management programs in design/graphics, biosystems, and facilities. Three textbooks were assigned three times each. *Managing Automotive Businesses* by Garner was assigned as the operational text in all three automotive programs. *Occupational Safety and Health for Technologists, Engineers, and Managers* by Goetsch and *Accident Prevention Engineering and Technology* by the National Safety Council were assigned three times for risk management courses. Six different textbooks were each assigned two times in the areas of leadership, people, processes, and quality management. Three different textbooks were each assigned once in project and systems management. Table 6 presents a summary of the most frequently assigned textbooks for the miscellaneous management programs studied.

Table 4. Most Frequently Assigned Textbooks by Management Competency within Manufacturing Management Programs

	Textbook (Author)	Frequency of Use
Leadership/ Self Mgmt.	Four different textbooks assigned once	1
People Mgmt.	*Supervision Today!* (Robbins)	3
Operations Mgmt.	*Lean Thinking* (Womack & Jones) *Lean Production Simplified* (Dennis)	2 2
Processes Mgmt.	*Operations Management* (Stevenson)	2
Project Mgmt.	Four different textbooks assigned once	1
Systems Mgmt.	*Introduction to Materials Management* (Arnold)	2
Quality Mgmt.	*Quality Improvement* (Besterfield) *Six Sigma Black Belt CSSBB Primer* (Wortman)	2 2
Risk Mgmt.	*Occupational Safety and Health for Technologists, Engineers, and Managers* (Goetsch) *Accident Prevention Engineering and Technology* (National Safety Council)	2 2

Data were limited for master's programs because few were ATMAE-accredited and public information was sporadic. Summary data on these programs are presented in Table 7. Construction, manufacturing, industrial technology, and miscellaneous management programs had some assigned textbooks in common. Table 8 provides a summary of the textbooks used across all programs by management competency. In seven of the eight competency areas, one textbook was used more frequently. Two textbooks were assigned frequently for process management courses. It should be noted that the most frequently assigned textbooks for project and systems management were contextual. *Estimating in Building Construction* by Dagostino and Feigenbaum was used by CM programs, whereas *Manufacturing Facilities Design and Material Handling* by Stephens was used by MM and ITM programs. *Quality Improvement* by Besterfield was used across all programs except CM. *Occupational Safety and Health for Technologists, Engineers, and Managers* by Goetsch and *Supervision Today!* by Robbins was used across all programs.

Table 5. Most Frequently Assigned Textbooks by Management Competency within Industrial Technology Management Programs

Management Competency	*Textbook* (Author)	Frequency of Use
Leadership/ Self Mgmt.	Four different textbooks assigned once	1
People Mgmt.	*Supervision Today!* (Robbins)	3
Operations Mgmt.	*Lean Thinking* (Womack & Jones) *Lean Production Simplified* (Dennis)	2 2
Processes Mgmt.	*Operations Management* (Stevenson)	2
Project Mgmt.	Four different textbooks assigned once	1
Systems Mgmt.	*Introduction to Materials Management* (Arnold)	2
Quality Mgmt.	*Quality Improvement* (Besterfield) *Six Sigma Black Belt CSSBB Primer* (Wortman)	2 2
Risk Mgmt.	*Occupational Safety and Health for Technologists, Engineers, and Managers* (Goetsch) *Accident Prevention Engineering and Technology* (National Safety Council)	2 2

Table 6. Most Frequently Assigned Textbooks by Management Competency within Miscellaneous Management Programs

Management Competency	*Textbook* (Author)	Frequency of Use
Leadership/ Self Mgmt.	Essentials of Management (Dubrin)	2
People Mgmt.	*Supervision Today!* (Robbins) *Supervisor's Safety Manual* (National Safety Council)	2 2
Operations Mgmt.	*Managing Automotive Businesses* (Garner)	3
Processes Mgmt.	*Introduction to Operations and Supply Chain Management* (Bozarth & Handfield)	2
Project Mgmt.	Three different textbooks assigned once	1
Systems Mgmt.	Three different textbooks assigned once	1
Quality Mgmt.	*Quality Improvement* (Besterfield) *Quality Management* (Goetsch)	2 2
Risk Mgmt.	*Occupational Safety and Health for Technologists, Engineers, and Managers* (Goetsch) *Accident Prevention Engineering and Technology* (National Safety Council)	3 3

Table 7. Most Frequently Assigned Textbooks by Management Competency within Master's Programs

Management Competency	*Textbook* (Author)	Frequency of Use
Leadership/ Self Mgmt.	*Essentials of Management* (Dubrin)	2
People Mgmt.	*Human Challenge: Managing Yourself and Others* (Tucker)	2
Operations Mgmt.	*Health Communication in 21st Century* (Wright)	3
Processes Mgmt.	Not available	
Project Mgmt.	*The AMA Handbook of Project Management* (Dinsmore & Cabanis-Brewin)	1
Systems Mgmt.	Four different textbooks assigned once	1
Quality Mgmt.	*Quality Management* (Summers) The Six Sigma Handbook (Pyzdek & Keller)	1 1
Risk Mgmt.	Three different textbooks assigned once	1

Table 8. Most Frequently Assigned Textbooks by Management Competency Across all Technology Management Programs

Management Competency	*Textbook* (Author)	Frequency of Use
Leadership/ Self Mgmt.	*Essentials of Management* (Dubrin)	6
People Mgmt.	*Supervision Today!* (Robbins)	6
Operations Mgmt.	*Lean Thinking* (Womack & Jones)	4
Processes Mgmt.	*Operations Management* (Stevenson) *Operations and Supply Chain Management* (Jacobs & Chase)	3 3
Project Mgmt.	*Estimating in Building Construction* (Dagostino & Feigenbaum)	4
Systems Mgmt.	*Manufacturing Facilities Design and Material Handling* (Stephens)	7
Quality Mgmt.	*Quality Improvement* (Besterfield)	10
Risk Mgmt.	*Occupational Safety and Health for Technologists, Engineers, and Managers* (Goetsch)	11

The top twelve textbooks most frequently assigned to management courses, regardless of program type or competency area, are shown in Table 9. Six of these textbooks are duplicates of the nine shown in Table 8. Four of the additional textbooks dealt with safety and health. The other two additional textbooks covered quality and materials. *Quality Management* by Summers and *Essentials of Management* by Dubrin were the only textbooks used both at the graduate and undergraduate level.

Table 9. Most Frequently Assigned Textbooks Across all Technology Management Programs

Textbook (Author)	Frequency of Use
Occupational Safety and Health for Technologists, Engineers, and Managers (Goetsch)	11
Quality Improvement (Besterfield)	10
Supervision Today! (Robbins)	9
Quality Management (Summers)	8
Safety and Health for Engineers (Brauer)	7
Accident Prevention Engineering and Technology (National Safety Council)	7
Manufacturing Facilities Design and Material Handling (Stephens)	7
Essentials of Management (Dubrin)	6
Operations Management by Stevenson	6
Introduction to Materials Management (Arnold)	6
Industrial Safety and Health Management (Asfahl & Rieske)	6
Fundamentals of Occupational Safety and Health (Friend)	5

Findings: Citation Analysis

In this section, the authors provide the results of the citation analysis for the most frequently assigned textbooks across the accredited programs. One of the most frequently assigned textbooks, *Manufacturing Facilities Design and Material Handling* by Stephens, did not contain bibliographic data. Citation information on *Safety and Health for Engineers* by Brauer and *Fundamentals of Occupational Safety and Health* by Friend were not available, so they were dropped from the analysis. As the risk management competency had 5 out of 10 books, removing two of the titles from the citation analysis did not affect the validity of the research. *Lean Thinking* by Womack and Jones was added to the citation analysis as it was frequently assigned in operations management and had an available bibliography.

The most frequently cited authors were corporate authors such as those that set standards, non-governmental organizations, professional associations, and government agencies. Most of these corporate authors were found under the risk management competency due to the importance of industrial safety. The following tables show the frequency of citation by textbook and the corresponding management competency. Table 10 shows the number of works cited for each of the selected textbooks. It should be noted that over 60% of the citations were from three of the textbooks. Table 11 shows the number and percentage of citations related to each of the technology management competencies. Over 80% of the citations related to risk, quality, and leadership/self-management with approximately half of those related to risk management. There was no consistent textbook assigned for any of the project management courses across all of the programs. Thus, a citation analysis for this competency area was omitted.

Table 10. Selected Textbooks with the Number of Works Cited and their Percentage of Contribution to the Citation Analysis

Textbook (Author) [competency]	Works Cited	Percentage
Essentials of Management (Dubrin) [leadership]	830	30%
Accident Prevention Engineering and Technology (National Safety Council) [risk]	703	25%
Occupational Safety and Health for Technologists, Engineers, and Managers (Goetsch) [risk]	279	10%
Quality Management (Summers) [quality]	270	10%
Operations Management (Stevenson) [processes]	212	8%
Industrial Safety and Health Management (Asfahl & Rieske) [risk]	210	7%
Supervision Today! (Robbins) [people]	173	6%
Introduction to Materials Management (Arnold) [systems]	48	2%
Lean Thinking (Womack & Jones) [operations]	37	1%
Quality Improvement (Besterfield) [quality]	34	1%

The authors cited most frequently for each of the management competency areas are shown in the figures. Within the leadership/self-management area (see Figure 1), ten authors accounted for 80% of the cumulative ranking. This does not mean these authors received 80% of the total citations. It means these authors were cited more times within the selected textbooks than any of the other authors. For example, one author was cited eight times in the textbook, while nine other authors were cited five times each. The reader may recognize several of the authors including business and technology writer Ed Frauenheim [7], [8], Bloomberg Business columnist Jena McGregor, and various Wall Street Journal contributors.

Table 11. Number and Percentage of Works Cited for Each Management Competency

Technology Management Competency	Citations/ Competency	Percentage
Risk Management (397 per book on average)	1192	42%
Leadership/ Self-Management	830	30%
Quality Management	304	11%
Processes Management	212	8%
People Management	173	6%
Systems Management	48	2%
Operations Management	37	1%
Project Management	N/A	N/A

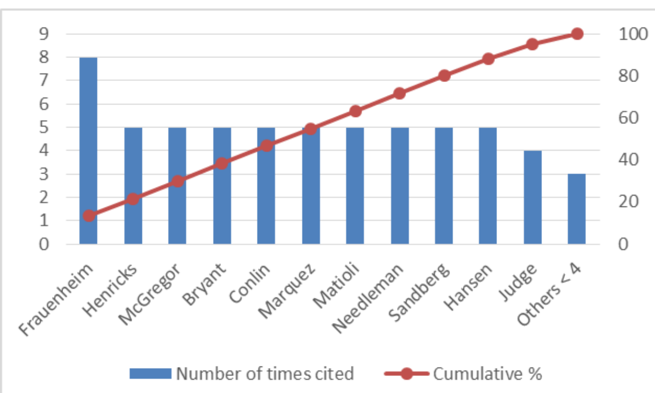


Figure 1. Leadership/Self-Management Author Rankings

In the area of risk management (see Figure 2), four authors accounted for 80% of the cumulative ranking. In this competency area, corporate authors such as the American National Standards Institute (ANSI), National Safety Council (NSC), National Fire Protection Association (NFPA), and the National Institute for Occupational Safety and Health (NIOSH) dominated the citations. For ANSI, 26 of the citations were co-authored with ASME. All of these corporate authors were cited at least 60 times among the three selected textbooks.

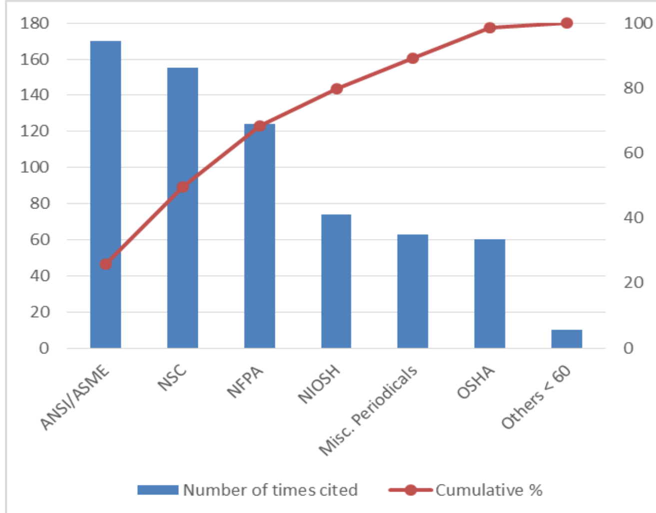


Figure 2. Risk Management Author Rankings

For quality management (see Figure 3), six authors comprised 80% of the cumulative ranking across two of the selected textbooks. For quality, the American Society for Quality (ASQ) was cited 10 times. Other familiar authors such as Juran, Wheeler, Feigenbaum, and Crosby were cited eight, seven, five, and five times each, respectively. It should be noted that there were numerous article references to Deming in the textbooks, but that his actual works were cited only two times.

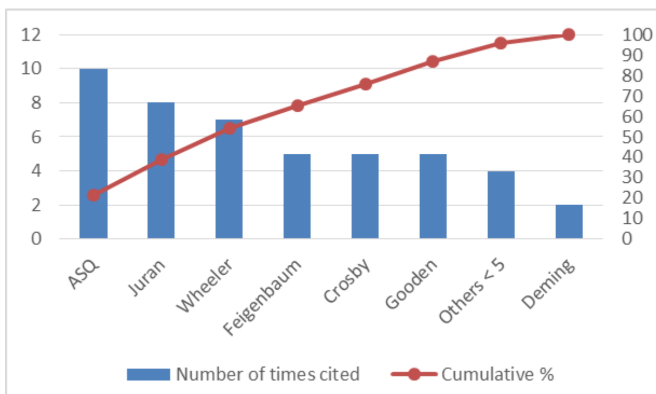


Figure 3. Quality Management Author Rankings

In the rankings for process management (see Figure 4), six authors comprised 80% of the cumulative total. Hopp, Womack, Goldratt, and Jacobs were each cited four times for multiple works. The other authors cited frequently were Juran, Stevenson, and Besterfield at three times each. Of note is that both Juran and Besterfield were cited in both the quality and process textbooks, indicating both the multidisciplinary nature of the technology manager competencies and the influence of these authors across a wide spectrum of literature.

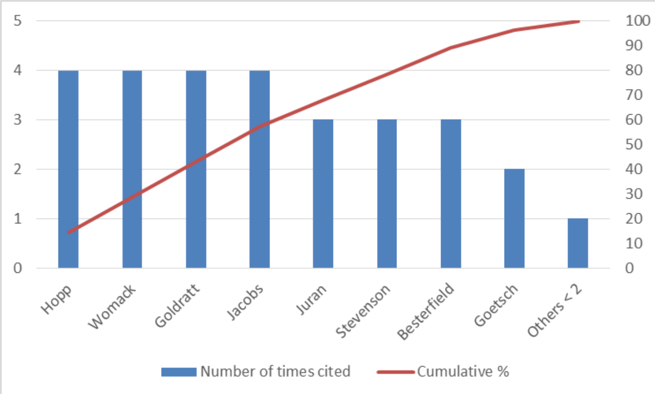


Figure 4. Process Management Author Rankings

The findings for people management are shown in Figure 5. For this competency area, no particular authors emerged more than others. Rather, a variety of periodical articles by multiple authors accounted for a majority of the cumulative total. Most authors were cited two times or less. The exception was Locke [9], the noted professor and psychologist in goal-setting theory, who was cited three times.

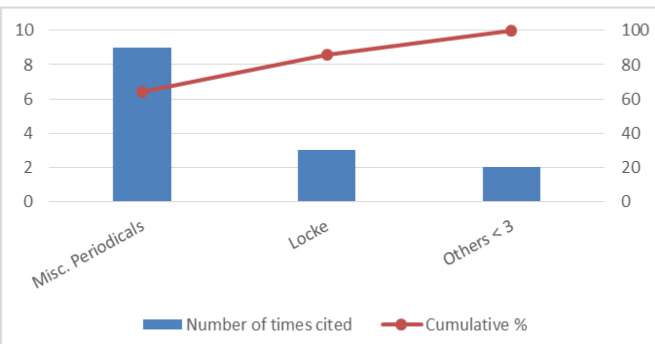


Figure 5. People Management Author Rankings

In systems management (see Figure 6), four authors accounted for 80% of the cumulative total. Schonberger was cited five times, whereas Vollman [10], Buffa [11], and Goldratt were each cited twice. Readers may note that Goldratt was also cited frequently in the selected process management literature. This expresses his influence as an author across the multiple paths of technology management competency. The findings for operations management are shown in Figure 7. For this competency area, two authors were cited three times and three authors were cited two times, accounting for 80% of the cumulative total. Noted author Schonberger was again cited frequently for his writings on world class manufacturing as applicable to both systems and operations management. Other authors included Rother, Ohno, and Suzaki across multiple works.

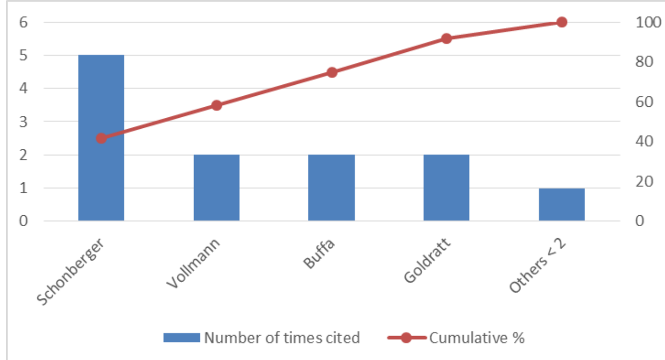


Figure 6. Systems Management Author Rankings

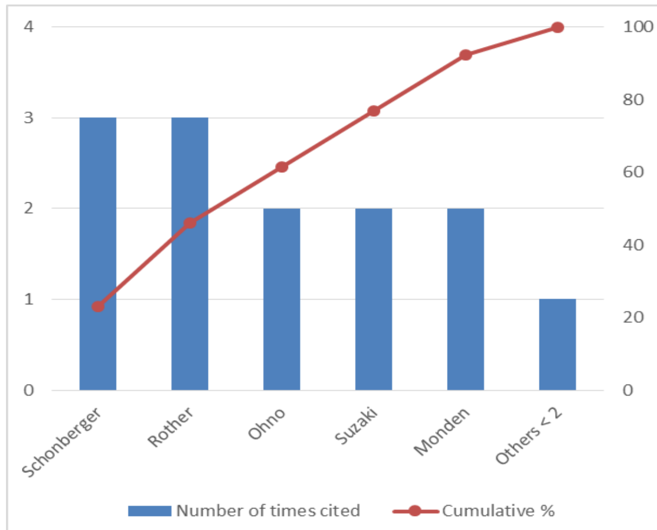


Figure 7. Operations Management Author Rankings

Table 12 shows a summary of the most frequently cited authors across all technology management programs and competencies. The top four citation sources were corporate authors (ANSI/ASME, NSC, NFPA, and NIOSH) in the area of risk management. Miscellaneous articles with unattributed authors accounted for 72 of the citations. The Occupational Safety and Health Administration (OSHA) was cited 60 times in the selected literature. The frequency of cited authors then dropped dramatically. The two primary authors cited most frequently were Juran and Goetsch with 13 and 12 citations, respectively. Juran's books on quality were cited in four of the selected textbooks across three of the competency areas. The textbook authors that cited Juran were Arnold, Summers, Besterfield, and Womack in the competencies of systems, quality, and operations. Goetsch's titles were cited in three of the selected textbooks across three of the competency areas. The textbook authors that cited Goetsch were Summers and Stevenson in the competencies of quality and process. Goetsch also self-cited other publications seven times in the selected textbook he wrote, which was analyzed in the risk management competency. If the number of self-citations is eliminated, Goetsch has five occurrences.

The next set of most-frequently-cited authors were professional societies and institutes. The corporate authors cited were the American Society for Quality (ASQ), American Petroleum Institute, Underwriters Laboratories, American Society for Testing and Materials (ASTM), and the American Welding Society (AWS). The number of citations ranged from 9 to 11 each. The remaining authors were a mix of individual and corporate authors cited from five to eight times each, with most cited five times. A large number of authors were cited four times, of which two are shown in Table 12.

Summary and Interpretation

The textbooks, *Occupational Safety and Health for Technologists, Engineers, and Managers* by Goetsch (Risk) and *Supervision Today!* by Robbins (People) were assigned most frequently and consistently across all programs. *Quality Improvement* by Besterfield (Quality) was assigned most frequently across all programs except CM. In terms of the rankings across management themes and program types, the most frequently assigned textbooks pertained to the management competencies listed here in descending order: Risk (5), Quality (2), Systems (2), Leadership/Self (1), People (1), and Processes (1). The variation in operations management was most likely due to the contextual nature of the competency (e.g., construction, manufacturing, etc.). For example, *Construction Management* by Halpin would not be assigned for a manufacturing program. Textbooks pertaining to process and project competencies have the most variation in their assignment. The lack of a consistently assigned textbook in the area of project management may simply indicate a large variety of instructional choices.

Some textbooks were used across graduate and undergraduate management programs. *Quality Management* by Summers and *Essentials of Management* by Dubrin were the most frequently assigned textbooks at both the graduate and undergraduate level. There was sporadic, and therefore unreliable, information on textbook use in the graduate management programs studied. The citation analysis indicated the body of knowledge for risk/safety management resided primarily with corporate authors in well-recognized professional and governmental institutions. This is congruent with the regulatory nature of safety and risk. Given that safety is a subset of risk, a reliance on professional and government standards as a primary information source was expected.

Table 12. Most Frequently Cited Author Summary

Author	Cited Frequency
American National Standards Institute (ANSI) / ASME (26 in common)	175
National Safety Council (NSC)	159
National Fire Protection Association (NFPA)	124
National Institute for Occupational Safety and Health (NIOSH)	74
Misc. Periodical Articles	72
Occupational Safety and Health Administration (OSHA)	60
Juran, J. M.	13
Goetsch, D. L	12*
American Society for Quality (ASQ)	11
American Petroleum Institute	10
Underwriters Laboratories	10
American Society for Testing and Materials (ASTM)	9
American Welding Society (AWS)	9
Schonberger, R. E.	8
Frauenheim, E.	8
Centers for Disease Control	8
Compressed Gas Association	7
U.S. Dept. of Transportation	7
Wheeler, D. J.	7
American Conference of Governmental Industrial Hygienists	6
Goldratt, E. M.	6
Womack, J. P.	5
McGregor, J.	5
Besterfield, D.	5
Crosby, P. B.	5
Hendricks, M.	5
Bryant, A.	5
Conlin, M	5
Feigenbaum, A.V.	5
Marquez, J.	5
Matioli, D.	5
Needleman, S. E.	5
Sandberg, J.	5
Gooden, R. L.	5
Hansen, F.	5
Stevenson, W. J.	4
Deming, W. E.	4

*Seven self-citations

The body of knowledge for leadership/self-management and people management tends to reside in more recent publications and journals written by a variety of contemporary authors and commentators. These sources encompass the "soft skills" that often depend heavily on the present state of the culture. For example, the increased presence of women and minorities in technical management roles has influenced the literature. Updated theories on leadership and the management of people with journal articles were congruent and expected. Conversely, the body of knowledge for quality management resides with a known set of seminal works with well-known authors. The repository for the quality management body of knowledge is ASQ and those authors whose writings were the foundation for TQM in the 1980s. Technology management fully recognizes the works of quality management authors such as Juran, Feigenbaum, Crosby, and Deming.

The process, operations, and systems management bodies of knowledge appeared to draw from a variety of works in multiple disciplinary areas with crossover in quality. Much of the quality literature dealt with process control and systems thinking. Thus, the overlap was not surprising. The emergence of lean and theory of constraints as philosophical management systems has also contributed to the body of knowledge. The works of Goldratt and Womack have greatly influenced management thinking, and Schonberger was one of the first authors to suggest greater integration of design and manufacturing. Project management citations were not analyzed, as there was no consistent textbook assigned. However, the Project Management Institute (PMI) is a well recognized repository for the Project Management Body of Knowledge (PMBoK). It was postulated that a future review focused on the assigned textbooks for project management courses would have a high level of PMBoK citations.

Future Implications and Opportunities

Further research of ATMAE technology management program-assigned textbooks across a broader spectrum of works would further enhance the development of a body of knowledge. However, this current study can serve as the foundation for an ATMAE-recognized technology management body of knowledge (TMBoK). With this information, students and faculty have sources for developing the required competencies and training entry-level technology managers. In 2014, the most frequently assigned textbooks were adopted as the recommended resources for the Certified Technology Manager (CTM) exam study guide, and their content forms the basis for the test. Technology management students and industry practitioners can use this information to prepare for the CTM exam. ATMAE-accredited technology management programs can use this information for program evaluation and assessment. Further research is specifically needed on technology management seminal works for project and people management.

References

[1] Yanez, M., Khalil, T. M., & Walsh, S. T. (2010). IAMOT and education: Defining a technology and innovation management (TIM) body-of-knowledge (BoK) for graduate education (TIM BoK). *Technovation, 30*(7-8), 389-400.

[2] Doggett, A. M., McGee, P., & Scott, S. (2013). Technology management competencies. *Technology Interface International Journal, 14*(1), 70-79.

[3] Association of Technology, Management, and Applied Engineering (2015). Retrieved from https://en.wikipedia.org/wiki/Association_of_Technology,_Management,_and_Applied_Engineering

[4] Mitchell, I. (1995). The application of citational and co-citational analysis to the property discipline. *Journal of Property Valuation and Investment, 13*(4), 11-24. doi:http://dx.doi.org/10.1108/14635789510099418

[5] MacRoberts, M. H., & MacRoberts, B. R. (1986). Quantitative measures of communication in science: A study of the formal level. *Social Studies of Science, 16*(1), 151-172.

[6] MacRoberts, M. H., & MacRoberts, B. R. (2010). Problems of citation analysis: A study on uncited and seldom-cited influences. *Journal of the American Society for Information Science and Technology, 61*(1), 1-13.

[7] Bassi, L., Frauenheim, E., McMurrer, D., & Costello, L. (2011). *Good company: Business success in the worthiness era*. San Francisco: Berrett-Koehler Publishers.

[8] Currall, S. C., Frauenheim, E., Perry, S. J., & Hunter, E. M. (2014). *Organized innovation: A blueprint for renewing America's prosperity*. New York: Oxford University Press.

[9] Locke, E. A., & Latham, G. P. (1990). *A theory of goal setting and task performance*. Upper Saddle River, NJ: Prentice Hall.

[10] Vollmann, T. E., Berry, W. L., Whybark, D. C., & Jacobs, F. R. (2004). *Manufacturing planning and control systems for supply chain management.* New York: McGraw-Hill.

[11] Buffa, E. S., & Sarin, R. K. (1987). *Modern production operations management*. New York: Wiley.

Biography

A. MARK DOGGETT is an associate professor in the Architectural and Manufacturing Sciences Department at Western Kentucky University. He earned his B.S. and M.S degrees from California State University, Fresno (Industrial Technology, 1981 and 1999) and Ph.D. (Interdisciplinary Studies: Education and Human Resource Studies: Manufacturing Technology Management, 2003) from Colorado State University. Dr. Doggett is currently teaching at Western Kentucky University. His interests include technology management, lean, theory of constraints, quality, decision-making, problem-solving strategies, and the development of distance learning approaches. Dr. Doggett may be reached at mark.doggett@wku.ed

Appendix

Table A1. List of ATMAE-Accredited Management Programs with Publically Available Textbook Information

Institution	TM Programs
Bemidji State University	2
Bowling Green State University	1
Buffalo State College	2
California University of Pennsylvania	1
Central Connecticut State University	2
Central Michigan University	2
East Carolina University	2
Eastern Illinois University	2
Eastern Kentucky University	2
Elizabeth City State University	1
Farmingdale State College	2
Illinois State University	2
Iowa State University	2
Jackson State University	1
Jacksonville State University	2
Kent State University	1
Middle Tennessee State University	1
Millersville University of Pennsylvania	2
Minnesota State University - Moorhead	1
North Carolina AT&T State University	2
Northern Illinois University	2
Ohio Northern University	2
Ohio University	1
Pennsylvania College of Technology	1
Purdue University	2
San Jose State University	1
Southeastern Louisiana University	1
Southern Illinois University at Carbondale	1
Southern Missouri State University	3
Southwestern Oklahoma State University	1
St. Cloud State University	2
Tennessee Technological University	1
Texas Southern University	1
University of Arkansas - Fort Smith	1
University of Arkansas at Pine Bluff	1
University of Central Missouri	5
University of Louisiana at Lafayette	1
University of Nebraska at Kearney	2
University of North Dakota	1
University of Northern Iowa	2
University of Southern Maine	2
University of Texas at Tyler	1
University of Wisconsin - Platteville	3
Western Illinois University	1
Western Kentucky University	3

Table A2. Authors Identified for Each Management Competency and the Textbooks Analyzed for Citations

Management Competency	Authors	Citation Frequency	Textbooks Analyzed
Leadership/ Self Management	Frauenheim, E.	8	Dubrin, A. J. (2011). *Essentials of management*, (9th ed.) South-Western College Pub
	Henricks, M.	5	
	McGregor J.	5	
	Bryant A.	5	
	Conlin M.	5	
	Marquez J.	5	
	Matioli, D	5	
	Needleman, S.	5	
	Sandberg, J.	5	
	Hansen, F.	4	
	Judge, T.	4	
	Others < 4	3	
People Management	Misc. Journals	8	Robbins, D. E. & DeCenzo, D. A. (2010). *Supervision today!* (6th ed.) Pearson.
	Locke, E.	3	
	Others < 3	2	
Operations Management	Schonberger, R.	3	Womack, J. P. & Jones, D. T. (2003). *Lean thinking* (2nd ed.) Productivity Press.
	Rother, M.	2	
	Ohno, T.	2	
	Suzaki, K.	2	
	Monden, Y.	2	
	Others < 2	1	
Process Management	Hopp, W.	4	Stevenson, W. J. (2010). *Operations management* (10th ed.) McGraw-Hill
	Womack, J.	4	
	Goldratt, E.	4	
	Jacobs, F.	3	
	Juran, J.	3	
	Stevenson, W.	3	
	Besterfield, D.	2	
	Goetsch, D.	2	
	Others < 2	1	
Project Management	N/A	N/A	No single textbook was consistently assigned
Systems Management	Schonberger R.	5	Arnold, J. R. T., Chapman, S. N., & Clive, L. M. (2011). *Introduction to materials management* (7th ed.) Prentice Hall
	Vollmann, T.	2	
	Buffa, E.	2	
	Goldratt, E.	2	
	Others < 2	1	
Quality Management	ASQ	10	Besterfield, D. (2012). *Quality improvement* (9th ed.) Prentice Hall Summers, D. C. (2008). *Quality management* (2nd ed.) Prentice Hall
	Juran, J.	8	
	Wheeler, D.	7	
	Feigenbaum, A.	5	
	Crosby, P.	5	
	Gooden, R.	5	
	Others < 5	4	
Risk Management	ANSI/ASME (26 in common)	170	Goetsch, D. L. (2010). *Occupational safety and health for technologists, engineers, and managers* (7th ed.) Prentice Hall National Safety Council (2009). *Accident prevention manual for business and industry: Engineering and technology* (13th ed.) Hagen, P. (ed) Asfahl, C. R. & Rieske, D. W. (2009). *Industrial safety and health management* (6th ed.) Prentice Hall
	NSC	155	
	NFPA	124	
	NIOSH	73	
	Misc. Periodicals	63	
	OSHA	60	
	American Petrol. Inst.	10	
	Underwriters Lab	10	
	CDC	8	
	Goetsch, D. (*self-cited)	7*	
	Minster, G.	4	
	Hartshorn, D.	3	
	Smith S.	3	

Should Knowledge-Worker Job Descriptions Fit the Job or the Worker?

Bryan Booker, Eastern Michigan University

Abstract

Knowledge-worker job design is a fundamental engineering management responsibility. The design and documentation of job descriptions may sound like bureaucratic work, and the effort may appear to be both time-consuming and unsustainable; however, what if the job were customized to better fit the unique person and documented within each person's job description? The documentation of the customized job is expected to improve knowledge-worker capability and motivation. In this study, the author measured the value of customizing and documenting knowledge-workers' job design to better fit their knowledge, skills, abilities, and characteristics. Job customization was conceptualized as both the assignment of a unique set of tasks to a job holder to improve his/her person-job fit and the documentation of the job design as a position description that describes the job holder's unique roles and responsibilities. In this study, the author confirmed significant correlations between the customization of a knowledge-worker's job design with job outcomes, including job satisfaction and intent to quit. The documentation of a custom job design with a unique position description was significantly correlated with measures of improved person-job fit. The results of this study have implications for engineering managers responsible for job design, task assignment, and work group performance.

Introduction

Peter Drucker [1] described knowledge-worker productivity as the biggest of the 21st century management challenges. "In the developed countries, it is their first survival requirement. In no other way can the developed countries hope to maintain themselves, let alone maintain their leadership and their standards of living" [1]. A short-term focus prevents some managers from focusing on knowledge-worker improvement. How might a manager of knowledge workers, with a large variety of non-routine tasks, use job design and descriptions to close person-job fit gaps and add value when assigning work group responsibilities? The job description for a group of jobs frequently documents similar responsibilities, requirements, and a common set of expectations that are infrequently changed. However, job candidate or incumbent capabilities and motivation vary both among individuals and within individuals over time. For example, industrial engineers are knowledge workers who are often assigned to the improvement role of lean leader or coordinator. The lean leader job description may include a wide variety of responsibilities and tasks that the industrial engineer may not be prepared to fulfill. The engineer may not have the motivation, knowledge, skills, abilities, preferred behaviors, work experiences, or delegation experience necessary for fulfilling the full job description.

The effects of a job design can be measured in terms of person-job fit. Person-job fit is a component of person-environment fit. How can person-job fit be optimized and continually adapted with a fixed job design? The potential benefit of a customized job design may be great for knowledge-worker jobs designed with a large variety of non-routine tasks—might these knowledge workers be more capable and motivated to perform an increasing percentage of their job responsibilities or tasks? Employees can distinguish among person-organization fit, needs-supplies fit, and demand-abilities fit [2]. Ideal person-job fit will occur when both demands-abilities fit and needs-supplies fit are high. Demands-abilities fit measures the degree to which the person is capable of fulfilling the job demands and the needs-supplies fit measures, as well as the degree to which the person's needs are fulfilled by the job. "Both needs-supplies fit and demands-abilities fit are complementary, such that the combination of person and situation - make whole - or add to what the other is missing" [2]. This current study was an effort to better understand the effects of knowledge-worker job-design customization. The study showed how customizing and documenting a knowledge-worker's job design can add value when there is improved fit with the worker's knowledge, skills, abilities, and characteristics (KSAC).

Problem Statement

The study problem is summarized in the following question: How might a manager of knowledge workers, with a large variety of non-routine tasks, use job design and descriptions to close person-job fit gaps and add value when assigning work group responsibilities and tasks?

Engineering Management Application

Kern [3] reviewed trends in engineering management literature from 1993 through 2000 and concluded: "The consistent discussion of personnel subjects such as performance evaluation, teamwork, and job satisfaction clearly distinguish[es] engineering managers from their engineer colleagues in professional literature" [3].

The responsibilities of job design and job customization fit within the bounds of the engineering manager role. What approach might an engineering or technical manager take to close knowledge-worker performance gaps? The engineering manager's alternatives to job customization may include: requesting, requiring, or coaching the job incumbent to change; job reassignment; or simply allowing performance gaps to exist. The knowledge-worker manager's need for current performance frequently leaves knowledge-worker processes and work place design improvement opportunities unaddressed [4]. A better alternative may be to customize the assignment of job tasks for improved work group and system performance.

Booker [5] confirmed correlations between the customized design of knowledge-worker jobs and improvement in the job outcome measures of job satisfaction, person-job fit, and intent to quit. A task assignment tool or job aid was also tested with favorable reviewer results when compared to their current assignment methods. The task assignment tool was designed to guide a knowledge-worker manager through the task assignment decision process—an assignment priority index for each task assignment option provided a normalized measure for comparing person-task assignment alternatives.

Supporting Literature

The focus of the studies found in the literature showed that the use of job descriptions and job customization has waned since the critical studies were performed in the 1960s through the 1980s. However, returning to the fundamentals of work design requires another critical need. This time, the need is for measuring the value of job customization in the form of customized job descriptions. The purpose of measuring the value of using these often-neglected HR documents is that their value may be overlooked when designing a job with the incumbent in mind.

Although some studies in the literature address the relationship between person-job fit and work-related outcomes, one gap in the literature is the use of a valid and reliable tool to measure task assignments and relate that tool's output to desired work outcomes. The research areas most directly related to this current study included person-environment fit, job satisfaction, job design, and job descriptions. Job customization literature is often related to job incumbent-initiated customization and job design methods.

A meta-analysis of research regarding relationships among the various components of person-environment fit was concerned with the moderators of the fit-outcome relationships and evaluating empirical evidence regarding their impact [6]. A significant correlation between job satisfaction and both person-job fit and person-organization fit was found to exist. The study showed positive correlations with measures of overall performance, but the results were not significant; that is, the correlations varied greatly based on the method used to assess performance. The study concluded that direct or perceived measures of fit had stronger relationships than indirect objective measures for job satisfaction, overall performance, and intent to quit. They also confirmed that the temporal or time separation of relationships had little effect on fit-attitude relationships except for organizational commitment. These findings support the validity of collecting participant data with a cross-sectional design that collects all of the data at one point in time.

Models have been developed to characterize and measure job designs. The job characteristics model was developed to measure the motivational potential of job designs—the model factors included skill variety, task identity, task significance, feedback, and autonomy [7]. Kareasek et al. [8] designed a job questionnaire to measure the content of a job holder's work tasks in a general manner that was applicable to all jobs and job holders. Gazzara [9] defined a knowledge worker's task quotient as an ideal mix of routine, problem solving, and project tasks—in theory, satisfaction should increase as the mix approaches the worker's ideal mix. Morgeson and Humphrey [10] developed a comprehensive measure for assessing job design entitled the Work Design Questionnaire. Jones and Chung [11] described a methodology for measuring engineering knowledge-worker productivity—a questionnaire for collecting data from full-time engineering knowledge workers. Morgeson and Humphrey [12] developed an integrated conceptualization of a work design model that incorporated known work design factors; the model included task, social, and contextual characteristics applied to individual jobs and teams. These models provided a foundation on which the current study on customized job designs was built.

Every employee's job has a description and role within the organization; the description may be documented or undocumented. It may be defined by the job incumbent, supervisor, or even co-workers within the work group. The job designed by the incumbent may match the desires of the incumbent, but is often not the best match for their organization's needs. "Employees naturally gravitate toward pursuit of self-interests while at work and toward the expenditure of their effort and time on the more desirable tasks. This tendency often leads to misdirected effort, from the company's point of view" [13]. Grant [14] evaluated job descriptions as an effective way of improving job performance; however, he characterized job descriptions as being poorly designed and infrequently used. Wrzesniewski and Dutton [15] described job description customization by an incumbent as "job crafting." Job incumbents craft their jobs in lieu of an intentional method due to unmet needs. This current study built on the foundations of these previous works. However, these foundations have small cracks, one of which is the lack of a valid and reliable tool to use when studying the effects of customizing job descriptions to improve the overall work system. The study outcomes provided rationale for adopting procedures and practices for customizing knowledge-worker job designs and subsequently documenting the new designs with customized job descriptions or unique position descriptions.

Methodology

Population Selection

Subject groups were identified that might more frequently have jobs that were customized to better fit their knowledge, skills, abilities, and characteristics. The lean leader and youth leader populations were selected to characterize and generalize the results to be applied more broadly to a category of knowledge workers responsible for a variety of non-routine tasks. Similarities between the two groups were identified during job design projects with both groups; however, the two groups were different enough to provide study outcomes that might be generalized to a broader class of knowledge-worker job designs with a variety of non-routine tasks. The observed job similarities included: clear strategic links between the job and the organization; a wide variety of non-routine tasks; the application of knowledge, project work, team work, facilitation, and training; a variety of communication skills; and, an outcome assessment. Lean leaders were defined as professionals responsible for managing processes related to the implementation of lean principles and practices. Youth leaders were defined as professionals managing the activities of youth-oriented programs.

Data were collected at two professional conferences. Printed surveys were distributed at professional conferences to increase the participation rate and to allow the subjects to use a portion of their conference time to complete the lengthy 20-minute survey. Lean leader data were collected at the IIE Operational Excellence Conference held on October 26 and 27, 2009, in St. Louis, Missouri. Youth leader data were collected at the Youth Specialties Youth Leader Conference held on October 31, 2009, in Cincinnati, Ohio. An electronic survey link was sent to members of the IIE - Lean Division via electronic mail. The survey link was also posted in the Youth Movement and Youth Worker Journal newsletters. Table 1 contains the survey response quantities by type. The distribution method for the surveys did not enable an exact count for number of surveys distributed. Therefore, the number of usable surveys are reported along with the total number of surveys received.

Table 1. Survey Response Counts

Survey Statistic	Lean Leader	Youth Leader	Total
Total Respondents	156	165	321
Paper Copy	19	60	79
Electronic - URL	137	105	242
# Usable Responses	113	141	254
Unusable	43	24	67
% Returned Usable	72.4%	85.5%	79.1%

Data Collection Design

An anonymous survey was selected to collect data, given the required but sensitive person-job fit questions. Job outcome data were collected using previously validated measures of job satisfaction, task performance, intent to quit, and person-job fit. All survey item sources were selected from published journal studies that demonstrated Cronbach's correlation alpha values greater than 0.70, which indicates internal consistency among items that measured each construct. A second version of the youth leader survey collected data to compare and correlate the job customization measures with two other job design models in order to measure the relative importance of job customization variables with other factors known to affect job satisfaction and intent to quit. The measures and their sources are listed in Table 2.

Hackman and Oldham's [7] job characteristics theory theorized that five core job dimensions (skill variety, task identity, task significance, autonomy, and feedback) influence three critical psychological states (experienced meaningfulness of the work, experienced responsibility for outcomes of the work, and knowledge of the actual results of work activities). The three psychological states do not cause workers to be internally motivated, to perform well, or to experience job satisfaction; however, they do create conditions that reinforce repeated high internal work motivation, high-quality work performance, high satisfaction with the work, and low absenteeism and turnover [7]. The study's seven questions came from their job characteristics model.

Table 2. Data Collection Sources

Item(s) Source	# Items	Variable Measured
Inscape Publishing [16]	2	Preferred behavior, DiSC
Booker [5]	2	Job customization
	8	Demographics
	7	Job description characteristics and use
Job Content Questionnaire Karasek et al. [8]	6	Co-worker social support
	3	Decision authority
	7	Skill discretion
	5	Supervisor social support
Job Characteristics Survey Hackman and Oldham [7]	2	Feedback from agents
	1	Task identity
	2	Task significance
	2	Job satisfaction
Lauver et al. [17]	2	Intent to quit
Cable and DeRue [2]	3	Person-job fit: demands-abilities
	3	Person-job fit: needs-supplies
	2	Person-organization fit
Scroggins [18]	2	Person-job fit: Self-concept-job fit
Gilbert et al. [19]	15	Personal preferences
Total	74	

Inscape Publishing [16] developed the two questions used for classifying a subject's preferred behavior type according to one of the following labels: Dominance, Influence, Steadiness or Conscientiousness. Booker [5] developed and validated the two job customization measures and the seven job description characteristics. Karasek et al. [8] developed the 21 questions as part of their job content questionnaire. Lauver and Kristof-Brown [17] developed the two intent-to-quit questions in a project where they studied person-job fit and person-organization fit. Cable and DeRue [2] administered these eight questions within their study and concluded that needs-supplies and demands-abilities types of person-job fit measures were complementary. Scroggins [18] developed two questions for a new measure of a type of person-job fit called self-concept-job fit. Gilbert et al. [19] developed the 15 questions for a multi-dimensional work preference measure designed to measure personal preferences that affect work or job selection.

Test Statistics

Pearson's product-moment correlation coefficients were used to assess the correlations between the degree of job customization and dependent variables including: person-job fit, job satisfaction, task-performance, and intent to quit. The model's independent variables included: preferred behavior, task preferences, demographics, person-organization fit, and other dependent variables. The β coefficient for each correlation indicated the strength of the relationship. Correlation was tested by developing confidence intervals for βs. The variable correlation analysis methodology was similar to that performed by Lauver and Kristof-Brown [17].

Validity

The data collection content, clarity, ease-of-use, grammar, and survey completion time were assessed by six lean leader professionals, four youth leader professionals, and twelve graduate students studying engineering management. Feedback was incorporated into the survey designs with minor grammatical changes and the elimination of question redundancy. Additional survey items were presented to 69 youth leaders to measure person-environment and job characteristics known to significantly correlate with the study outcome criteria, but which were expected to not significantly correlate with job customization. Items from the job content questionnaire [8] were included to measure co-worker social support, supervisor social support, and feedback from agents. Items from the job characteristics model [7] included feedback and job significance. Concurrent validity was assessed by comparing the results to a previous study using the same questions. Scale reliabilities between person-job fit and outcome measures were compared to Cable and DeRue's [2] study results that administered the same person-job fit survey items. Outcome and person-job fit correlations were compared to the meta-analysis results [6]. Alternate-form reliability was assessed by presenting two or more items for person-job fit types and output criteria. Internal consistency among items measuring the same construct was assessed using Cronbach's alpha reliability test. Electronic surveys presented the survey items with common format and scales to reduce measurement error.

Results

Analysis of the study data showed many insights into the use of job description customization and desired outcomes. The study data were primarily analyzed by subject group (e.g., lean leaders versus youth leaders) to provide an improved understanding of the importance of properly designed and used job descriptions.

Subject Group Comparisons

The lean leaders in the sample were significantly older, more likely to be male, had a higher level of education, and had more experience as a leader than the youth leader sample group. There was a significant positive correlation between the job customization measure and reported age. Forty-five percent of the lean leaders (n=36) indicated that industrial engineering was the discipline that their degree(s) best fit. The other most frequently held degrees were: 19% engineer-other, 14% business, and 10% manufacturing engineer. There was a significant positive correlation between the job customization measure and reported age with a p-value of 0.004. Table 3 shows statistics for age by subject groups. There were significant differences for lean leader education level in measures of person-job fit and intent to quit. Lean leaders with associate's degrees reported lower levels of person-job fit than those with master's and doctoral degrees. Subjects with bachelor's degrees reported significantly lower levels of person-job fit than those with doctoral degrees. Those with associate's degrees reported a greater intent to quit than those with doctoral degrees. There were significant correlations between leader role experience and both task performance ($r = 0.249$, $p = 0.003$) and job demand-abilities fit ($r = 0.158$, $p = 0.023$). Table 4 lists the reported education level of both subject groups.

Table 3. Age by Respondent Group

Age Grouping	Lean Leaders	Youth Leaders		
	Count	%	Count	%
17-21	0	0%	0	0%
22-26	12	15%	22	17%
27-31	7	9%	36	28%
32-36	9	11%	20	16%
37-41	11	13%	12	9%
42-46	10	12%	12	9%
47-51	12	15%	12	9%
52-56	11	13%	11	9%
57-61	7	9%	2	2%
62-66	3	4%	1	1%
67-71	0	0%	0	0%
Mean Age	42.1 years	36.0 years		

Table 4. Education Level by Group

Highest Degree	Lean Leader	Youth Leader		
	#	%	#	%
High School	0	0%	12	9%
Associate	2	2%	8	6%
Bachelor	32	39%	58	45%
Masters	43	52%	48	37%
Doctorate	3	4%	0	0%
None of Above	2	2%	3	2%

The lean leaders and youth leader samples showed significantly different levels on several measures (see Table 5). The data support the value of including both groups within the study to better generalize the results.

Table 5. Differences between Lean Leader and Youth Leader

Measure	Subject Groups	Difference (LL – YL)		
	Lean Leaders	Youth Leaders	95% CI Lower	95% CI Upper
Job Satisfaction	5.66	**6.03**	-0.625	-.0107
Intent to Quit	**3.76**	2.79	0.502	1.442
Task Performance	**5.80**	5.48	0.037	0.583
Person-Org Fit	5.09	**5.64**	-0.898	-0.195
Person-Job Fit (Need-Supplies)	4.75	**5.29**	-0.898	-.0192
Promotability (1 to 3)	**2.26**	1.93	0.149	0.506
Preferences				
WI: Mechanical	**5.06**	3.94	0.578	1.673
WI: Numbers	**5.23**	2.59	2.165	3.124
WI: Study	**5.68**	5.03	0.281	1.005
WI: HelpOthers	5.79	**6.27**	-0.834	-0.129
WV: GetAlong	4.95	**5.45**	-0.862	-0.140
WV:Results Focus	**6.20**	5.77	0.118	0.724
Prefer Guidance	4.76	**5.39**	-1.067	-0.188
Prefer Ideas	**6.20**	5.71	0.126	0.849

Notes: **Bold font** indicates highest-level subject groups
All scales ranged from 1=strongly disagree to 7=strongly agree, except Promotability, which ranged from 1 to 3.
3 = Promotable to the organization's top-level jobs
2 = Promotable to the next one or two more demanding level of jobs
1 = Current job-level demands

There were significant correlations between leader role experience and both task performance (r= 0.249, p = 0.003) and job demand-abilities fit (r = 0.158, p = 0.023). The lean leader's perception of both task performance and job demand-abilities fit were positively correlated with on-the-job experience. There were no other significant correlations between job experience and job customization, job outcomes or person-environment fit. The relatively few differences within the population data support the value of including both groups within the study and the differences allow the study results to be more generalized. Lean leaders reported higher intent to quit their job; greater expectation for being promoted to higher levels of the organization; higher preference for tasks working with numbers and keeping data records; higher preference for studying and using information; and, higher preference for thinking in terms of ideas, concepts, theories, creative thinking, and research. Youth leaders reported greater satisfaction with their jobs; greater person-organization fit; greater need-supplies job fit (needs being supplied by their job); higher preference for tasks requiring caring for, coaching, and helping others; higher preference for tasks that allow them to be well liked and get along; higher preference for tasks where guidance is given to clarify task expectations or helpful training and specific instructions are provided; and, preferred behavior that is characterized as more accepting, enthusiastic, and sociable.

Outcomes

The key study outcomes are summarized in Table 6. These outcomes include: 1) job customization measures; 2) job customization correlation with person-job fit; 3) job customization correlation with outcomes; 4) job description usefulness; and, 5) job description accuracy effect.

Table 6 Study Outcomes

#	Outcome	Significant Findings
1	New Measure for the Level of Job Customization	Reliability and validity tests confirm the measure's appropriateness for measuring the degree of job customization.
2	Job Satisfaction Correlation with Person-Job Fit	Correlations between Job Satisfaction and components of Person-Job fit for this study's subjects were strong when compared to the Kristof-Brown et al. [6] meta -analysis. Similarly the intent to quit measure had a strong negative correlation with both person-job fit and person-organization fit.
3	Job Customization Correlation with Job Outcomes	Correlations between the job customization measure and the outcomes of job satisfaction (r = 0.238) and intent to quit (r = -0.184) were significant.
4	Job Description Use Significance	a. A minority of the respondents reported yes to the question "Do you or your supervisor use your job description?" b. A significant increase in job satisfaction was measured for those using job descriptions. c. A significant increase in both job satisfaction and person-job fit were measured for those who had periodic job description reviews. d. The Kano study indicated that the customization of a job description to better match the incumbent's knowledge, skills, and abilities would be perceived as a "delighter."
5	Job Description Accuracy Effect	Job description accuracy was significantly correlated with outcomes of person-job fit (r = 0.422), job satisfaction (r = 0.361), and intent to quit. (r = -0.183).

Outcome 1: Job Customization Measure

Job customization was operationalized as the change of tasks, roles, or responsibility assignments to better fit the job incumbent's knowledge, skills, abilities, or characteristics. Two items were designed to assess the degree to which the respondent's job tasks, roles, or responsibilities were changed to better utilize their knowledge, skills, abilities, or characteristics. The measure was recorded as the mean score from the following two question responses, scored on a seven-point Likert scale ranging from "Strongly Disagree" to "Strongly Agree": "Some of my current job tasks, roles, or responsibilities have been changed or reassigned to better utilize my knowledge, skills, abilities, or characteristics" and "The design of my job (assigned tasks, roles, and responsibilities) has been changed to better fit my knowledge, skills, abilities, or characteristics."

The Cronbach's alpha reliability measure for the two job customization questions was 0.764, which was greater than the 0.70 threshold [20], indicating acceptable internal consistency. A second version of the youth leader survey was designed with additional questions to test the divergent validity of the job-customization measure; the survey included the measures of other factors that are known to be significantly correlated with the study outcome measures—69 youth leaders provided these additional data to test correlations between these other known significant factors and the new job-customization measure. Co-worker support, decision authority, skill discretion, and supervisor support were documented by Karasek et al. [8]. Table 7 contains the job customization validity test correlation matrix, which shows significant correlations with the study outcomes but not with other factors known to be significantly correlated with the outcome criteria; note that the job customization measure was significantly correlated with feedback.

Table 7. Job Customization Validity Test – Correlation Matrix

P-Job Measure	P-Job Measure	r	Sig.
Job Satisfaction	Job Customization	.277	*
	Intent to Quit	-.588	***
	Person-Org. Fit	.460	***
	Person-Job Fit	.722	***
	Co-Worker Support	.436	***
	Decision Authority	.387	**
	Supervisor Support	.488	***
	Feedback	.489	***
	Job Significance	.362	**
Job Customization	Person-Job Fit	.308	*
	Feedback	.250	*
Intent to Quit	Person-Org. Fit	-.420	***
	Person-Job Fit	-.595	***
	Co-Worker Support	-.477	***
	Decision Authority	-.398	**
	Skill Discretion	-.402	***
	Supervisor Support	-.482	***
	Feedback	-.515	***
Person-Org. Fit	Person-Job Fit	.533	***
	Co-Worker Support	.350	**
	Decision Authority	.465	***
	Skill Discretion	.256	*
	Supervisor Support	.376	**
	Feedback	.313	*
	Job Significance	.318	**
Person-Job Fit	Co-Worker Support	.303	*
	Decision Authority	.392	**
	Skill Discretion	.408	**
	Supervisor Support	.366	**
	Feedback	.564	***
	Job Significance	.283	*
Co-Worker Support	Decision Authority	.345	*
	Skill Discretion	.285	*
	Supervisor Support	.702	***
	Feedback	.386	**
	Job Significance	.276	*
Decision Authority	Supervisor Support	.489	***
	Feedback	.463	***
	Job Significance	.316	*
Skill Discretion	Supervisor Support	.307	*
	Feedback	.326	**
Supervisor Support	Feedback	.481	***
	Job Significance	.271	*
Feedback	Job Significance	.375	**

Table 7 shows Pearson's correlation coefficients (r).
p-value significance: *** 0.000, ** < 0.01, * < 0.05

Outcome 2: Job Customization Correlation with Person-Job Fit

The correlation of job satisfaction and person-job fit in this study was greater than the upper limit of the 95% confidence interval for the 23 different studies in Kristoff-Brown et al.'s [6] meta-analysis (see Table 8). The significantly higher correlation may be interpreted to mean that a good person-job fit for knowledge workers with a variety of non-routine tasks may have a greater effect on job satisfaction than for other job types. Table 9 shows the correlation matrix for the custom measure and job outcomes recorded from the 132 cases that provided the complete data set. Correlations between job satisfaction and components of person-job fit for this study's subjects were strong when compared to the Kristof-Brown et al. [6] meta-analysis. Similarly, the intent-to-quit measure had a strong negative correlation with both person-job fit and person-organization fit. The measure of task performance had a non-significant correlation with all outcome measures; however, the non-correlation was also reported in the meta-analysis study. The evidence supports a positive relationship between the job-customization measure and the measures for person-job fit.

Outcome 3: Job Customization Correlation with Outcomes

The evidence supported significant correlations between the job-customization measure and the outcomes of job satisfaction and intent to quit. Table 10 presents the correlation matrix.

Table 8. Meta-Analysis: P-J and P-O Fit Correlations with Study Outcomes

Outcome Variable – Perceived	Fit Type	No. of Studies	Low 95% CI	Up 95% CI	"r" [6]	"r" this study
Job Satisfaction	Person-Job	23	.23	.67	.58	.77
Job Satisfaction	Person-Org	30	.23	.67	.56	.58
Overall Performance	Person-Job	3	-0.25	.61	.22	.20
Overall Performance	Person-Org	7	-0.10	.30	.12	.17
Intent to quit	Person-Job	11	-0.65	-0.15	-0.49	-0.63
Intent to quit	Person-Org	24	-0.61	-0.25	-0.52	-0.56

Notes: CI interval ranges for Person-Job and Person-Org versus Job satisfaction were both .23 to .67. Correlation coefficients from studies with direct reports of perceived person-environment fit.

Table 9. Job Customization and Person-Job Fit Correlation (r / p values)

Measure	Custom Job	Person-Job Fit	Demand-Abilities	Need-Supplies
Person-Job Fit	0.350			
	0.000***			
Demand-Abilities	0.300	0.900		
	0.000***	0.000		
Need-Supplies	0.312	0.918	0.691	
	0.000***	0.000	0.000***	
Self-Concept-Job	0.286	0.768	0.641	0.566
	0.000***	0.000	0.000***	0.000***

Notes: DA, NS and SCJ fits are components of Person-Job fit
p-value significance: *** 0.000, ** < 0.01, * < 0.05

Table 10. Job Customization and Outcome Criterion Correlation (r/p values)

Measure	Custom Job	Task Perf. Avg.	Job Sat.
Task Performance	0.088 0.294		
Job Satisfaction	0.238 0.000***	0.092 0.266	
Intent to Quit	-0.184 0.008**	-0.044 0.604	-0.664 0.000***

Notes: p-value significance: *** 0.000, ** < 0.01, * < 0.05.
Table presents Pearson's correlation coefficients (r) and p-values.

Outcome 4: Job Description Usefulness

Subjects were asked to provide responses regarding their job descriptions. A minority of the respondents reported yes to the question: Do you or your supervisor use your job description? Thirty-two percent of the lean leaders and 43% of the youth leaders reported that they both had a job description and that it was used. Lean leaders were more likely than youth leaders to have tasks prioritized by importance and to have the expected amount of time that they should allocate to each task included in their job descriptions. For the leaders who used their job descriptions, over half of both leader types reported that they and their supervisor identified gaps between their job requirements and their knowledge, skills, and abilities. This study confirmed the significant effect of supervisor job description use on study outcomes of job satisfaction, intent to quit, and person-job fit. There was a significant positive difference in levels of job satisfaction and person-job fit for those respondents who periodically reviewed their job descriptions with their supervisors, when compared to those who did not. Table 11 summarizes the effect of supervisor job description use on study outcome ratings.

Respondents with a job that was customized were asked if their job description was changed to better fit their knowledge, skills, abilities, or characteristics (KSAC). This study showed that the key job incumbent characteristics driving job description changes were experience, skills, knowledge, and, to a lesser extent, education. The average person-job fit rating for those with customized jobs and updated job descriptions was 6.031, as compared to 5.614 for customized jobs with no updated job description. The person-job fit rating was reported as 5.287 for the remaining subjects without customized jobs. The level comparisons had similar variances so a t-test was used to evaluate the differences. The definition for the sample subgroup with customized jobs was operationalized as those who strongly agreed with the two job-customization questions by recording a level 6 or 7 on the seven-point scale. At a 95% confidence level, those with documented customized jobs reported higher levels of person-job fit than both those with customized jobs with no job description updates and those who did not report customized jobs. Furthermore, those with customized jobs but no updated job description reported higher levels of person-job fit than those who reported no job customization.

Table 11. Job Description Use Outcome Effects (r/p values)

Question	Values = Yes responses – No responses		
	Job Satisfaction	Intent to Quit	P-Job Fit
Do you or your Supervisor use your job description?	0.363	-0.555	0.252
	0.012*	0.044*	0.090
Have you or your supervisor identified gaps between your job requirements and your knowledge, skills and abilities?	0.065	-0.581	0.111
	0.733	0.118	0.604
Are you assigned tasks prioritized by importance within your job description?	0.153	0.506	0.240
	0.414	0.188	0.218
Do you have an expected amount of time that you should allocate to each task included in your job description?	-0.035	0.376	0.073
	0.857	0.360	0.736
Do you or your supervisor review your job description periodically?	0.431	-0.689	0.594
	0.049*	0.085	0.014*

Notes: Statistic: T-Test with Non-pooled standard deviations;
Values = Mean "Yes" Responses – Mean "No" Responses and p-values;
p-value significance: *** 0.000, ** < 0.01, * < 0.05;
Outcomes measured on 7-point scale

Customized Job Description Expected Value: Kano-style functional and dysfunctional questions were asked to identify the expected effect of both the presence and absence of a job description that was customized for the incumbent. The following two questions were posed:

Functional Question: *How would you feel if your current job description was customized to better match your knowledge, skills, attributes and characteristics?*

Dysfunctional Question: *How would you feel if your current job description is a listing of job responsibilities common to most (lean or youth depending on survey) leaders?*

Of the seven response categories in the Kano study, the "delighter" category was the most frequently selected among the sampled lean leaders and youth leaders. Forty-one percent of youth leaders and 31% of lean leader respondents reported satisfied feelings if they had a customized job description; however, if the job description was not customized, they did not have a feeling of dissatisfaction.

Outcome 5: Job Description Accuracy Effect

The degree of job description accuracy was significantly correlated with outcomes of self-reported person-job fit, job satisfaction, and intent to quit. This outcome supports the need to keep job descriptions accurate in order to provide higher employee engagement, as evidenced by greater job satisfaction and a lower intent to quit. Table 12 summarizes the job-description outcome correlation results.

Table 12. Job Description Accuracy and Outcome Correlations (r/p values)

Measure	Job Description Accuracy
Person-Job Fit	0.195 0.000***
Task Performance	0.012 0.251
Job Satisfaction	0.130 0.000***
Intent to Quit	-0.055 0.002**

Notes: p-value significance: ***0.000, ** < 0.01, * < 0.05
Table presents Pearson's correlation coefficients (r) and p-values.

Summary and Conclusions

There were five key study outcomes related to knowledge -worker job design and documentation. First, a valid measure of the degree of job customization was established. Second, there were significant positive correlations obtained between self-reported measures of job customization and person-job fit measures of demands-abilities fit, needs-supplies fit, and self-concept-job fit. Third, there was a significant positive correlation between job customization and job satisfaction; and, a significant negative correlation between job customization and intent to quit. Fourth, the use of job descriptions was significantly and positively correlated with levels of job satisfaction; and, subjects with improved job designs and updated job descriptions that reflected those changes recorded significantly higher levels of person-job fit than those with no updated job description. Fifth, there was a significant positive correlation between job-description accuracy levels and measures of person-job fit and job satisfaction; and, there was a significant negative correlation between job description accuracy and intent to quit. Kano-style functional and dysfunctional questions were asked in order to identify the expected effect of both the presence and absence of a job description that was customized for the job incumbent. Most of the lean and youth leaders perceived the customization of a job description to better match their knowledge, skills, and abilities as a "delighter." By definition, the absence of a delighter does not cause dissatisfaction but their presence was correlated with improved job satisfaction.

This was an exploratory study of the effects of job customization and job documentation. The data provided evidence that the job-customization measure was valid, reliable, and useful for evaluating the value of job customization. Evidence was provided for the conclusion that the customization of a job design to better fit a job incumbent's knowledge, skills, abilities, and characteristics is significantly correlated to improvements in person-job fit, job satisfaction, and the lowering of intent to quit. There was also evidence that accurate job descriptions are related to improved person-job fit and that the documentation of a customized job as a unique position description is correlated with improved person-job fit.

This study provides support for the decision to document job designs for each position holder as a unique position description rather than a generic job description for each job type in order to improve job satisfaction and person-job fit. Ratings of job satisfaction were significantly increased if a job description was used and if it was reviewed periodically. Other observations included a significant positive correlation between the sample's lean leader age and the level of job design customization; this suggests that job customization may occur naturally over time. Wrzesniewski et al. [15] described this natural process of job customization as job crafting, and Miner [21] described it as structural evolution through idiosyncratic jobs. A strong significant correlation was found between person-job fit and job satisfaction for the lean leader and youth leader groups, which was greater than the upper limit of the 95% confidence interval for a meta-analysis that included 23 different studies. A conclusion may be drawn that person-job fit is a stronger driver of job satisfaction for the two knowledge worker subject groups than for the broader work force job designs.

Future Research Directions

Further research in the following four areas may improve the understanding and application of the research outcomes and conclusions.

1. Further define the elements of task performer knowledge skills and abilities characteristics that may more accurately predict task performance and differentiate among performers. Consider refining the definitions of skills and abilities to more precisely differentiate the two.
2. Apply a task assignment tool index to a work group's full set of task assignments. The total group's task performance index might be maximized using operations research methods as a starting point for an optimal work group person-task assignment solution.
3. Evaluate the effect of the frequency of a work group's person-job task reassignments on job outcomes.
4. Evaluate the effect of a collaborative group process for reassigning a set of tasks that are identified as transferable.

In the literature, research has been focused on improving the person-job selection process rather than on the process for improving the incumbent's person-job fit. A concerted knowledge-worker effort to define worker tasks, improve task design, evaluate person-task fit, customize job designs, and document existing job designs in the form of a unique position description is recommended.

How Might Engineering Managers Customize Their Knowledge-Worker Job Designs?

The highly leveraged benefits of improved knowledge-worker job satisfaction and productivity that are expected to result from improved person-job fit seem to warrant an engineering manager-driven process to continually improve their work group's job designs. A job design improvement process requires an understanding of the job requirements and the incumbent's knowledge, skills, abilities, and characteristics. The job design process may include gap assessment, job design methods, structured task assignment, and the documentation of job designs as position descriptions that are designed and written to enhance person-job fit. Based on this study, technical managers can take the following steps to improve and customize knowledge-worker job designs:

1. Periodically discuss their knowledge workers' job duties and compare them with their job descriptions. Bring these duties and job descriptions into alignment through role discussion and negotiation. This will improve the person-job fit.
2. Conduct an exit interview when a worker vacates a position. Identify the duties they had upon exiting the position and compare to the duties stated in the job description. Perhaps the job description has a temporal dimension, whereby the knowledge worker adds and develops listed duties to the point where they are ready for a new position. The job description will need to be recast for the new person who will take the position, as they will not have the characteristics and experience of the person vacating the position.
3. If a knowledge worker has been in the same position for more than the typical promotion cycle in the firm, examine his/her duties against the job description. Has there been skill development along the temporal dimension? If not, this may signal the need for more responsive training opportunities and, potentially, better motivation processes on the part of the organization and the engineering manager.

Attention to the alignment of job descriptions and knowledge-worker duties is not a bureaucratic process; it is a foundational effort to improve the person-job fit, provide greater job satisfaction, and reduce the worker's intent to quit.

Acknowledgements

The author would like to thank Dr. Larry Mallak, who provided support throughout the research project.

References

[1] Drucker, P. (1999). Knowledge-worker productivity: the biggest challenge. *California Management Review, 41*, 92.

[2] Cable, D., & DeRue, D. S. (2002). The convergent and discriminant validity of subjective fit perceptions. *Journal of Applied Psychology, 87*, 10.

[3] Kern, S. (2002). Content and Trends in Engineering Management Literature. *Engineering Management Journal, 14*, 43.

[4] Davenport, T., Thomas, R., & Cantrell, S. (2002). The mysterious art and science of knowledge-worker performance. *MIT Sloan Management Review, 44*, 7.

[5] Booker, B. (2010). *Development of a task assignment tool to customize job descriptions and close person-job fit gaps.* Unpublished doctoral dissertation, Western Michigan University

[6] Kristof-Brown, A. L., Zimmerman, R. D., & Johnson, E. C. (2005). Consequences of Individuals' Fit at Work: A Meta-Analysis of Person-Job, Person-Organization, Person-Group, and Person-Supervisor Fit. *Personnel Psychology, 58*, 281-342.

[7] Hackman, R. J., & Oldham, G. R. (1980). *Work Redesign*. Addison-Wesley Publishing Company.

[8] Karasek, R., Brisson, L. C., Houtman, I., Bongers, P., & Amick, B. (1998). The Job Content Questionnaire (JCQ): An Instrument for Internationally Comparative Assessments of Psychosocial Job Characteristics. *Journal of Occupational Health Psychology, 3*, 34.

[9] Gazzara, K. D. (2004). *Using task-quotient (TQ) to maximize individual motivation and job satisfaction*. Paper presented at the Engineering Management Conference, IEEE/UT.

[10] Morgeson F. P., & Humphrey, S. E. (2006). The Work Design Questionnaire (WDQ): Developing and Validating a Comprehensive Measure for Assessing Job Design and the Nature of Work. *Journal of Applied Psychology, 91*, 1321-1339.

[11] Jones, E., & Chung, C. (2006). A Methodology for Measuring Engineering Knowledge Worker Productivity. *Engineering Management Journal, 18*, 32.

[12] Morgeson F. P., & Humphrey, S. E. (2008). Job and team design: Toward a more integrative conceptualization of work design. *Research in Personnel and Human Resources Management, 27*, 39-91.

[13] Grant, P. C. (1989). *Multiple Use Job Descriptions: a guide to analysis, preparation, and applications for human resource managers*. (1st ed.). Westport: Quorum Books.

[14] Grant, P. C. (1997). Job descriptions: What's missing. *Industrial Management, 39*, 9.

[15] Wrzesniewski, A., & Dutton, J. E. (2001). Crafting a Job: Revisioning Employees as Active Crafters of Their Work. *The Academy of Management Review, 26*, 179-201.

[16] *Everything DiSC® DiSC Theory*. (2004). Inscape Publishing.

[17] Lauver, K. J., & Kristof-Brown, A. (2001). Distinguishing between Employees' Perceptions of Person–Job and Person–Organization Fit. *Journal of Vocational Behavior, 59*, 17.

[18] Scroggins, W. A. (2003). Selection, meaningful work and employee retention: A self-concept based ap-

proach to person-job fit. Doctoral dissertation. *ProQuest Information and Learning*.
[19] Gilbert, G. R., Sohi, R. S., & McEachern, A. G. (2008). Measuring work preferences: A multidimensional tool to enhance career self-management. *Career Development International, 13,* 23.
[20] Nunnally, J. C. (1983) *Psychometric Theory*. New York: McGraw-Hill.
[21] Miner, A. S. (1990). Structural Evolution through Idiosyncratic Jobs: The Potential for Unplanned Learning. *Organization Science, 1*, 195-210.

Biography

BRYAN BOOKER is an assistant professor of engineering management at Eastern Michigan University. He earned his B.S.I.E. degree from Iowa State University, M.S. (engineering management, 1990) from Western Michigan University, and Ph.D. (industrial engineering, 2010) from Western Michigan University. He teaches courses in management, engineering economy, manufacturing processes, and lean manufacturing. He spent four years with Goodyear Atomic working as an industrial engineer in the recycling and assembly division of a uranium enrichment facility. He invested 20 years with Haworth, Inc., serving in a variety of engineering and management roles. While completing his Ph.D., he worked as a Senior Management Consultant for Resource Dynamics International. His first year of full-time teaching (2010-2011) was at the University of Minnesota-Duluth, where he served as assistant professor in the Department of Mechanical and Industrial Engineering. His research is focused on job design, project management, lean manufacturing, business process improvement and management. Dr. Booker may be reached at bbooker1@emich.edu

INSTRUCTIONS FOR AUTHORS: MANUSCRIPT REQUIREMENTS

The TECHNOLOGY INTERFACE INTERNATIONAL JOURNAL is an online/print publication. Articles appearing in TIIJ generally come from educators wanting to discuss "best practices" activities in their classrooms, or from industry personnel wishing to publish innovative designs or novel applications from their businesses or organizations. All submissions to this journal, including manuscripts, peer-reviews of submitted documents, requests for editing changes, as well as notification of acceptance or rejection, will be handled electronically. The only exception would be CDs containing high-resolution pictures and/or images to be used during journal production.

All manuscript submissions must be prepared in Microsoft Word (.doc or .docx) and contain all figures, images and/or pictures embedded where you want them and appropriately captioned. Also, each figure, image or picture that was imported into your Word document must be saved individually at the highest resolution possible from the program in which it was created—preferably as a 300-dpi or higher JPEG (.jpg) file; that means one additional file for each figure in your manuscript that has a higher resolution than the image embedded in the manuscript being submitted. If, for example, a table or graph is created directly in Word, you do not have to submit it again in a separate file. Use the respective figure number (where it goes in your manuscript) as the file name. You can send all of these files separately via email, or zip them all into one file to be sent via email or snail mail on a CD. Send all submissions to the manuscript editor: philipw@bgsu.edu

The editorial staff of the Technology Interface International Journal reserves the right to format and edit any submitted document in order to meet publication standards of the journal. Included here is a summary of the formatting instructions. You should, however, review the sample Word document included on our website (www.tiij.org/submissions) for a detailed analysis of how to correctly format your manuscript.

The references included in the References section of your manuscript must follow APA-formatting guidelines. In order to help you, the sample document also includes numerous examples of how to format a variety of scenarios. If you have a reference source for which you are not able to find the correct APA format, contact me for help anytime (philipw@bgsu.edu). Keep in mind that an incorrectly formatted manuscript will be returned to you, a delay that may cause it to be moved to a subsequent issue of the journal.

1. Word document page setup: Top = 1", Bottom = 1", Left = 1.25", Right = 1.25". This is the default setting for Microsoft Word.

2. Page Breaks: No page breaks are to be inserted in your document.

3. Paper Title: Centered at the top of the first page with a 22-point Times New Roman (Bold), Small-Caps font.

4. Body Fonts: Use 10-point Times New Roman (TNR) for body text throughout (1/8" paragraph indention); 9-point TNR for author names/affiliations under the paper title; 16-point TNR for major section titles; 14-point TNR for minor section titles; 9-point TNR BOLD for caption titles; other font sizes may be noted in the sample document.

5. Images: All images should be included in the body of the document. As noted earlier, all objects/images that have to be embedded into Word (i.e., an image not created in Word) must also be saved as a 300-dpi or higher image—if supported by the software program in which it was originally created—and saved as a separate file and submitted along with the original manuscript.

6. In-text referencing: List and number each reference when referring to them in the body of the document (e.g., [1]). The first entry must be [1] followed by [2], [3], etc., continuing in numerical order through your references. Again, see the sample document for specifics. Do not use the End-Page Reference utility in Microsoft Word. You must manually place references in the body of the text.

7. Tables and Figures: Center all tables and figures. Captions for tables must be above the table, while captions for figures are below; all captions are left-justified.

8. Page Limit: Manuscripts should not be more than 15 pages (single-spaced, 2-column format).

9. Page Numbering: Do not use page numbers.

TIIJ is now an official journal of IAJC.
WWW.IAJC.ORG

TIIJ Contact Information

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

TIIJ